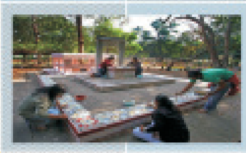
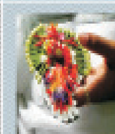
INDIAN CARTOGRAPHER

Journal of the Indian National
Cartographic Association (INCA)

CARTOGRAPHY AND CLIMATE CHANGE





Volume-36
Part-I

CHIEF EDITOR
Prof. V.C.Jha
President INCA,2016

DEPARTMENT OF GEOGRAPHY
VIDYA-BHAWAN
VISVA BHARTI (A Central University)
SANTINIKETAN-731235
WEWEST BENGAL


36th INCA International Congress
on
CARTOGRAPHY FOR ANALYSIS AND MANAGEMENT
OF CLIMATE CHANGE
9-11th November 2016
Organised by : Department of Geography
VIDYA-BHAVANA, VISVA-BHARATI, SANTINIKETAN
HDFC BANK
36th INCA International Congress

INDIAN CARTOGRAPHER
Journal of the Indian National Cartographic Association
(INCA)

Volume - 36
Part-I

CARTOGRAPHY AND CLIMATE CHANGE

Chief Editor
Vibhash Chandra Jha
President INCA 2016

Associate Editors
Uma Shankar Malik
Gopal Chandra Debnath
Sri Narayan Ojha
Umesh Kumar Singh
Sucheta Mukherjee
Bhaskar Das

The views expressed by the author(s) are their own and INCA does not necessarily endorse them in part or whole.

ISSN : 0927-8392

Publication Year : 2016

Price : 1000/- (Set)

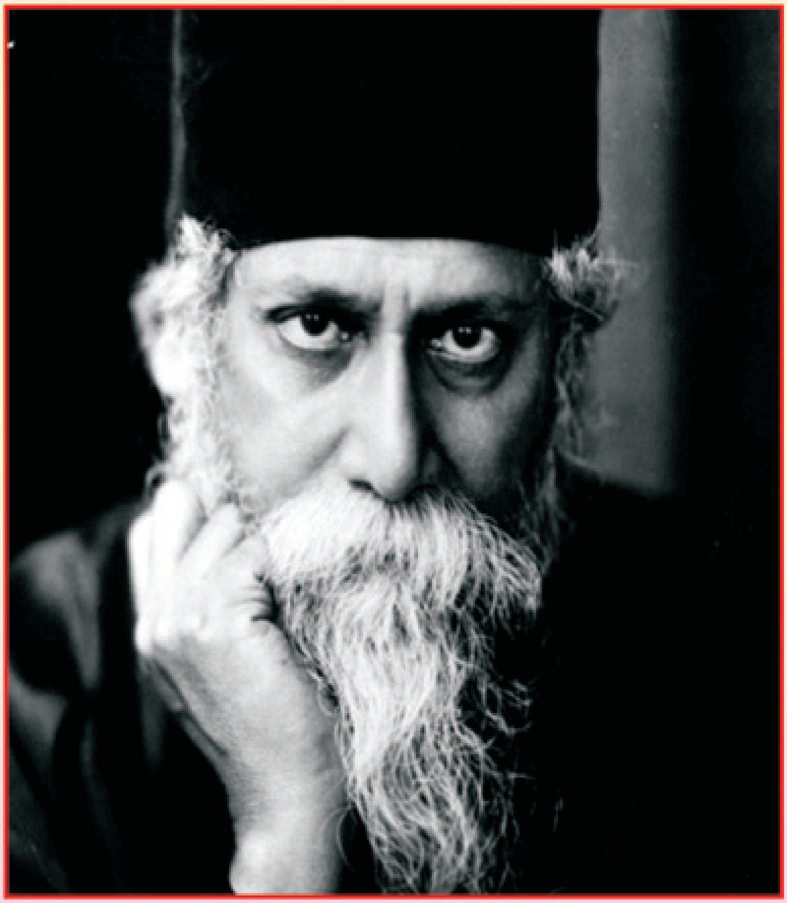
Published by :
INCA
Regd. Office :
Room No. 234, 2nd Floor, APGDC Block,
Survey of India, Uppal
Hyderabad-500039

Printed by :
Manav Prakashan
131 Chittaranjan Avenue,
Kolkata-700 073
Mo. 9831581479

NOBEL LAUREATE

GURUDEV RABINDRA NATH TAGORE

(7th May 1861 – 7 August 1941)

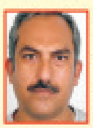


About the Editors

Professor Vibhash Chandra Jha is a renowned Geographer and his area of specialization id Geomorphology, Cultural Geography, Geography of Buddhism, Geo-informatics and Geospatial Technologies (Remote Sensing, GIS & GPS). Professor Jha, has been the Principal (Dean) of of Vidya Bhavana (Institute of Humanities and Social Sciences), Visva-Bharati (A Central University), Santiniketan, West Bengal, India and Organising Chair for the 36th INCA. Recently, Professor Jha completed his extended tenure of deputation as Director, National Atlas & Thematic Mapping Organisation (NATMO, an Institution of National Importance), Department of Science & Technology, Ministry of Science & Technology, Government of India, located at Kolkata.

Professor Uma Shankar Malik is Head of the Department of Geography, Vidya Bhavana, Visva-Bharati. He has been associated with teaching and ancillary activities at several universities, namely, North Bengal, Burdwan and so on.His research has mainly focused in the fields of Economic, Industrial and Urban Geography. He has 30+ years of teaching experience, has edited several books and has been life member of professional bodies like IIG, IIRS, IGF, RSA, ILEE, NAGI and so on. He was Organising Secretary of 36th INCA Congress.

Dr Gopal Chandra Debnath has served NATMO for over 3 decades before joining Department of Geography, Visva-Bharati as Associate Professor. His research specialization is in population studies and demography and has extensive training in mapping, remote sensing and GIS. He is member of more than 35 professional societies including INCA. He has been the Treasurer for 36th INCA Congress.



Dr Sri Narayan Ojha, Senior System Programmer-cum-Associate Professor at Integrated Science Education & Research Centre, Siksha Bhavana (Institute of Science), Visva-Bharati has been teaching Computer Science and Technology Management for about 30 years. He nurtures his research interest in the interdisciplinary interfaces of science, social sciences and languages. Dr Ojha is life member of professional societies like Indian Biophysical Society, has been an expert member of Microsoft Localization Programme and has worked on pioneering national projects like National Knowledge Commission, National Knowledge Network, New Linguistic Survey of India and National Translation Mission. He has been convener for two sub-committees of 36th INCA Congress.

Dr. Umesh Kumar Singh is Assistant Professor of Environmental Science at Integrated Science Education and Research Centre (ISERC), Siksha-Bhavana (Institute of Science), Visva-Bharati, Santiniketan. He is a member of 36th INCA International Congress on cartography for analysis and management of climate change. His areas of interest are Hydrogeology, Water and Soil Pollution, Solid Waste Management and Climate Change.

Dr. Sucheta Mukherjee, presently Assistant Professor at Sripat Singh College, Jiaganj, Murshidabad, has extensively worked on remote sensing and GIS and has authored valuable research papers. She is an active member of Executive Committee of INCA and has been a significant contributor in organization of 36th INCA Congress. Her areas of interest are Applied Geomorphology, Use of Geospatial techniques in geomorphology, Climatology and Environment Management

Dr Bhaskar Das, serving as Cartographer in the Department of Geography, Visva-Bharati, has extensively worked on remote sensing and GIS at various institutions, governmental agencies and under national and regional research projects. He has widely travelled to Europe and South-East Asia for professional purposes. His computer application skills has been a good support in organizing the 36th INCA Congress.

Contents

Preface

The Indian National Cartographic Association (INCA) organizes an annual conference at a premier institution in the country where geographers, cartographers and those from allied disciplines congregate to present research papers and exchange views on the recent developments in their fields and subfields. This year it has been the privilege of the Department of Geography, Vidya Bhavana (Institute of Humanities and Social Sciences), Visva-Bharati (A Central University), Santiniketan to hold this conference from the 9th – 11th of November 2016. This year's the focal theme was "Cartography for the Analysis and Management of Climate Change". The scientific research papers presented in twenty technical sessions were very informative regarding role of cartography in the environment with an interdisciplinary approach on climate change mitigation.

A total of 307 papers were received for presentation in the conference both from India and abroad. The papers had been grouped thematically into twenty sub-themes. The sub-themes were as follows:

1. CARTOGRAPHY FOR SPACESHIP EARTH
2. CONCEPTUALIZING MAPS AND APPLICATION OF GEO-SPATIAL APPROACH IN CLIMATE CHANGE STUDIES
3. EVOLUTION AND APPRECIATION OF ENERGY MANAGEMENT AND GREEN TECHNOLOGIES
4. MAPPING OF POLLUTION, POPULATION AND NATURAL RESOURCES
5. GEOMORPHOSITES, CLIMATE CHANGE AND VULNERABILITY
6. GEOHYDROLOGY, SOILS AND FLUVIAL DYNAMICS
7. CARTOGRAPHY FOR LAND DEGRADATION AND DESERTIFICATION
8. MOUNTAIN CARTOGRAPHY AND DEGLACIATION
9. MILITARY CARTOGRAPHY AND MITIGATING CHALLENGES
10. ENVIRONMENTAL POLITICS ON CLIMATE CHANGE
11. AGRICULTURE AND CARTOGRAPHY
12. CLIMATE CHANGE MANAGEMENT IN COASTAL AND URBAN INDUSTRIAL AREAS
13. CHANGING RURAL AND URBAN GEOGRAPHY
14. TOURISM INDUSTRY ISSUES AND CHALLENGES FROM CLIMATE CHANGE
15. DYNAMICS OF SOCIO-CULTURAL ENVIRONMENT ADOPTING CLIMATE CHANGE
16. CLIMATE CHANGE, SUSTAINABILITY ISSUES AND DEVELOPMENT PLANNING

17. GEO-SPATIAL TECHNOLOGY AND LARGE SCALE MAPPING
18. CARTOGRAPHY AND SCHOOL EDUCATION
19. CARTOGRAPHY AND CULTURAL GEOGRAPHY
20. HISTORICAL CARTOGRAPHY

Keeping in view the contemporariness and relevance, forty two papers which were presented in various technical sessions have been selected by the editorial board for publication in Part-I of the JOURNAL OF INDIAN CARTOGRAPHER, Volume 36, CARTOGRAPHY AND CLIMATE CHANGE.

The Part-I of this journal spins around the role of cartography in environmental assessment and climate change mitigation which is one of the major environmental issues in the present scenario. Majority of the papers highlight the physical changes like radical landscape transformation, land degradation, flood problem, soil erosion, and geomorphic changes and have been studied using LANDSAT and ASTER data. There are various indices like Normalized Suspended Material Index (NSMI), Normalised Difference Suspended Sediment Index (NDSSI) and Normalized Difference Turbidity Index (NDTI) and different maps which have been discussed in this section to evaluate the sediment distribution, land degradation, soil erosion, slope, physiography, drainage density, land-use and land-cover of particular geographical area. The model based studies at GIS platform is important for proper identification, delineation and characterization of natural resources. Paper on Subarnarekha basin highlights that, NSMI, NDSSI and NDTI method based on LANDSAT 8 digital data is very reliable to understand the turbidity zones and sediment concentration zones. Furthermore, next paper highlights that multiplied raster of Physical vulnerability index of land degradation, Socio-Economic vulnerability index for land degradation and Land vulnerability index are revolutionary concepts to indicate that land degradation process whether temporary or permanent, leads to decline in ecosystem and productive capacity. Apart from natural resources appraisal, Subarnarekha basin, Darkeshwar River, Ganga River, Kulick River, Bengal basin, Gharwal Himalyas, Doon Vally, Bardhman District, South Andman district, Purulia district, and Rajghat Dam Reservoir have been thoroughly discussed in this section based on the LANDSAT and ASTER data.

Some papers have attempted to highlight the role and challenges of cartography in environment and climate appraisal. Climate change has potentiality of grave consequences on the entire humanity in term of natural hazards. Climate change is an inevitable process on our planet and brings with it a permanent alteration of physical environment which encompasses habitats and influences geomorphic processes in operation on terrain. Two papers highlight that the hydrological status of plateau region of Jharkhand and Gandheswari River, Bankura district is in vulnerable condition mainly due to climate change. Similarly, the issues of depletion of groundwater resources in northwest India, impact of climate change on arid agro-ecosystem in Rajasthan and impact of climate change on Jharkhand agriculture have been discussed in this section. Rising temperature and changes in precipitation have been observed throughout globe that could adversely affect global hydrological cycle. Therefore, the papers make it urgent to look at the climate change and their consequences in foresecable future.

The compilation in this volume makes it evident that Cartography could serve the policy makers by creating maps and models showing potential areas to be affected by natural hazards. Implication of numerous scientific models and statistical evaluation in Cartography has extended it as an effective tool for data visualization for environmental assessment. Cartography as a science of map making is gradually getting importance for analysis and management of climate change in recent years, particularly after the advancement of Digital Cartography.

Climate change affects all ecosystems e.g., Agro-ecosystem, river ecosystem, marine ecosystem, forest and grassland ecosystem and consequently appears as severe threat to the life support systems. Particularly in GIS domain, cartography has in fact a lot of options in depicting the impacts of climate change.

I am very grateful for the cooperation of the contributors who very carefully prepared their manuscripts and sent them, more or less, on time. I believe that the contents and the quality of the papers, apart from adding to the excellence of the volume, would help open a new horizon and give a new dimension to the theme Cartography for Analysis and Management of Climate Change. The 36th Indian National Cartographic Association (INCA) International Congress would not have been possible without the financial assistance from a number of sponsors and exhibitors, namely Department of Science and Technology, Government of India, New Delhi, Indian Space Research Organisation, Bengaluru, Anthropological Survey of India, Kolkata, National Remote Sensing Centre, Hyderabad, Survey of India, Dehradun, National Atlas and Thematic Mapping Organisation, Kolkata, DST, Govt. of India, Department of Science and Technology, Government of West Bengal, Kolkata, OPSIS System Pvt. Ltd., NABARD, HDFC Bank, HP (Hewlett-Packard, India) and Visva-Bharati, Santiniketan.

I take this opportunity to thank Professor Swapan Kumar Datta, Vice-chancellor (Offg.), Visva-Bharati, Professor Ashutosh Sharma, Secretary, DST, Dr. Swarna Subba Rao, Surveyor General of India, Dr. S.K. Jha Vice Admiral, AVSM, NM(Retd.), Professor Surya Kant, Shri O. P. Sarna and colleagues from academics and administration, research scholars and students of the Department of Geography and other departments of Visva-Bharati University for their help in various ways.

V.C. JHA

1

Presidential Address
Cartography for the Analysis and Management of Climate Change

Vibhash Chandra Jha

Respected and esteemed personalities sitting on the dais honouring this 36th International Congress of the Indian National Cartographic Association (INCA) by their august presence, distinguished members of INCA, my dear young and budding cartographers committed to have a large vision for new dimensions and application of Indian and International cartography, my colleagues, students, friends, Ladies and Gentlemen,

It gives me immense pleasure to welcome you all today to Visva-Bharati, Santiniketan for the 36th INCA International Congress 2016 organised by the Department of Geography, VidyaBhavana(Institute of Humanities and Social Sciences).

Apart from being home to two Nobel Laureates and poet of two national anthems, serenity is the essence of Santiniketan. It is also a place where we try to meet up the infrastructural shortcomings through our simplistic but generous hospitality and I hope you will enjoy our warmth during this onset of winter. The organizers of INCA have also spared your time to witness the open-air class-rooms in Patha-Bhavana and enjoy the majestic Uttarayan complex. The institutions of Santiniketan were founded on a simple Tagorean principle - (I quote) "the higher education is that which does not merely give us information but makes our life in harmony with all existence" (unquote). Thus, in my judgment, Santiniketan is the most suitable venue for deliberating on the focal theme of 36th INCA.

The focal theme for the Congress: Cartography for the Analysis and Management of Climate Change, has been chosen keeping in mind the issues for sustainability and the role cartography can play for assessment and delineating regions affected by our changing climatic trend.

Ladies and gentlemen, climate change can be assessed in terms of impact on physical environment and thus the regions which encompasses our physical environments viz, glacial and peri-glacial response, marine response, fluvial response leading to geomorphological hazards and finally biotic response leading to extinction of some species, gradual adaptation of some species as a result of changes in habitats, migration of species with locomotive capabilities to suitable regions.

Warm areas are getting warmer, colder regions are also getting warmer gradually with glaciers melting and increasing the waters of the numerous channels it feeds and hence the risk of flooding, coastal regions are in the risk of gradually getting inundated by rising seawater. Change in land cover patterns from removing forest covers to give way to agricultural land-use leaves perpetually dense naturally vegetated regions exposed to elements of weather during fallow seasons. Removal of forest cover directly reduces the presence of moisture in the atmosphere of that particular region. The rate of precipitation is also affected. Absence of complete vegetative cover leads to removal of top layers of soil which are usually nutrient rich and this in turn lowers the crop yield of that particular farmland. Collectively this affects the yield of food-crop and thereby the food supply of our growing population.

"Scientific studies of climate change date from the 18th century when the first concepts of former ice ages were being developed. Since then, data on climatic change have been amassed from more and more lines of evidence - from instrumental observations, historical records, dendrochronology, pollen analysis, geological evidence from sediments and fossils, oceanographic evidence and glaciological investigations. There is no reason to think that the series of Pleistocene glacials and inter-glacial has ended, and probability is that, in another few thousand years or less, the Earth's climate will enter into the next glacial phase, unless human interference with the atmosphere is of sufficient magnitude to override this progression, which seems unlikely. Since about the middle of the last century, man has begun unintentionally to interfere with climate on an unprecedented and ever increasing scale, by burning fossil fuels and altering the composition of the atmosphere.Palaeo-climatic evidences have shown a close link between CO_2 fluctuations and glacial - interglacial oscillations (Embleton and Clifford, 1989: Natural hazards and global change, ITC Journal, Netherlands pg.174).

However human impact on our atmosphere through carbon content is small compared to the natural ocean - atmosphere CO_2 exchanges as marine biological activities have a strong influence .The oceans not only act as a vast heat - sink but also play a crucial role in global heat balance which in turn influences our rate of global precipitation. Increase or decrease in rates of precipitation directly influences the rate of surface runoff on the surface of our Earth. Some fluvial responses hence will be direct and some indirect like the effect on vegetation cover and hence the rate of sediment transfer to drainage channel will be affected thereby influencing floods, droughts or situations alike. Arid regions will experience severe and rapid sediment transfer to drainage channels due to lack of vegetative cover and semi - arid and tropical regions will undergo channel enlargement, deposition of sand on channel adjoining farmlands and floodplain instability. Thus fluctuations in precipitation and evaporation rates will lead to alteration of channel discharge ratio affecting severely agriculture and production of our food crops.

Extreme events like flash floods, embankment breaching by channel waters, gullying, increased sediment discharge thereby leading to river braiding, meandering, have recently increased because of anthropogenic influences on catchments, especially deforestations and floodplain channel changes

Ladies and gentlemen, another geomorphologic system that is potentially vulnerable to climate change is the permafrost region. About 1/5 of our land surface is encompassed by continuous and discontinuous permafrost in Canada, Greenland, Northern Europe, Northern Russia, Alaska in U.S.A. Those regions lying on the fringe zone or transitions regions between permafrost and temperate climatic zones are in a state of delicate thermal equilibrium. In areas of frozen unconsolidated sediments where the ground ice content is almost 80% by volume longer thawing periods due to warming will bring about surface collapse, mud flow, thaw lakes and rise of disease causing vectors on the biological side. The installations of oil and gas pipelines will be affected and overflowing of river channels will increase.

Ladies and gentlemen , keeping in mind the impact climate has on our lives and the progress of our generation into the digital age , this Congress is a sincere attempt to link Cartography for

Analysis and Management of Climate Change. All of you present here today in this auditorium will definitely agree that Cartography today is more precise and has multiple opportunities for research from spatial organisation of geographical features to recording spatial impact of climate change. Cartography as a tool in policy making will permeate and benefit all sections of the society and raise awareness about locational factors of resources, extent of depletion and reduction of ecological resources, sustainability, prediction and, recording and analysis of areal extent of disaster brought about by climate change like inundation of coastal regions , breaching of embankments, by tropical cyclones, flooding to name the most severest forms. Natural disasters affect a nations, food-supplies, transport routes through which relief materials can be supplied, settlements, migration and in short the quality of life. Development and nation building can only take place where the common citizen is accorded priority to lead a decent standard of living. The onus is on us to give them so and help in national development where quality of life improves.

Ladies and gentlemen Cartography in our country is a resource by itself lying latent and can act as master-key to open opportunities for resource development, providing information regarding location, spatial organization, accessibility and finally assessment and analysis. The multiple applicability of cartography is itself a major deciding factor in its demand and the training of cartographer's should be done keeping in mind that they will train our next generation of cartographers who will recognize the immediate demand of our nation for development and progress.

The Indian National Cartographic Association (INCA), since1979, has been playing a crucial role in this effort by providing a platform to planners, academics, researchers, and technical experts in the field of cartography to integrate, discuss, analyze and deliberate on a number of issues where cartography can play a crucial role. School students are also encouraged to develop their interest in cartography from a young age by participating in the Annual Map Quiz which is a very popular and prestigious among our schools and the final awards are distributed at the International Congress held every year with the winners being specially invited to attend and receive their awards. This is a little effort in encouraging and guiding our future cartographers. INCA is not just for professionals but also for social awareness about cartography and the prize winning participants of "INCA-National Map Quiz" from our schools are hear to affirm.

A significant aspect of INCA is also to co-operate with professional organizations of allied disciplines and to promote academic interaction within an inter-disciplinary frame with an objective to improve the teaching of cartography at all levels. The papers presented in this Congress will also be published in the in-house journal named "Indian Cartographer" which is a compilation of technical papers.

Ladies and gentlemen, I finish now by reminding you all that cartography has a cognate role together with remote sensing and GIS in nation building and the immediate imminent need of the hour is to develop a institute that shall endeavor in creating professionals trained to use cartography for creating products which will cover all fields that are crucial to nation building. It may be apt to end with a famous quote of Tagore -"You can't cross the sea merely by standing and staring at the water." Hence, we need to act and act together!

Thank you, All

2

The Nature of Shore Platforms and Their Morphological Diversity in Response to Wave Energy at their Fringes of Neil Island: A study in South Andaman district

Anurupa Paul, Ashis Kumar Paul and Jatisankar Bandyopadhyay

Introduction

Modern carbonate bank or carbonate platform is fringed with the coralline island by deposition of detrital sediments and also by alteration with combination of physical, biological and chemical processes over time and space. The gently sloping flat provides an area for accumulation of sediments transported from seaward reef banks, landward parts of island fringe, chemical precipitation from sea water during tidal submergence, and in-situ production of sediments by bio-destructions, bio-encrustations and weathering activities. This is also known as carbonate factory or carbonate machine for its role of production, transportation and accumulation of sediments dominated by carbonate groups and less amount of silliciclustic groups.

The major constructional components of the detrital sediment reservoir include rigid skeleton of the coral by calcification and algal encrustation, dead coral debris, calcareous algae in cementing the detrital sediments, the skeletal remains of benthic producers of dwelling organisms and erosional products of the limestone cliffs. Precipitation of cements can stabilize sediments through the binding effects by evaporation under sub-aerial exposures and repeated wetting in the tidal submergence. Destructive processes include bio-erosion or the degradation of reef framework through mechanical boring, etching and chemical dissolution and physical processes in which waves and tidal current abrasion mechanically break down the skeletal structure of the carbonate material. Physical processes that mechanically erode, transport and deposit $CaCO_3$ are of permanent importance in controlling the distribution, structure and morphology of reef flat and sedimentary landforms (Masselink, 2013).

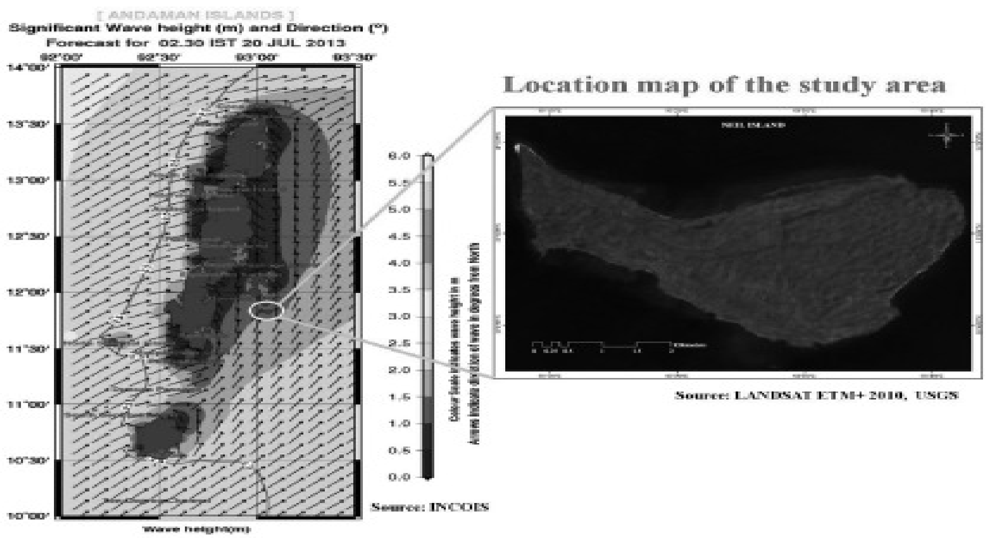
Such wider carbonate platform is produced on the windward side that is dominated with detrital sediments and extensive cays on the leeward side of Neil island in South Andaman. Ecogeomorphological mapping of such carbonate platform is studied in the present work for understanding the various ecological and physical processes as well as the delineation of sedimentary landforms under different energy settings. (Boaden, P.J.S. & Seed, R.,1985).

Study area

The Neil island is fringed with diverse patterns of carbonate platforms on the basis of local bathymetry, configuration of the shoreline, structure and composition of reef terraces attached to the island platforms, location of windward and leeward reefs, along the island shores, tidal immersion with sub aerial exposures, bio-encrustation, weathering with erosion and accretionary process and the signature of events of tectonics. The platforms are categorized into (i) reef front seaward slope, (ii) reef flat with consolidated coral debris, (iii) narrow beach fringed shore with coral line sands and other bioclusts, and (iv) the vertical cliff zone along the fringe of the island platform. Each and every morphological zones represent an expression of processes, sediment types and structural composition of the island.(Fig.1)

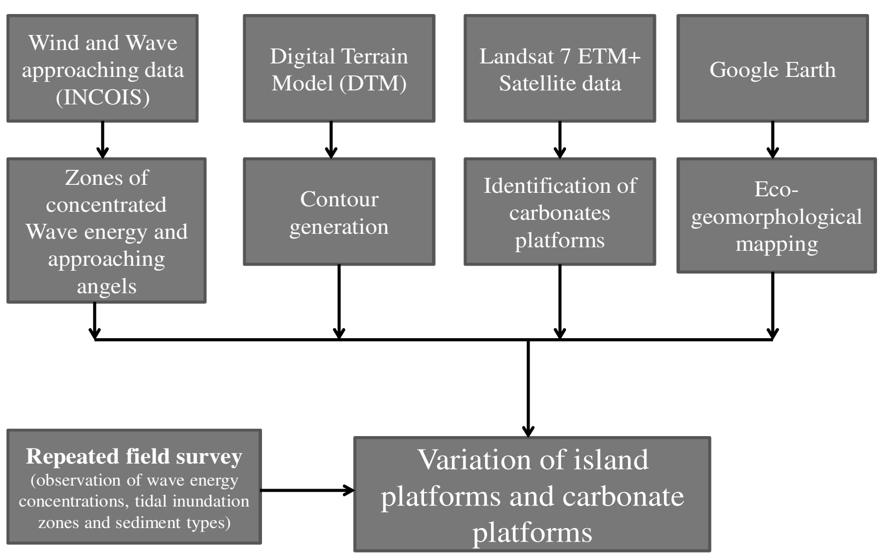
Figure 1

Location map of the study area



Materials and methods of study

Methods of study



Eco-geomorphological zones of carbonate banks

(i) The windward reef front is characterized by wave beaten consolidated platform. Vigorous coral growth is present on the seaward slope, but the massive reef edge is affected by wave erosion with the development of finger like spurs or buttresses running normal to the bank line.(Table.1)

The massive reef edge has become dislodged by tsunami waves of 2004 and drifted over the reef flat in the form of large boulders or debris. Reef edge of windward and leeward slopes is also undermined by the biological activity or bio-erosion of various reef boring organisms (e.g. fungi, sponges, bivalves).

(ii) The larger part of reef flat immediately behind the seaward crest of spurs or buttresses is occupied by surface encrusted coralline algae (e.g. calcareous lithothamnian flat). This is also known as smooth algal ridge which receives the highest impact of breaking waves along the low tide shoreline of the reef flat on the windward side. The crest of the algal ridge along the bank line is dissected by smooth sided surge channels with the presence of significant wave action. However, the reef flat of sheltered platform accommodates the supply of the huge amount of smaller size debris dominated by branching corals. As wave action is less severe in the embayed shore, the reef crest on the seaward side is dominated by robust corals such as Millepora and Accropora in the form of heavy thickets.

(iii) The back reef flat of Neil island is highly variable in character. They are subdivided into various habitat types on the basis of subaerial emgerence, temperature changes, salinity changes, micro topographic variations, slopes, pockets of depression, water circulation in the high tidal submergence and the rate of weathering process.

Hard surfaces with available moisture supply is colonized by calcareous algae ((zoozanthale) and unconsolidated sediments by sea grasses in the area of back reef flat immediately behind the smaller depressions of salt water storage. Such algae encrusted surfaces are hardened and roughened with roots pinnacles by the formation of calcareous beach rocks under a moderate sloping platform. Beach rocks of different material composition are wider and extensive in other areas of back reef flat and behave resistant to wave action. But they are micro folded and jointed by the factors of stress and strain (Sharma, V. & Srinivasan, M.S.,2007) during the events of tectonics (along the regional thrust and local upliftment and subsidance). However, beach rocks of wide and extensive areas of carbonate platforms are affected by weathering with dissolution process and eroded by the bio-encrustation process in fewer places of the island.

(iv) Presence of conglomeratic and coralline beach rocks is also exposed along the fringes of the island platform towards west and east as raised beach terraces. They are cliffed, highly fossiliferous, graveliferous with coral debris and bivalves, and dark black in colour, probably due to exotic deposits of volcanic ash.

Pools of salt water bodies are extended along the modern platform (back reef flat) in between the algal ridge crest zone and zone of beach rock diversity. Moderate water circulation, very low amount of sediment accumulation, tidal connection with surge channels and frequent tidal inundations are favorable for the growth of cup corals, colonies of sea grasses and ideal habitats for sea cucumbers and various ornamental fishes. Several smooth reef rubbles are deposited and finer sediments are also transported and deposited into the pools of salt water bodies by repeated submergence of tide waters and by tsunami waves generated in 2004, December 26 in the groups of Andaman and Nicober islands.

(v) A well defined boulder zone is also located at the outer edge of reef flat by the deposition of wave drifted reef rubbles dislodged by tsunami waves from the reef front sub tidal bank. They are drifted across the back reef flat to reach the outer edge of the reef flat. Abundant supply of the debris of branching corals has raised the surface elevation of reef flat in and around the embayed shores of windward reef (Paul, A.K.,2005).

(vi) On the inner reef flats of slightly protected environment benthic foraminiferans, gastropods and other rock boring mollusks and bivalves are abundant. Types of bio-erosion are recorded in this part of the inner reef flat by identifying the bio-encrustation and rock boring activities of organisms. Low energy, tidal immersion and submergence as well as distance from the bank margin setting with shelter flat provide favourable condition for attachment surface of marine organisms.

(vii) Another dynamic depositional environment with water level weathering, salt weathering and dissolution process active on the inner reef flat are seen along the temporary wave breaking zone of the high tide shoreline that is very close to the vertical limestone cliff of the island platform. Various rock pools in the form of larger potholes are developed over the limestone pavements by hydraulic eddies of waves and attrition process of smaller boulder size reef rubbles (mostly by stoney corals) with surface frictions in the region. Taffoni structures are very common on the reef boulders, limestone pavements and also on the cliff wall vertical surface due to active presents of salt weathering and wave splashing along the landward extended wave breaking zone of the high tide line. Very well defined notches and limestone caves are produced along the cliff wall up to a certain elevation by wave scouring and dissolution process. The cliff retreat process is activated by the formation of joints and clefts across the limestone wall, seepage of water flow from the land wards side through the joints in the monsoon months, chemical dissolution process in rapid rate and mass wasting of limestone boulders from the vertical wall and crest of the cliff line in the transition of modern carbonate platform and island mergin limestone cliff. .(Fig.2)

(viii) Finally, a well developed beach is fringed at the end of carbonate bank with coralline sands of different bio class. The smaller particles of reef rubbles, foraminifers, shell fragments, debris of oysters, algal materials, sponges and various skeletal remains of branching corals and stony corals are abundant in composition of beach sediments. As they are highly washed away into the ashore by wind waves sand storm generated waves they are relatively sorted and looking as milky white in colour. In the areas of low cliff with favorable shoreline configurations and shelter, powdery sands of finer grains are deposited by current drifts and windblown activities in the form of sand ridges or sand cays.(Fig.3and 4).

Figure 2

Photographic Plate, A) Spurs and grooves on lithothamnian flat, B) Jointing and failure of blocks, limestone cliff, C) Algal encrusted carbonate platform, D) Formation of caving by limestone dissolution process

Table 1

Major depositional environments of the carbonate banks of Neil island

Environment	Location	Energy Setting	Biota
Windward reef front slope	Bank margin, low turbidity	High wave energy, unidirectional	Diverse corals and reef frame work
Spurs and Grooves	Bank margin, high turbidity	High tidal energy, bidirectional	Rock boring shells and little organic activity
Lithothamnian flat	Bank surface, exposed	Medium energy, grain mobility	Calcareous algae with cementing activities
Pools of water bodies with patch reefs	Bank surface, mildly exposed	Medium energy, fines winnowed but sand cemented	Sea grasses, living corals

Limestone pavement surface	Bank surface, sheltered	Low energy, poor circulation	Algal encrustations and rock boring organisms
Beach rock with Taffoni structures and bio-encrustation	Bank surface sheltered	Low energy, poor circulation	Few biota with fossil corals debris
Wave breaking zone with coralline beach sands	Bank surface exposed to wave breakers, high tide line	Wave breaking energy at the high tide limit, swash-backwash currents	Hermit crabs, Gastropods, Foraminifers
Notches and Cave deposition	Cliff base scoured zone, wave run up length.	Reflective energy of waves with splashing and scouring	Barnacles and larger Shells attached with the limestone cliff wall

Figure 3

Various Eco-Geomorphological Zones Of The Carbonate Bank Of Inter Tidal Environment On The Windward Side Of Neil Island, South Andaman District

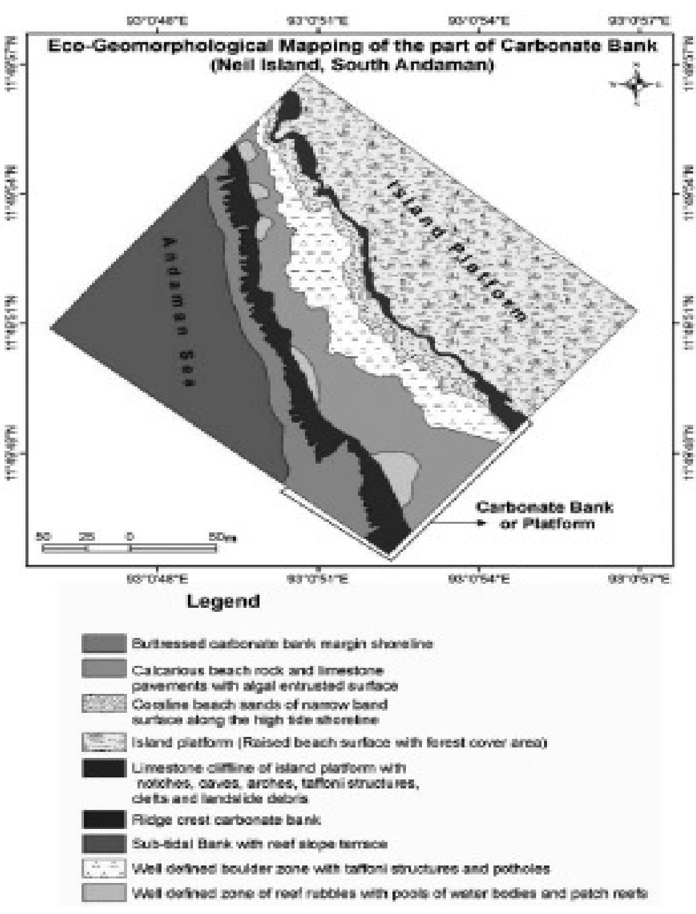


Figure 4

Various Eco-Geomorphological Zones Of The Carbonate Bank Of Sub Tidal Environment On The Leeward Side Of Neil Island, South Andaman District

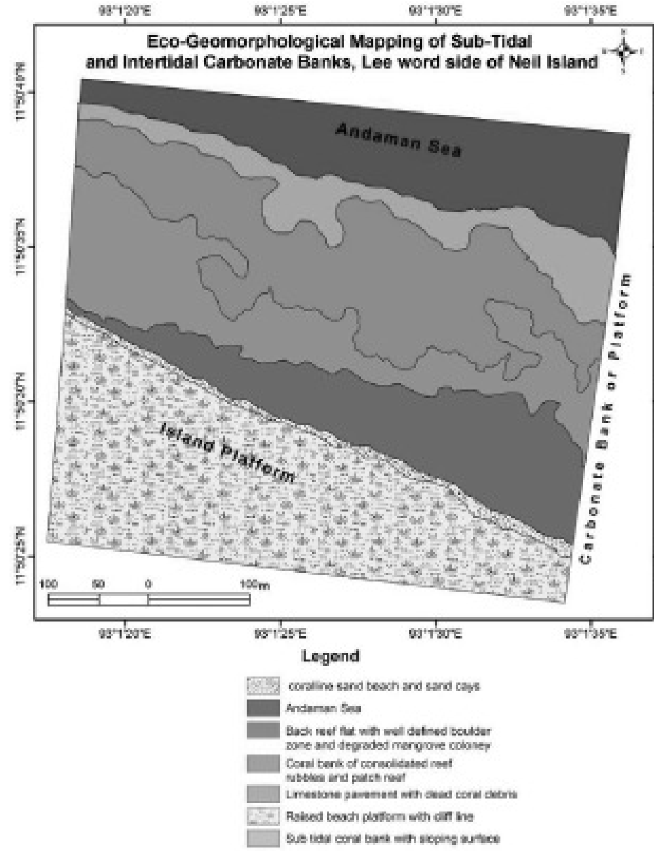
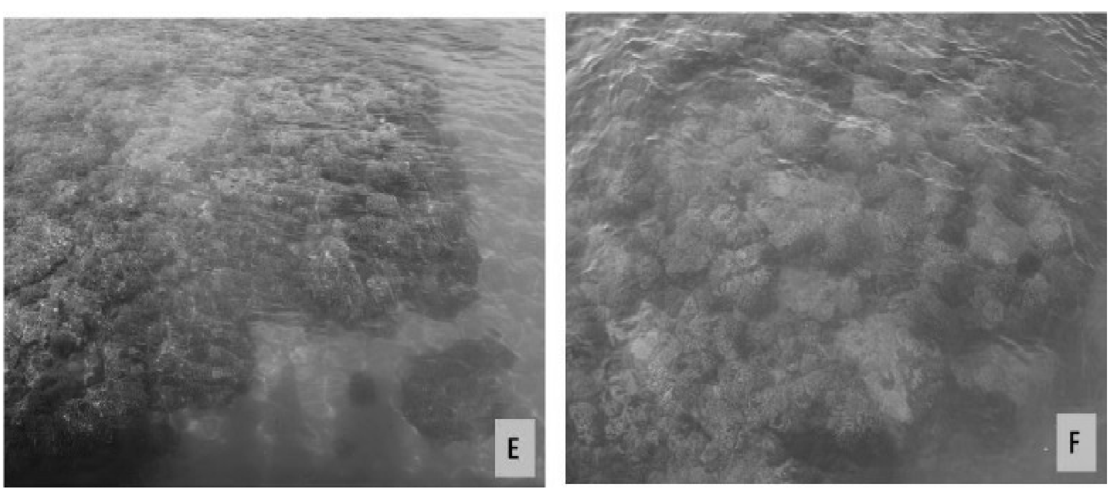


Figure 5

Photographic Plate, E) Sub tidal carbonate bank with secondary deposits, F) Sub tidal carbonate with dead coral debris



Environmental settings and sediment sources:

The environmental settings of the carbonate banks of Neil island are diverse on the basis of the shoreline configurations, shelter provided by embayed shores, exposed windward reef flat to high wave actions, distance from the bank margin to the inner reef flat, platform slopes, elevations and tidal range. Carbonate bank margins are influenced by high wave action with unidirectional energy setting and repeated wave beaten banks and exposed reef flats of the island. Steeps sloping banks of seaward site are favorable with water circulation and transparencies of sea water for luxuriant growth of corals (dominated by Acropora and Millepora species) in the windward reef of Neil island.(Fig.5)

The immediate reef flat behind the bank margin is influenced by high tidal energy with bidirectional current movement and high turbidity. As the distance increases the reef flat surface is influenced by medium energy tides with mobility of grains on the basis of surface exposures. Reef flat surfaces of some areas are mildly exposed to medium energy currents of tidal submergence, and under such setting of energy level and surface exposures the fine grained materials are winnowed but sand size materials are cemented.

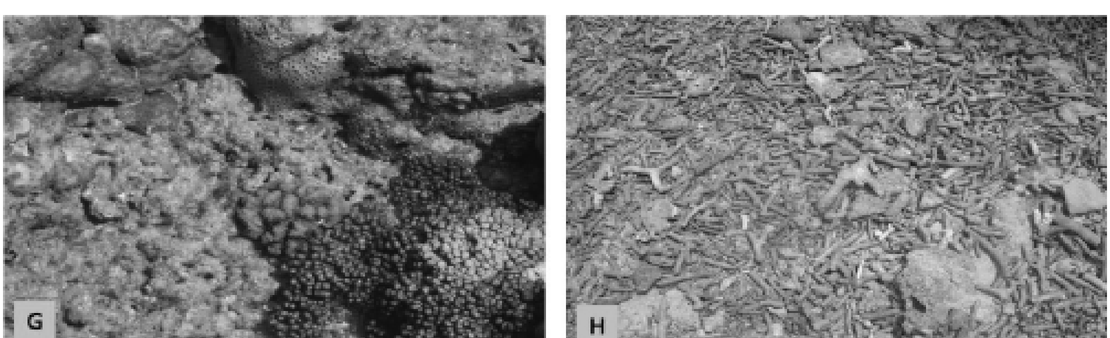
Surfaces of inner reef flat are sheltered and affected by low energy environment due to distance and configurations of the shoreline. Circulation of water is also poor in the inner flat. However, the high tide shoreline is affected by moderate wave breakers with turbulent energy at the transition between inner reef flat and vertical cliff line. Storm waves or tsunami generated waves reach the cliff zone and produces reflective energy with scouring, splashing, and cross currents in the higher parts of the landward reef flat.

Sediment sources have been identified on the basis of estimated material composition, location, distance, topography, and energy settings on the carbonate banks or the fore reef back reef flats. Reef rubbles and other large size dead coral debris are transported from the sub-tidal coralline banks and drifted across the platform surface by events of energy levels. Carbonate muds are transported by tidal waves and tsunami generated waves from the seaward side and deposited over the patch reefs of cup corals under basinal depressions with pools of water bodies (Fig.6). Chemically precipitated sediments from the seawater (e.g. aragonites, magnesium sulfates, calcium carbonates, calcites and dolomites) occupy the inner parts of the reef flat. Other bio-clasts are transported from the diverse habitat of the carbonate banks. Weathering and dissolution process for the in situ rocks are pavement surface and limestone cliffs generate a group or class of sediments at the base of cliff zone. Finally, the mass wasting products from the crystal parts of limestone cliff supply boulders, gravels and pebbles on the platform surface.

Sediment is processed in the carbonate platform surfaces and redeposited in different environmental setting with time and gradually become consolidated by lithification process.

Figure 6

Photographic Plate, G) Area of patch reef in the windward reef flat, H) Supply of dead coral debris into the embayed shore of Neil Island by Tsunami and Storm drifts



Major findings

1. Carbonate platforms are factory for sediment production through ecological process, chemical precipitation of cements from sea water, in-situ deposition of other organisms or bio-clusts, and erosional products of limestone cliffs.
2. Diverse sedimentary depositional landforms and erosional landforms are seen on the modern carbonate platforms provided by configurations of the shoreline, rate of withering process, hydrodynamic regimes and energy settings, ecological processes, and by physical processes on the island fringe environment.
3. Eco-geomorphological mapping contributes the delineation of the boundaries of erosional and depositional landforms of carbonate banks and their dynamics over the space and time.
4. The evolutionary processes of ancient carbonate banks can be explained by understanding the dynamisms of modern carbonate platforms (Woodroffe, C. D.,2002).

Conclusion

Windward side of the Neil island is fringed with well defined inter tidal carbonate platform of pavements, beach rocks, detrital sediments, reef materials of boulder conglomerates, lithothamnian algal ridge crest, marginal buttressed banks, spurs and grooves and surge channels with coral rubbles, boulder zones, muds and other skeletal materials of rock boring organisms and algal mats. They are processed by the interaction of physical, biological and chemical activities under diverse energy settings of the shoreline.

However, the relatively sheltered shores of the leeward side with a little bit embayed configurations have accumulated sand cays sediments of unsorted grains and various bioclusts over the underlying reefal banks. Various rhythmic features, wash over deposits and drifted rubbles are also visible on the shore face. Sub-tidal banks of degraded reefs are widely extended in three stepped platforms in the region. Pellet muds and carbonate muds are deposited in the upper inter-tidal rubble zone in which mangroves of carbonate settings are located.

Carbonate platforms or carbonate banks of Andaman islands are largely affected by upliftment and subsidence through the seismic activities in the tsunami event of 2004.

References

Boaden, P. J. S. & Seed, R. (1985). *Coral reefs: In: An Introduction to Coastal Ecology*. Blackie, New York. pp. 90-105.

Masselink, G. (2013*). Coastal Environment and Global Change*. AGU, Wiley, London. p. 438.

Paul, A. K. (2005). *Tsunami: An assessment of the Disaster over the nations in the Indian Ocean*. ACB Publications, Kolkata, p. 80.

Sharma, V. & Srinivasan, M. S. (2007). *Geology of Andaman Nicobar: The Neogene.* Capital publishing company, New Delhi, p. 163.

Woodroffe, C. D. (2002). *Coasts: Form, Process and Evolution*. Cambridge University Press, p. 525.

3

Coastal Mud Banks of Subarnarekha Delta with Special Reference to Degradation and Accretion under Physical Processes

Ashis Kumar Paul and Amrit Kamila

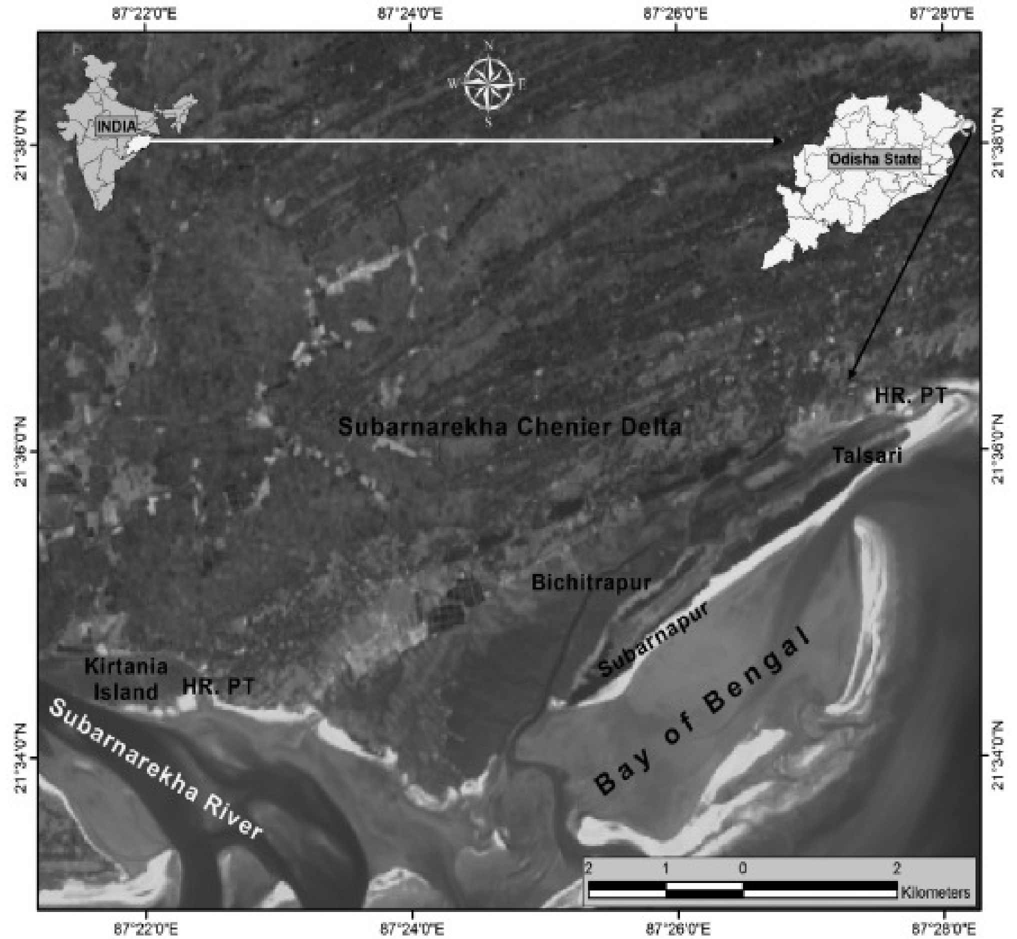
Introduction

Subarnarekha mud banks are widely distributed in different sub-environments of the Chenier delta (Fig.1). They are concentrated in the island platforms, estuary fringes, backwater tidal flat, mangrove swamp terrace, and in the near shore tidal flats behind the shore parallel sand ridges or bars (emerged in the low water) of the deltaic coast. Temporal images (LANDSAT ETM+ 2012 Feb and Oct and Google Earth 2014 Feb and Oct) of Subarnarekha estuary fringe areas show the deposition of soft muds in extensive tracts at the near shores particularly in the month of October during the freshets of Subarnarekha River (Kamila et al. 2016). However the muds are redistributed in other sub-environments by tidal currents and longshore currents during the period of the dry phase of Subarnarekha river systems particularly within the month of February (post monsoon season). River discharges of Subarnarekha played an important role to deliver muds onto the near shores for accumulation in the shallow seas under the protective barriers of shore parallel emerged bars in the southeast of the Subarnarekha river mouth. As a result of such depositional process and nearshore morphology wide and extensive mud banks are developed in the delta fringe position of the coast.

Resuspension of muds by littoral currents and tidal currents are carried into the deltaic sub-environment of estuarine island platforms, estuary banks, backwater tidal flats and mangrove swamps surfaces for accumulation with inundation levels and frequencies of high tides (Masselink et al. 2011). High discharges of muds also resulted in a significant flood year (1978, 2008) of Subarnarekha River in the coastal zone that favoured the accumulation and extension mud banks in the near shores of the delta. Rapid shift of mud banks was recorded from near shores and estuary banks, particularly by south west drift currents and by strong drifts in 2009 and 2013. The mud banks of the region can be categorized on the basis of the source of muds, e.g. mud banks formed by progradation of coastal mud, mud banks formed by the sediments and organic debris discharged from Subarnarekha estuary, mud banks formed by accumulation of tidal muds in the mangrove swamps and salt marsh platforms, and mud banks of thinly laminated muds deposited under repeated tidal inundations along the shelving banks.

Sediment input into the coastal zone by Subarnarekha river and coastal morphodynamica play significant role for sand-mud dynamics in the part of the Bay of Bengal coast of tropical climate (Nandi & Ghosh, 2014; Barman et al. 2016).

Figure 1
Location Map of the Study Area



Category of the Mud Banks

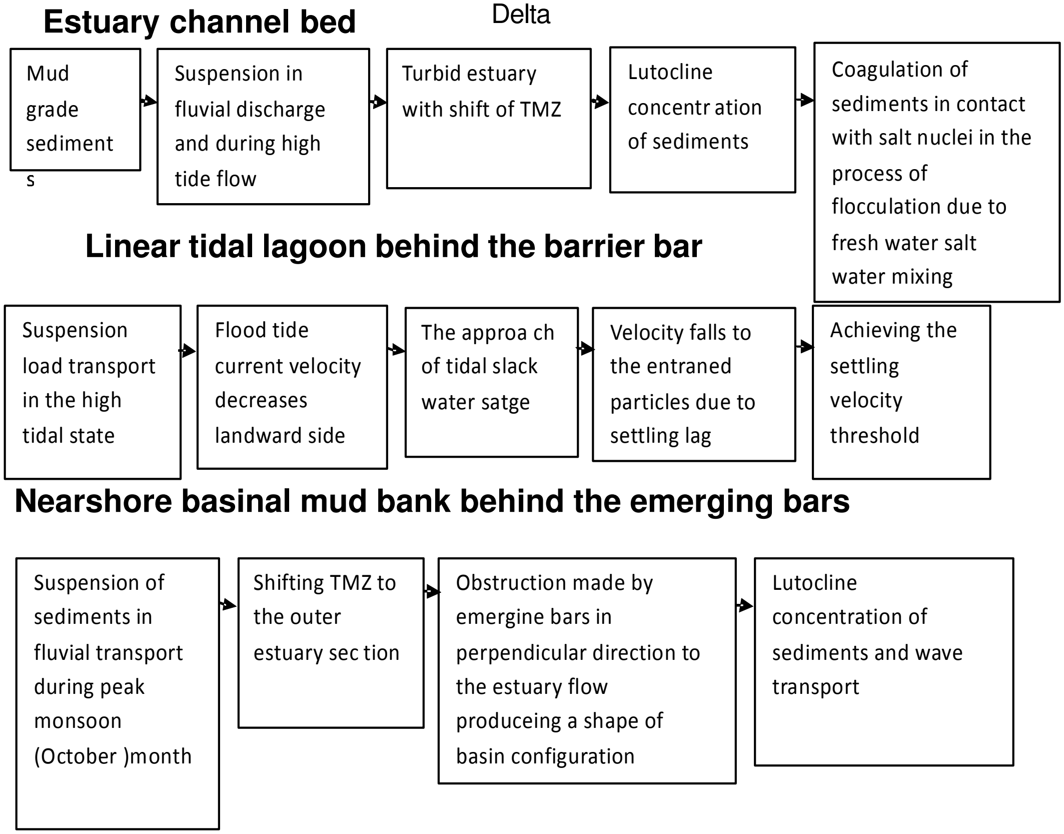
In the vicinity of the Subarnarekha river mouth, along the estuary fringes and at the back barrier tidal lagoon of Talsari-Subarnapur Chenier coast, diversity of mud banks is visible. Mud banks of Subarnarekha delta can be categorized into flowing types based on the source of mud.

- Mud banks formed by sediments and organic debris discharged from the Subarnarekha river and estuary sections;
- Mud banks formed in the vicinity of river mouth shores behind the barrier bars by aggregation of tidal muds;
- Mud banks formed by the accumulation of muds under salt marsh platforms, mangrove terrace and lagoonal basins or inter ridge swales;

The muds transported by river Subarnarekha during the episodic high discharge may be delivered to the adjacent shores particularly in the monsoon months (Fig.2).

Figure 2

Process of fine sediment transportation and accumulation over the mud banks of Subarnarakhe Delta



The gently shelving banks behind the barrier bars accumulates muds by these processes may lead to the formation of prograded muddy coasts associated with such delta, and its distinct coastal geomorphologies (mangroves, cheniers, salt marshes, tidal flats).

Supply of the muds by tidal currents and longshore drifts from the inshore may accumulate in the island platforms and over the lagoon field sedimentary surface dominated by salt marsh and mangrove swamp in the post monsoon and pre monsoon months (Haslett, 2000).

The particulate muds and flocculated muds deposit over the low gradient estuary banks (Woodroff, 2002) and shoaling flats of Subarnarekha during the end of south west monsoon when the salt water plumes are sufficiently mixed with the fresh water discharges along the sectional ridge of estuary around Turbidity Maximum Zone (TMZ) from Kirtania point to 6km upstream limit. Various islands of different size are developed along the reach distance of the estuary. The mud banks of inshore areas, islands and their platforms, estuary fringe tidal flats of the relatively sheltered section, and linear tidal basin of inert ridge shoal topography may contain the entire annual mud supply of the river Subarnarekha. As these banks occupy the inshore areas of river mouth immediately behind the shore parallel emerged bars, they dissipate waves from the Bay of Bengal and protecting the terrestrial part of the shore.

Habitat Dynamics of the Mud Banks

The mud banks of shelter areas allow developing the colony of halophytic grasslands or salt marshes and mangrove swamps for fineness of sediments, good drainage and organic matter content (Boaden & Seed, 1985). Further the floral habitat of the mud bank also can trap a large amount of silts at the high tide waters to raise the surface elevation. Filamentose turf of algae on the upper part of a tidal mud flat arrest finer sediment in the submergence of tides and hold the moisture to prevent desiccation from evaporation. Such high marsh is heavily drained by tidal creek dissection and produces other sub-habitats for the creek rims and creek banks.

The root zone stabilizes mud close to the surface that is colonized by salt marshes and mangrove swamps. Deposit feeding macro fauna can have profound effects on sediment stability, particularly in the mud where they are relatively more common than in sand. Mud banks of all categories with high organic matter and interstitial or burrow water (except the inshore mud banks) are highly bioturbated in the region (Table-1).

Table 1

Environment of mud accumulated sedimentary surface in the coastal face of Subarnarekha Delta

Sl No	Environment of Sediments	Resulting Sediments	Location of Sub Environment
1	Mangrove or salt marsh vegetated high tidal mud flat	Gray bioturbated root structured shelly muds	Tidal Lagoon with mangrove swamp, back shore of the barrier bar environment
2	Algal mat covered high tidal elevated mud flat	Desiccated laminated mud	Salt marsh terrace with algal mats, lagoon fringe area
3	Bare high tidal exposure of mud flats	Very thinly laminated, Dessicated with mud chip breccias and shelly fragments	Island platform fringes, estuary bank margin tidal mud flat
4	Burrow – pocked mid tidal mud flat with compact and cohesive surface	Intense Burrow structured laminated mud, Bioturbated and saturated mud with pits, piping and joints	Eroded and exposed mud banks after removal of wash over sand fan lobes
5	Mollusc inhabited mid tidal mud flat	Laminated shelly mud and with interstices filled with water	Estuary fringes mud bank, island platform mud bank
6	Shore faces mid tidal mud flat with sand ripples	Flaser bedding	Near shore basinal mud bank obstructed by emerging sand bars

Degradation of Mud Banks

Temporary mud attached to the shore of Subarnarekha river mouth leads to massive short term coastal progradation (over 1km wide shore behind the shore parallel bars), which is followed by equally spectacular coastal erosion by waves and strong tidal currents a few months later as the mud bank is reduced due to its migration towards the down drift direction. The mud banks of island front shores are cliffed by wave erosion, particularly in the post monsoon and pre monsoon months. Mud banks of higher elevation are affected by hypersalinity due to tidal drainage loss, evaporation, desiccation and salt encrustation. Mangroves of high salt tolerance are also unable to survive in such hyper saline patches. Dwarfed growth and die-back of mangroves occur in and around the saline blanks. Such areas are easily identified through remote sensing techniques for management options.

However, most of the are seriously degraded only due to advancement of overwash sand fan lobes on the vegetated and also by roll over process of the barrier dune ridge on the prograded of the swale topography of the study areas. The sand-mud interactions play a vital role under the chanier process along the deltaic shores through the events of storm breaks and tidal waves. A large part of the younger salt marsh patch of the Kirtania island platform of the estuary section is blanketed by overwash sand sheet of 1.0 m to 1.40 m thick and over 200 m wide and 142 to 160 m long which is directed towards north northeast of the local shoreline.

As the sand sheet is removed from the outer shore of the island towards south, the of modified forms is exposed and affected by consolidation, desiccation, intense bioturbation, wave reworking, current scouring or undermining at the high tides, clifflet formation, surface lowering by erosion with formation of the erosional scarps and wave cut banches, removal of nutrients, organic matters and salt marsh root zone degradation as well as chemical alteration of sediment. The phenomenal effects of overwash deposits are observed, particularly along the matured mangrove swamp fringed shoreline from which the frontal chenier sand ridge is partially removed by repeated storm breaks in the near past (1988, 1989, 1995, 1999, 2007, 2008, 2009, 2013 and 2014).

As a result of openness to wave attack and low elevation the southwestern part of back water swamp is affected by direct encroachment of overwash intrusion against the complete overwashed shoreline nearby the Subarnarekha estuary mouth (Maiti, 2013). At the end of the decade of 1990 when complete barrier overwash took place in the region the mud banks of mangrove swamp were trapped by repeated overwash intrusion and thicker deposits of sand fan materials with a significant amount of placer minerals (mostly by monazitic and illminitic placers). The overwash materials of sands (inorganic materials) were sufficiently advanced towards the inner swamp up to the bank margins of Talsari- Subarnapur tidal channel by repeated overwash process in the wet season (July to November) and wind blown activities in the dry season (March-June) over the years (1999 to 2014) since initiations. The new pneumatophores of matured mangrove vegetations (Avicennia sp.) were blanketed by an advanced sand sheet for a long time which has gradually altered the underlying mud banks, and has disturbed the physiological function of tidal roots or surface roots (breathing roots) of mangrove trees by making an anaerobic condition under the thicker deposits of washover sand terrace. The large mangrove trees of about 2.6 km areas are dying on the bank margins of Subarnapur tidal channel due to above reason.

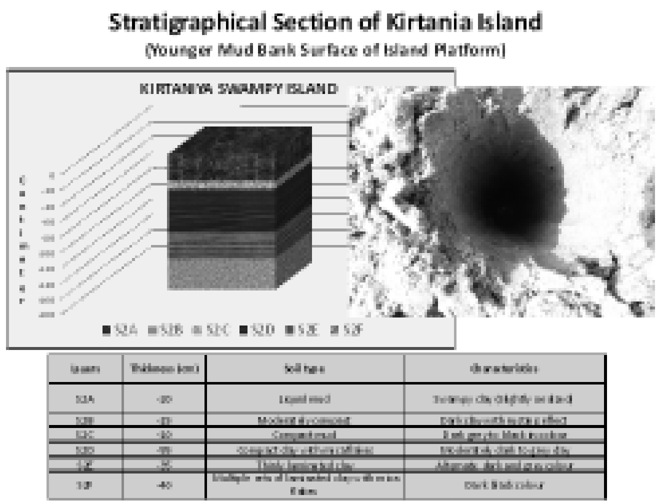
Areas of higher of the tidal lagoon are seriously affected by tidal drainage loss with increased hyper salinity and desiccation process. The coastal wetlands of such higher elevations (older) are degraded by salt encrustation.

Results of Sediment Records

Mud bank sediment logs are sampled from 0 to 200 cm depth zones in Kirtania island of estuary section and the Bichitrapur area of tidal lagoon (deltaic coasts of Subarnarekha river) for mechanical and chemical analysis. The analysis reveals that a thick deposit of overwash sand is lying just below the 13 cm clay zone, and alternate sand-mud zones are also extended up to 200 cm depth in Buichitrapur. Organic carbon decreases as depth increases, as well as the electric Conductivity of sediment is increased with decreased pH value in the deeper parts. Primary productivity is largely affected by such older deposits of overwashed sands from such lagoonal basin filled sedimentary depositional environment. Alternate thickness of sand-mud layers below the modern surface of lagoonal salt marsh platforms reveals that the accumulation of tidal muds in the sheltered environment and overwash sand encroachment across the barrier bar during storm landfall events or occurrences of unusual high tides in the near past (Fig.3 & Fig.4).

Percentage of silt content and clay content are high in the tidal sediments of the estuary fringed island of Kirtania. Multiple sets of laminated clay with mica flakes excavated from the depth of 180 cm sediment layer reveal the fluvial transport of the catchment area of the Subarnarekha river in this estuary section. However, the compact clay layer (dark in color) is available from the depth of 20 cm to 110 cm of the island surface. These compact clay layers are anaerobic in character and having moderate to low organic matter.

Figure 3
Stratigraphical Section of Kirtania Island and Associated Sediment Characters



Chemical and Mechanical Analysis of Sediments of Kritania Island Platform Mud Banks

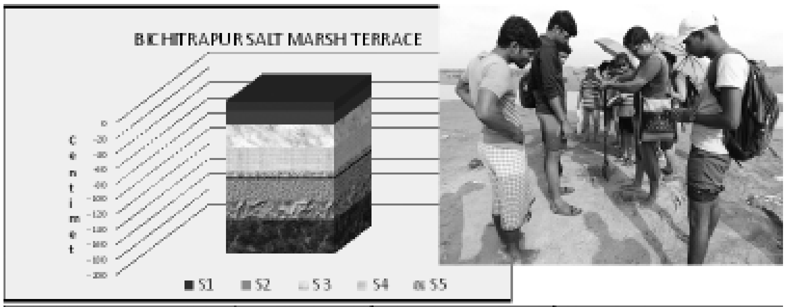
Sl. No	Parameter	Results (Depth wise sediments samples)					
	Depth	0-20 cm	20-35 cm	35-45 cm	45-100 cm	100-135 cm	135-175 cm
1	Ph (1:5 ratio)	6.75	6.23	6.34	7.15	6.68	6.74
2	EC (µs/cm)	2650	3630	3730	3570	3840	3140
3	Soil Texture	Clay loam	Clay loam	Clay loam	Clay loam	Clay loam	Clay loam
a	Sand (%)	27.5	25.4	29.3	28.7	31.9	27.0
b	Silt (%)	38.3	37.9	37.2	39.9	37.7	38.5
c	Clay(%)	34.2	36.7	33.5	31.4	30.4	34.5
4	OC (%)	0.55	0.74	0.52	0.61	0.42	0.42

Figure 4

Stratigraphical Section of Bichitrapur Salt Marsh Terrace and Associated Mud Bank

Stratigraphical Section of Talsari Back Water Salt Marsh Terrace

(Matured Mud Bank surface)



Layers	Thickness	Soil type	Characteristics
S1	-13	Mud	Dark gray in colour
S2	-17	Sand	Deep brown in colour
S3	-30	Sand	Whitish in colour
S4	-32	Sand	Yellowish in colour
S5	-8	Sandy mud	*Oxydised sandy mud with rusting colour in 1 in depth *In 83 cm from top surface decompo sed organic layer of 8 cm thickness
S6	-2	Sand	Whitish grey in colour Oxidized
S7	-28	Muddy sand	
S8	-26	Muddy sand to sandy mud	Moderately Oxidised and brownish in colour
S9	-46	Sticky clay	Black clay layer

Chemical and Mechanical Analysis of Sediments of Bichitrapur Salt marsh Terrace Mud Banks

Sl No	Parameter	Results (Depth wise sediment samples)								
	Depth (in cm)	0-13	13-30	30-60	60-92	92-100	100-102	102-130	130-155	155-200
1	Ph (1:5 ratio)	7.76	6.37	7.96	6.93	6.87	6.60	7.35	6.53	6.72
2	EC (µs/cm)	761	635	618	1541	1278	1946	2810	2220	5370
3	Soil Texture	Loam	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Sandy loam	Clay loam	Sandy loam	Clay loam
a	Sand (%)	44.1	86.2	87.1	85.9	86.7	45.9	25.3	47.3	28.2
b	Silt (%)	37.2	9.5	9.2	10.0	10.5	48.0	43.0	46.8	41.2
c	Clay(%)	18.7	4.3	3.7	4.1	2.8	6.1	31.7	5.9	30.6
4	OC (%)	0.72	0.13	0.09	0.03	0.07	0.28	0.67	0.09	0.22

Mud Bank Morphology

Muddy coasts of swale topography, estuary banks, island platforms and near shores of the present study area are associated with Subarnarekha river delta ion which are composed of fine sediments that carried as suspended load from the river catchment during the freshets of southwest monsoon months (September to October). Among these the shore attached forms along the estuary mouth banks, island banks and near shore sub-tidal behind emerging bars (3.5 km long and 2.0 km wide) and of average 2.70 m thick undergo episodic movement to seasonal change and events of river floods, longshore current velocity, storm landfall and unusual high tides. They have developed in an exposed situation, and the shore face mud has a high water content. These fluid muds usually dissipates the incoming wave energy in the open coastal environment (Parvathy et al. 2015) by the development and progradation with a fluvial supply of fine sediment. Mud banks migrate progressively triggered strong pre monsoon southwesterly winds on the coast. Mud banks not only dampened waves in the mouth of Subarnarekha estuary but also provided a useful, productive ecosystem for growth and extent of salt marsh and mangrove vegetations. Encroachment of overwash sand deposits into the landward side has disturbed the mangrove habitats and eroded along shore face by repeated storm landfall in the coastal zone since (1989 to 2013).

Table 2
Morphological Variation Along The Mud Bank Of Subarnarekha Deltaic Coast

Sl No	Mud bank Location	Latitude longitude position	Status of the mud bank	Morphological Characters
1	Kirtania Island platform mud bank	21°34”26.52’N 87°22”04.70’E Elv. – 1.5 m	Fresh silt with flocculated muds in the HTL ; Erosion since 2009	Accreted silty platform with salt marsh veg etation
2	Subarnarekha estuary fringed shoreface mud bank	21°34”09.72’N 87°23”26.19’E Elv. – 1.5 m	Flocculated muds with organic deposit and algal mat, dark colour peaty clay	Highly bioturbated mud banks and piping with creek extension and by headward erosion
3	Bichitrapur mud bank colonization of mangroves	21°34”19.66’N 87°25”04.74’E Elv. – 2 .0 m	Eroded mud banks with the break of slope and sheeting, dessicating cracks and washing process	Erosion and compact muds with oxidation; the degraded trunks of mangrove trees are exposed over the mud bank
4	Barrier back tidal lagoon with mud bank near Subarnapur	21°34”45.56’N 87°25”38.91’E Elv. – 4.0 m	In the form of tidal mud bank with salt marsh terrace and mangrove swamp	Very high elevated mud banks with algal mats and tidal creeks (valley deepening)

5	Subarnarekha river mouth mud bank behind the emerging bars	21°33”59.17’N 87°25”23.63’E Elv. – 0.2 m	Wide spread fluvial muds with the wave reworking process	Loamy sand with gently slopping flat
6	Talsari Harbour point mud bank to the west	21°35”55.23’N 87°27”16.74’E Elv. – 1.5 m	Lagoonal muds with swale surface and salt marsh terrace (presence of wind tidal flat) ; parallel tidal creeks with headward erosion	Over wash sand encroachment in this storm breaks and tidal muds are veneered the surface
7	Mud bank of basin fringe area on the landward side	21°35”13.14’N 87°25”20.36’E Elv. – 4.0 m	Elevated mud banks of tidal drainage loss and emerging hyper saline blanks	Terraced mud banks of the lagoon fringe area ; tidal creeks are fewer and flatter
8	Mangrove colonized swampy mud banks of lower elevation	21°34”41.80’N 87°25”20.40’E Elv. – 3.0 m	High tidal sheltered mud bank on the margins of Bichitrapur-Talsari tidal inlet channel	Low-lying mud banks with a rooted structure of man groves and fed by tidal creeks

The western shore attache are exposed to the wave attack after the erosion or removal of sand sheets from the lower beach face near chaumukn. Wave erosion with bank failures of large size mud blocks (30-55 cm in width and 48 to 69 cm in length) have generated cliff line, stepped surface, joined blocks and smaller scurps along the shore face in the region. Remnants of vegetation roots and organic matters are visible on the mud bank surface. Large unit of mud blocks is separated and removed from the thicker bank (>1.10m) by spalling along fractures and sandy planes.

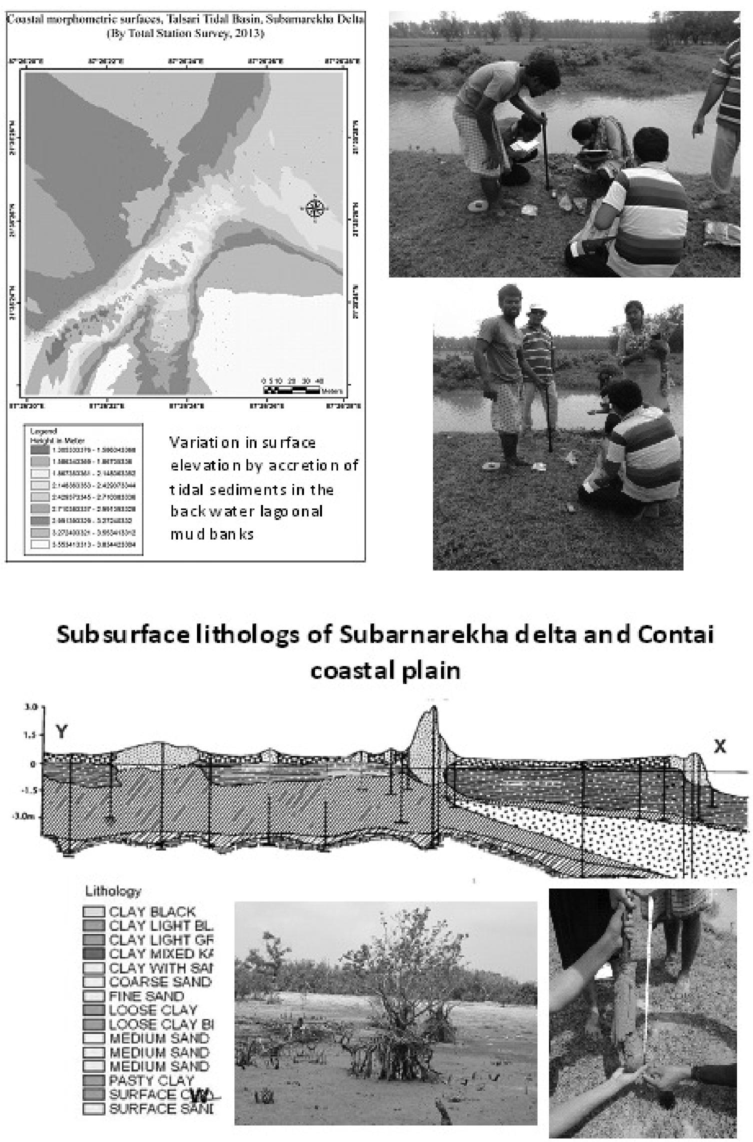
Areas of island fringed (Kirtania) are distinctly broken by over one meter cliff wall with wave erosion crenulated by gully channels. The shore platform at the base of the cliff wall is near horizontal and largely planated by a stage of erosion cycle. The larger boulder shaped mud lumps are distributed at the base of cliff wall of the mud banks. Mud balls are also visible on the surface of the near horizontal platform on the seaward side. However, the upper surface of an island crest mud bank is intensely affected by pitting and flaking. Small pieces of clay are eroded from the channel creeks by flaking. The interstitial or burrow water is also found very close to the surface of the pitted mud bank in this part.

Mud banks of Bichitrapur Talsari tidal lagoon attached with major inlet channels and tidal creeks are affected by the removal of grains with seepage or piping of outflowing ground water, and for which the back sapping and collapse of the free face are largely caused often by toppling along bank margins.

Finally, the colonized by mangrove swamps and salt marsh vegetations are degraded by bank failure due to thalweg shifting triggered by uneven sedimentation during the events of unusually high tides (Table-2).

Subarnarekha deltaic cheniers clearly provide the evidence of the episodic nature of sedimentation by storms on muddy coast and also by the pulsing effect of high magnitude river floods into the estuary fringes and also along the swale topography areas between parallel sand ridges of the modern coast. The episodes of mud progradation and episodes of ridge building are also triggered by longshore current velocity, wave heights, tidal prisms as well as relative sea level stages of the coastal plain (Paul, 2002).

Figure 5
Sediment sampling sites from the Swale Topography of Chenier Delta



Source: After Sabyasachi Maiti, CURRENT SCIENCE, VOL. 104, NO.12, 25 JUNE 2013 pp. 1709-1714

Major Findings

The above study reveals the following observations on coastal mud banks and their physical processes with special reference to degradation and acceration in the domains of various sub environments (Subarnarekha deltaic coast):

- The back water basin margin mud banks of Talsari- Subarnapur tidal lagoon are alternately affected by the deposition of barrier bar overwashed sand in the near past (Fig.5).
- The younger island platform supported mud banks of inner estuary sections are moderately stable except the marginal effects of washover sand deposits and wave erosion by storm breaks or during unusually high tides.
- The annual supply of muds of the Subarnarekha river is largely accumulated behind the emerged bars, but fits the formation of mud banks further inshore of the deltaic coast.
- Surface exposures of consolidated mud banks resulted from the removal of complete overwashed sand lobes become temporally desiccated and inundated by tides, and equally followed by spectacular coastal erosion by waves.
- Liquid muds, cohesive muds, semi consolidated muds and consolidated muds of different sub environments are hydro-geomorphologically altered through mechanical disturbances of sapping, seeping, piping, flaking, spalling, pitting, jointing, sheeting, collapsing, toppling and slumping.
- Swampy muds of the mangrove shore of the chenier delta are largely affected by overwash vulnerability of present.
- The algal mats of salt marsh terrace contribute primary productivity, which provide the food source for benthic fauna in the inter tidal areas.
- Understanding of mud bank dynamics of the different sub environment is immediately needed to restore the coastal wetland vegetation for coastal managers and administrators.

Conclusions

Prograded mud banks of deltaic platform have been develop by the high discharge fluvial supply of muds by Subarnarekha river; and shore parallel sand spits or barrier bars are developed along the shoreline of different periods by waves and wave induced longshore currents in the cuspate delta of Subarnarekha river. Usually, the mud is also redistributed into the estuarine stretch of the river by tidal mixing, flocculation and deflocculation process. However, some of the muds are re-transported by tides and accumulated in the tidal lagoon (barrier back lagoon basin) behind the shore fringed emerged bars, and over the island surface with tidal inundations.

Older muds are dark in color, sticky and peaty in character with presence of shell fragments and organic matter over which the chenier sand ridges are lying and exposed on in the shore face by erosion (Masselink et al. 2014). Younger muds are gray to moderately dark in color depending on the presence of fine sands and organic matter under depositional environments provided by configurations and topographic component of the deltaic coast.

Relatively younger mud banks from which the encroached overwash sand fan lobes or the barrier washed sands are removed, and thus usually exposed on the shore face, but altered with repeated wave beaten process during high tide events and have produced the oxygenated surface due to frequent exposer and rain wash process at present. They are rooted, compact, desiccated, sheeted and peaty in character, but not allowing the newer habitat for growth in the modified dynamic environment. Mangrove can not stand or exist over this mud bank and thus heavily degraded as the breathing roots were trapped by thicker sand sheets during overwash phenomenon induced by storm breaks and unusual high tides. Tidal roots of larger mangroves are physiologically unable to withstand the adverse condition of modified mud banks along the shore fringe areas of the barrier back environment. In the higher inter tidal zone of salt marsh terrace the environment is less energetic and as a consequence of the less mobility of mud bank sediments the oxygen is depleted rapidly within the sediment stratigraphy and for which the altered anoxic conditions of muds support hydrogen sulfide producing bacteria. This is the result in creation of thick black muds just below the active sediment surface of mud banks in the island platforms and lagoon fringed areas of the barrier back environment. Erosion of mud bank is significant in which wave and current energies are concentrated on the site specific shore face depending on the shoreline configurations, elevation of the surface and orientation of the estuary banks (Maiti et al. 2009).

The appearance and disappearance of mud banks play a significant role in energy settings of the chenier delta system for building the complex platform to adjust with sand-mud interaction under hydrodynamic regimes. The sea level still stands are favourable period in the past and present for progradation of mud banks and transgressive seas are responsible for active sand-mud dynamism and landward encroachment of sand ridges over the mud banks by rollover process

References

Barman, N. K., Chatterjee, S., & Paul, A. K. (2016). Coastal Morphodynamics: Integrated Spatial Modeling on the Deltaic Balasore Coast, India. Springer.

Boaden, P. J., & Seed, R. (1985). An introduction to coastal ecology. Glasgow: Blackie. 73-74.

Haslett, S. (2000). Coastal systems. Routledge. London and New York, 93-97.

Kamila, A., Bandopadhyay, J., Paul, A. K. (2016) Assessment of seasonal sediment distribution zones of estuarine sections and nearshore using Landsat-8 digital data: a case study of Subarnarekha Delta. Abstract 56, 36th INCA international congress 2016, Shantiniketan.

Maiti, S. (2013). Interpretation of coastal morphodynamics of Subarnarekha estuary using integrated cartographic and field techniques. Current Science (00113891), 104(12).

Maiti, S., & Bhattacharya, A. K. (2009). Shoreline change analysis and its application to prediction: a remote sensing and statistics based approach. Marine Geology, 257(1), 11-23.

Masselink, G., & Gehrels, R. (Eds.). (2014). Coastal environments and global change. John Wiley & Sons. 68-69.

Masselink, G.,Hughes. M.., Knight J. (2011) Tide dominated coastal environment-estuaries. In: Introduction to Coastal Processes and Geomorphology. Hodder education. U.K. 207-208.

Nandi, D., & Ghosh, C. (2014). Morphodynamic changes around Subarnarekha coast: study using multi change satellite data. Asian Journal of Science and Technology, 5(10), 620-624.

Parvathy, K. G., Noujas, V., Thomas, K. V., & Ramesh, H. (2015). Impact of Mudbanks on Coastal Dynamics. Aquatic Procedia, 4, 1514-1521.

Paul, A. K. (2002). Coastal Geomorphology and Environment: Sundarban Coastal Plain, Kanthi Coastal Plain, Subarnarekha Delta Plain. ACB Publications. 242-310.

Woodroffe, C. D. (2002). Coasts: form, process and evolution. Cambridge University Press. 388-400.

4

Land Degradation Processes and Status of Purulia District: A Part of Eastern Chotanagpur Plateau, West Bengal, India

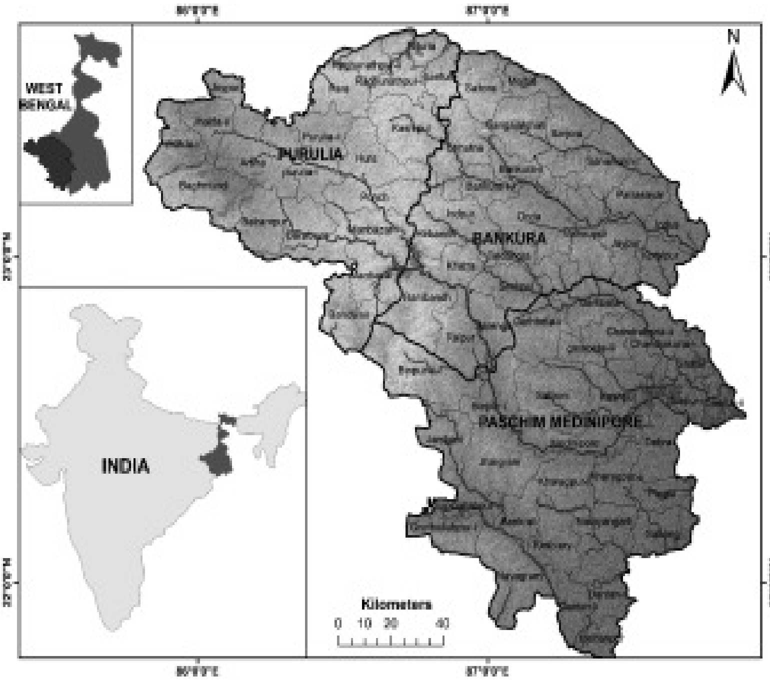
Avijit Mahala

Introduction

The concept of land degradation indicates temporary or permanently long-term decline in ecosystem function and productive capacity. Land degradation (soil salinity, acidity, erosion) is the decline in quality of land from the mismatch between land quality and land use (Fitzpatrick, 2002). It can also be explained by complexity of forest, pastures, woodland and consider the loss or reduction of biological or economic productivity(Stocking & Murnaghan, 2003). There is about 30% of forest, 10% of grassland, and 20% of cultivated land across the world suffers from land degradation related problems and 1.5 billion people are affected by it. The different types of land degradation are water erosion, wind erosion, soil fertility loss, water logging, salinization, lowering of the water table, deforestation, forest degradation, rangeland degradation, soil pollution (Types & The, 1976). The effect of land degradation includes decline in chemical, physical and biological properties of soil, biodiversity loss, reduction of availability of portable water, surface water as a lessened volumes, aquifers decline due to lack of recharge, reduced yields, famine, water and food insecurity, conflict over access to resources, and mass migration. According to different sources, the total area under desertification (arid, semi-arid, dry subhumid) in India are 228 m.hec. or 69% of total geographical area (Me&F, 2011). The different processes of land degradation have observed in India include vegetation degradation, water erosion, wind erosion, salinity, waterlogging, frost shattering, mass movement, man-made, barren/rocky, built-up land (Boever, Khlosi, Delbecque, Pue, & Ryken, 2013). The processes wise status of land degradation in India are water erosion (10.21%), water degradation (9.63%), wind/aeolian degradation (5.34%), forest shattering (3.1%), salinity/alkalinity (1.6%), mass movement (1.35%), water logging (0.3%), rocky/barren areas (0.5%), others (0.04%) (Me&F, 2011). (Atlas, 2010). The total estimated cost of land degradation in India is about 1.40% of GDP, 3.95% of AGDP, and Rs. 25,944 million (Weekly, 2003). In West Bengal, total 30.10% of TGA are degraded. Agriculture-water erosion, water body-drainage, and forest vegetal are some main processes of land degradation. In the eastern part of India or eastern Chotanagpur plateau fringe namely the Purulia district are the worst lands degraded areas in West Bengal. The pre-cambrian granite gneiss geology (Gour, Soumendu, & Nilanjana, 2014), laterite soil, undulating topography, high relief and slope, declining ground water (Bhunia, Samanta, Pal, & Pal, 2012), high drainage density (Shit & Maiti, 2012), and increasing aridity (P/PET) are some physical factors cause land degradation. High population pressure, greater dependency on agriculture land i.e. less availability of cultivable land are the anthropogenic factors of degradation.

Study Area

The eastern Chotanagpur or the western part of West Bengal namely Purulia district have been selected for current land degradation study. This district characteristically is a part of Chotanagpur plateau. The granite gneiss geology, undulating plateau upland with inter-fluvial lateritic upland, eastern flowing river system, low to medium precipitation (100-140cm), high temperature (35-40°C), tropical dry deciduous forest cover makes Purulia a homogenious region. The socio-economic characteristics (population density, agriculture dependent population, percentage of agriculture land, livelihood, cropping pattern) are also Similar for Purulia district.



Materials and Methods

Physical Processes of Land Degradation

The physical characteristics of, geology, soil, relief, slope, physiography, ground water, surface water (drainage density/drainage frequency), rainfall, aridity (P/PET), vegetation cover have largely influenced the land degradation processes. The study area namely Purulia have the physical characteristics like dissected and undulating plateau over granite gneiss geology with little soil depth, high aridity, less vegetation cover in whole Purulia district. The geology, geomorphology, soil, ground water, surface water (drainage density/drainage frequency), rainfall, aridity (P/PET), and vegetation cover have been studied for Purulia District. The different weightage raster (ranging from 100-200. 100= minimum degradation, 200=maximum degradation) for various physical factors of three districts have been created according to land degradation vulnerability. All physical factors weightage raster have been multiplied by Arc GIS raster calculator function for district for vulnerability identification

Table 1

Data sources and techniques of physical processes of land degradation study

Physical factors	Data types	Techniques
Geology	Map of "Geological Survey of India."	Vector mapping for different geologi cal characteristics
Soil	Map of "National Bureau of Soil Science "	Vector mapping for different soil groups

Relief	ASTER DEM 30m.USGS Earth Explorer	Relief raster creation for different relief classes
Slope	ASTER DEM 30m.USGS Earth Explorer	Slope(è) raster creation for different slope categories
Physiography	ASTER DEM 30m.USGS Earth explorer	Vector mapping for different physiographic unit
Groundwater	Mbgl data of Central ground water board	Mbgl raster creation for different availability classes
Drainage density	ASTER DEM 30m.USGS Earth Explorer	Drainage density raster creation by (drainage length/Sq.km)
Climate	Daily temp. & rainfall data of Indian Meteorological Dept.	Aridity(P/PET)raster creation for different aridity classes
Vegetation cover	Landsat8 OLI image USGS Earth Explorer	NDVI raster creation for different vegetation cover areas Physical vulnerability index for land degradation = (Geology * Soil * Relief * Slope * Geomorphology * Ground water * Drainage density * Climate * Vegetation) ^ 1/9.

Anthropogenic Processes of Land Degradation

The different anthropogenic processes for land degradation- LULC, population density, agriculture population, dependent population, forest cover, agriculture land, double cropping land, irrigated land, uncultivable land have been studied for purulia district at a village level. Vector map at village level of three districts for all socio-economic characteristics have been prepared. The different weightage raster (ranging from 100-200. 100= minimum degradation, 200=maximum degradation) for different socio-economic factors of all three district have been created according to land degradation vulnerability. Finally, all socio-economic factors weightage raster have been multiplied by Arc GIS raster calculator to identify the different land degradation vulnerable zones.

Socio-Economic vulnerability index for land degradation = (lulc*population density * agriculture population * dependent population * deforestation * agriculture land * double cropping land * irrigated land * uncultivated land) ^ 1/9.

Table: 2

Data source and techniques of anthropogenic processes of land degradation study

Anthropogenic factors	**Data types**	**Techniques**
PCA analysis	Primary census abstract and village directory-2011, Census of India	Descriptive statistics, correlation, pattern metrics for different socio-economic data
Landuse Landover	Landsat-8 OLI (11 bands) USGS Earth Explorer	Land use land covers classification by supervised techniques

Population density	Village directory-2011, Census of India	Total Population/area
Agriculture population	Primary census abstract-2011, Census of India	Main and marginal cultivator and agriculture labor population/total working population*100
Dependent population	Primary census abstract-2011, Census of India	Non-working population/ total population*100
Forest cover	Village directory-2011, Census of India	Forest land/total area*100
Agriculture land	Village directory-2011, Census of India	Irrigated and unirrigated land/ total area*100
Double cropping land	Village directory-2011, Census of India	Irrigated land/agriculture land*100
Irrigated land	Village directory-2011, Census of India	Irrigated land/agriculture land*100
Uncultivated land	Village directory-2011, Census of India	Area not available for cultivation and culti vable waste land/area*100

Land Degradation Vulnerability

The multiplied raster of "Physical vulnerability index of land degradation" and "Socio-Economics vulnerability index for land degradation" have been multiplied in Raster Calculator of Arc GIS 10.1 to find out the different land degradation vulnerable zones of the districts.

A. Physical vulnerability index for land degradation = (Geology * Soil * Relief * Slope * Geomorphology * Ground water * Drainage density * Climate * Vegetation) ^ 1/9.

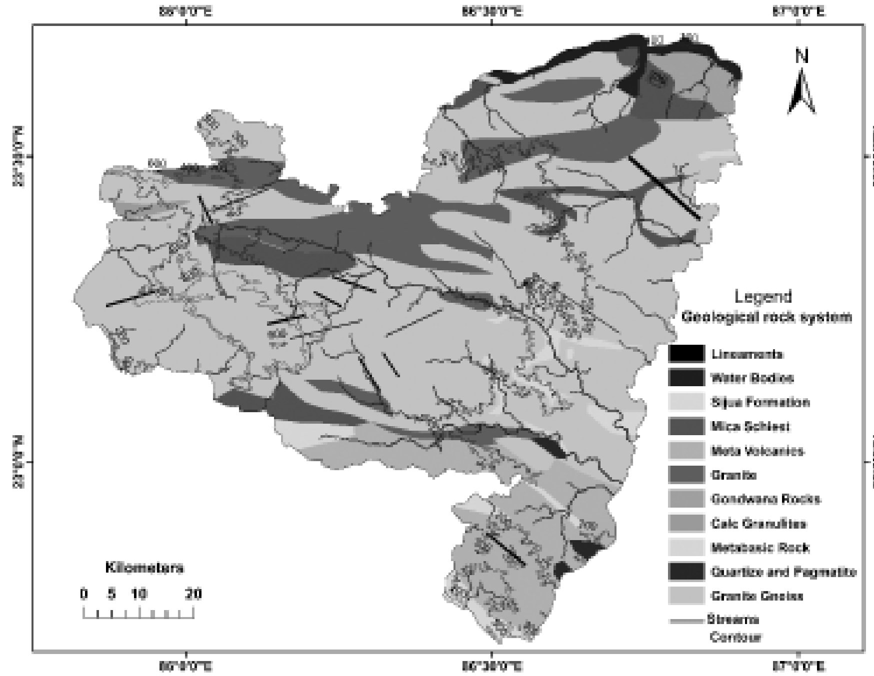
B. Socio-Economic vulnerability index for land degradation = (Lulc*population density * agriculture population * dependent population * deforestation * agriculture land * double cropping land * irrigated land * uncultivated land) ^ 1/9.

C. Land degradation vulnerability = (A. Physical vulnerability index for land degradation* B. Socio-Economic vulnerability index for land degradation) ^1/3.

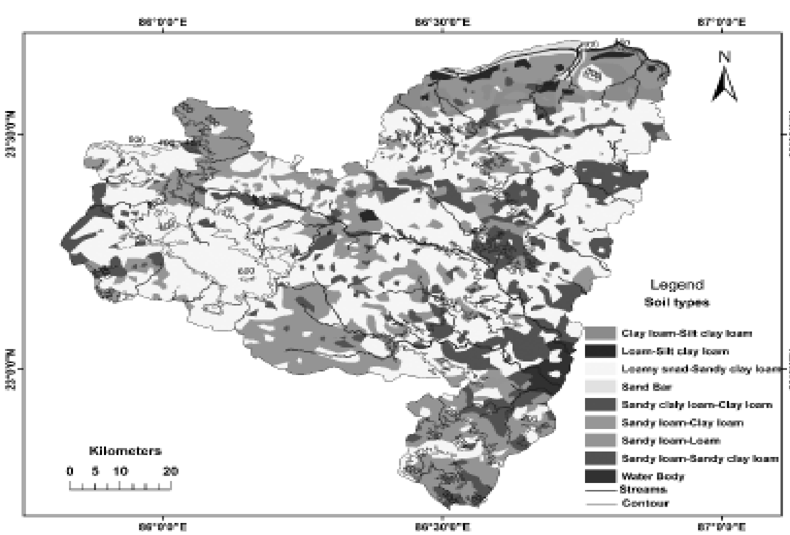
Physical Processes of Land Degradation of Purulia District

Geology and Land Degradation Processes of Purulia District

The entire district of Purulia can be divided into two geological formations (i) Archean formation (granite and gneiss) and (ii) Gondwana formations (Gour et al., 2014). The archean formation is the oldest and mostly distributed rock series of the district. Around 80% of the total area is covered by this types of rock system. The archean formation comprises meta-sedimentaries, calc-granulites, and metabasis. The older schist rocks include quartz-schist, phyllite, quartz. The granite rock includes gray banded granite-gneiss, porphyritic granite gneiss.



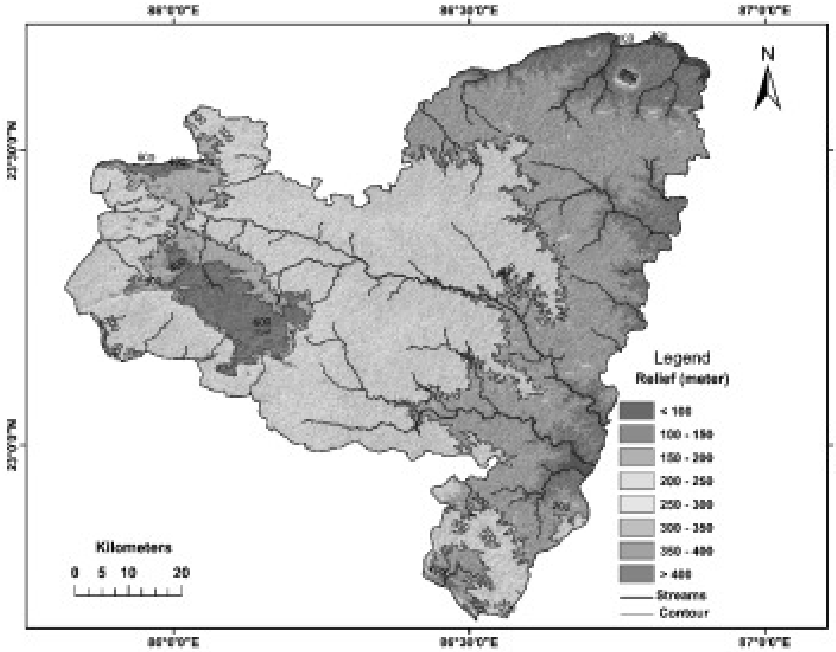
Soil and Land Degradation Processes of Purulia District



The soil of Purulia district can be broadly divided in two major types the sandy soil and loamy soil. The achaean gneiss and Schist covered largely middle and southern portion of the district have developed the sandy soil of large texture. The "Sandy loam-Loam" and "Loamy sand-Sandy clay loam" covered around 70% the district suffered from the different soil fertility characteristics

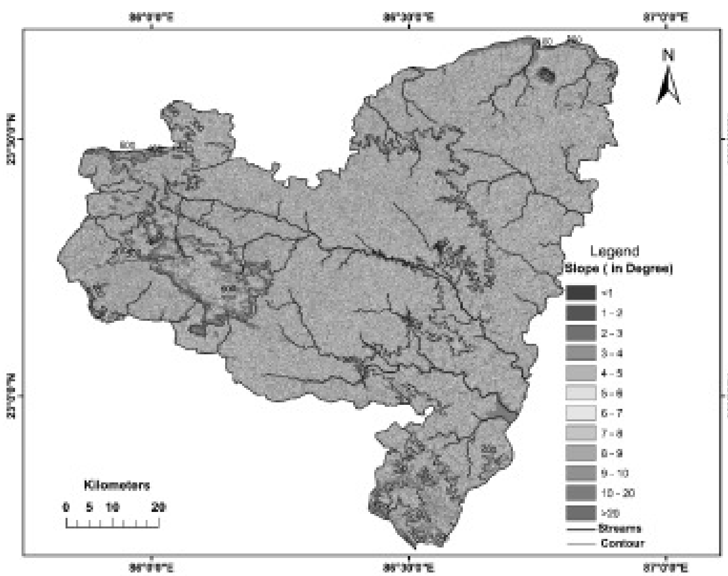
Relief and Land Degradation Processes of Purulia District

The high relief (>400) areas of Ajodhya hills is characterized by absolute high relief and undulating surface. The vast undulating surface with higher relief causes hindrance to any types of construction works. The steep slope has been developed in this types of relief surface.



Slope and Land Degradation Processes of Purulia District

The high sloped areas around the Ajodhya hills and western por The high steep slope does not permit to stabilize the soil regolith in this region causes low soil profile development. The medium sloped (5°-10°) areas largely distributed through the vast middle undulated platform of the district characterized by undulating upland and dissected plateau

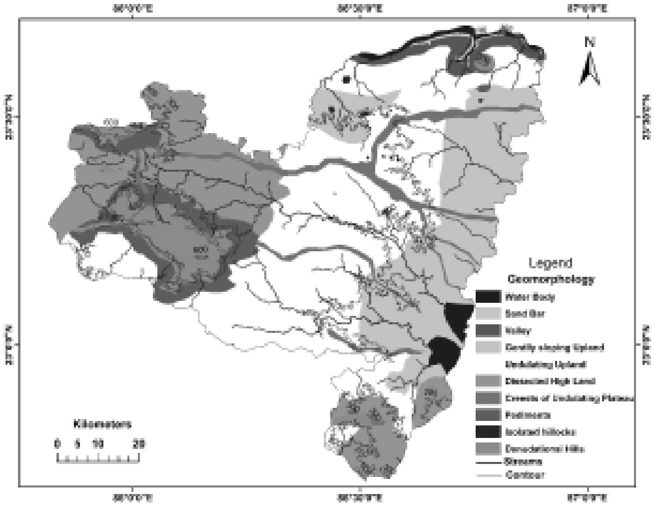


Geomorphology and Land Degradation Processes in Purulia District

Geomorphologically the district can broadly be classified into two group's viz. (i) Archean landform (Granite gneiss) and (ii) Gondwana landform. The Granite gneiss is subdivided into eight subdivisions viz; denudation hills, isolated hillocks, Pediments, Crest and Undulating plateau dissected highland Undulating upland, gently sloping upland and Valleys or Lowlands

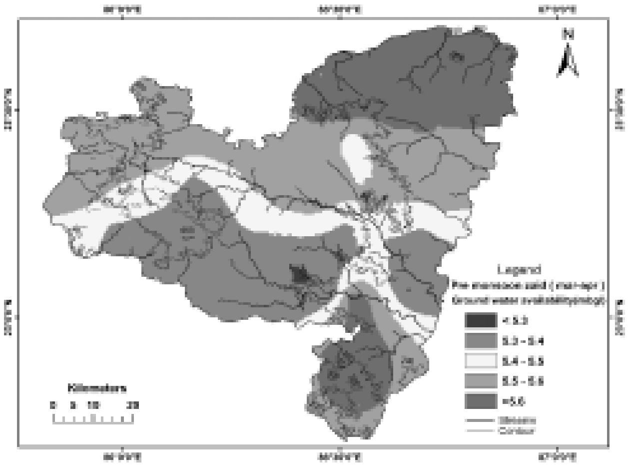
Groundwater and Land Degradation processes of Purulia District

The groundwater characteristics of Purulia district have shown that in Pre-monsoon zaid (mar-apr) season the average Mbgl of groundwater is highest (5.5) in northern and southern portion of the district. The low width aquifer and high extraction of water for agriculture causes the Mbgl values greater, leads the land to degrade.



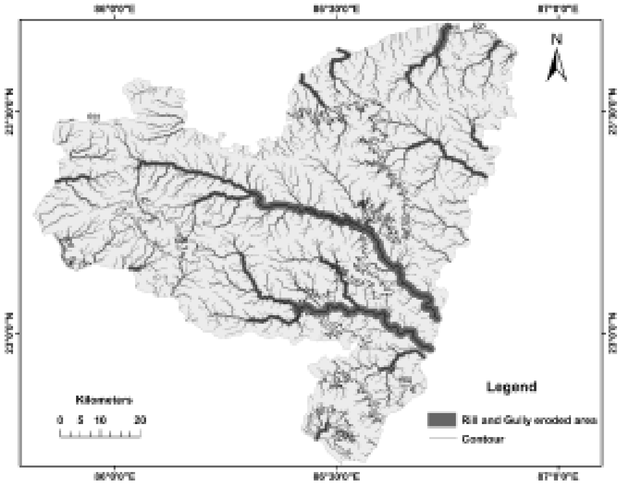
Drainage Density and Land Degradation Processes of Purulia District

The high drainage density (1.9-2km/sq. km) region of Purulia district is the western dissected highlands and southern flat -topped hills. The sloped nature has also converted this streams to erode more. Due to high erosion the soil of this region is either not developed or undeveloped



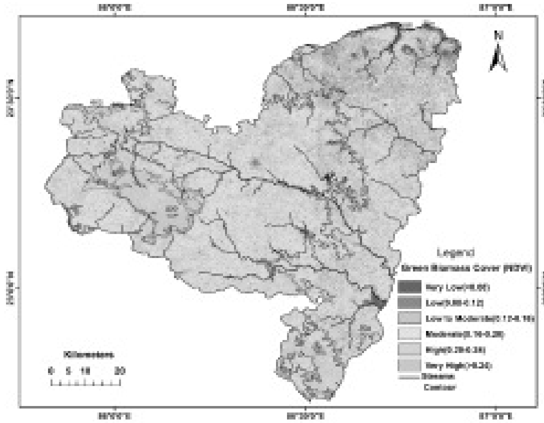
Climate and Land Degradation Processes in Purulia District.

The aridity index is low (<0.60) from middle to the northern parts of the district causes moisture stress leads to land degradation. The growing periods of this region is less to 150 days. The hilly areas of southern and western parts have high aridity index (>7.0). Causes high growing periods



Green Biomass Cover and Land Degradation Processes of Purulia district

The low biomass content areas (NDVI 0.08-0.12) is distributed all over the district except the Ajodhya Hills area. The vast open barren land has the characteristics of this types of NDVI values. This region has suffered from serious land degradation related problems. No vegetation over makes the region unproductive and unfertile.



Anthropogenic Processes of Land Degradation of Purulia District

Land use Land cover Characteristics and Land Degradation Processes of Purulia District

The land use pattern of Purulia district (fig:14) shows the dominance of anthropogenic activity over nature. The water body contains the total area of 1.67% to the total area of the district indicates water crisis in large parts of the district. The dense forest area cover 4.88% of the district concentrate mainly around Ajodhya hills. Previously it covers large parts of the district. The crop-land (59%) covers large parts in the middle dissected plateau area are increasing greatly in the previously occupied open forest area. The fallow land (21.35) covers in dissected form in all over the district. The forest degraded and scrubland (4.60) are increasing in nature have been placed in previously occupied dense vegetation area. The Barren and Rocky surface area (3.53) are largely distributed in the Achaean gneiss and schist geology. The sands and riverine covers 0.68% of the area, distributed in Riverside. The Built up area accompanied 4% of the area.

Population Density and Land Degradation Processes of Purulia District

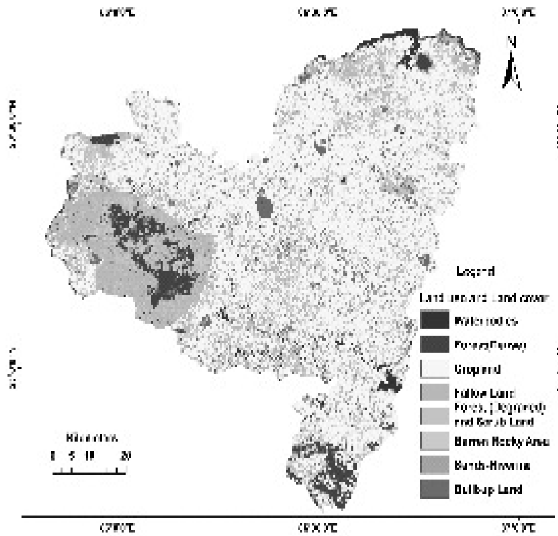
In major northern plain and main towns (Purulia, Adra) the population density are increasing(fig: 13). The large parts of the district occupy the population density of 2-3persion/ hec. Reflects the medium population density. The increasing population with high forest dependency creates pressure on land

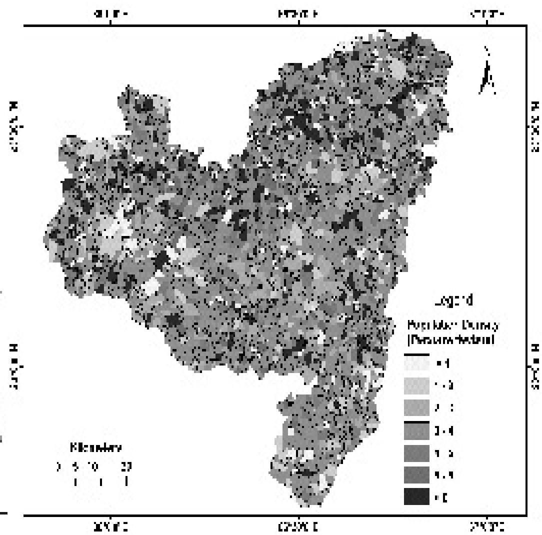
The Agricultural Dependency and Land Degradation Processes of Purulia District

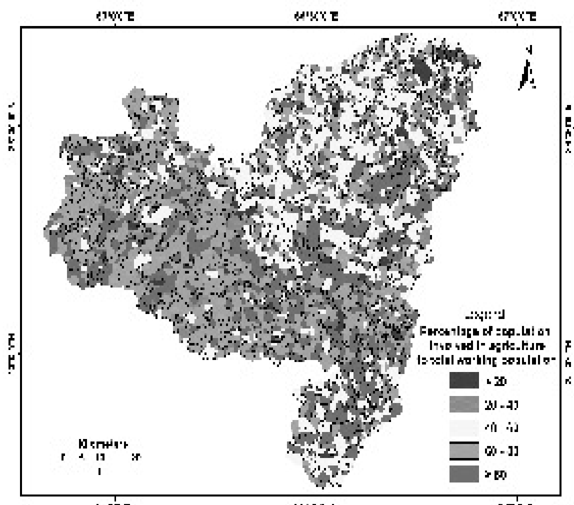
In Purulia (fig: 12) the agricultural dependency (>80%) is quite higher in southern and western upland areas, where there are no means of other employment, this area are largely dominated by tribal and marginal population who are mainly depends on agricultural activity, low investment with high agricultural; dependency causes land degradation in this region of the district. Medium to high agricultural dependency (60-80%) is distributed throughout the district. A large mass of the population in this agricultural; dependency region is marginal types.

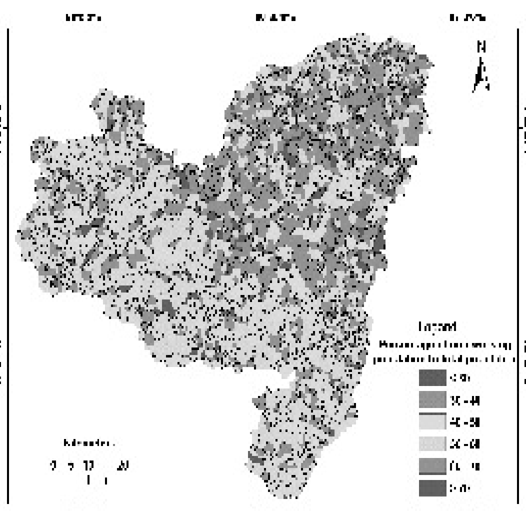
The Dependent Population and Land Degradation processes of Purulia District

The large parts of the northern plain and middle upland op Purulia district (Fig: 11) have shown high dependent population (>80). The extensive agricultural land in Damodar river basin of Purulia helps to increase the population which in turn gives pressure on land. The farmers practice subsistent agriculture, employ large unskilled, illiterate depend population causes successive low returns of the land









Deforestation and Land Degradation Processes of Purulia District

Low forest cover (<6%) shown in large parts of Purulia district, (fig: 18) causes sufficient land degradation. Increasing population with increasing agricultural land in low and middle areas causes sufficient land degradation

Agricultural Land and Land Degradation Processes of Purulia District

Total agricultural land (>60%) to total land in Purulia district (Fig: 17) are largely distributed in all over the district, with greater concentration on northern Damodar river plain areas. Large population pressure helps to introduce intensive subsistence agriculture. The unskilled pseudo labors, low organic matter, high irrigation, pesticides, chemicals have been used to serve the food of greater dependent population, decrease the land productivity. Low soil fertility and recurrent drought like situation in the district causes large parts of agricultural land converted to unfertile degraded lands.

Double Cropping Land and Land Degradation Processes of Purulia District

The double cropping land concentration of Purulia district (fig: 16) have shown higher concentration (>50%) in river valley of Damodar and Kangsabati basin. The large population with increasing dependency causes conversion of single cropping land to double cropping land in irrigation facilitate areas of the district. The large mass of population in Purulia district is marginal in nature have not applied sufficient nutrients in double cropping areas, for recent profit they use fertilizer, decrease the farm health. The immature soil with low productivity, greater use of fertilizer, low organic content in soil, with frequent irrigation and double cropping causes land degradation.

Irrigated Land and Land Degradation Processes of Purulia District

In Purulia (Fig: 15) the high irrigation area is superimposed to double cropping areas. In middle parts and large river basin (Damodar, Kangsabati) is the area where irrigation are largely practiced. A Large population with high dependency leads the farmer to practice intensive types of agriculture like low returns to land productivity, high cropping, low investment, and intension to high returns. All this are only possible when the lands are under irrigation. The high irrigation in dry land areas causes' salinization (due to high evapotranspiration), low soil fertility, an increase of crop affecting microbial activities, etc. The immature soil of the district get structural and chemical affected due to irrigation (like low aeration in soil, structural disturbance, changes in soil porosity characteristics, etc. The medium irrigated areas of the district are largely distributed in undulating plateaus are prone to soil erosion

Figure 2

Forest cover of Purulia

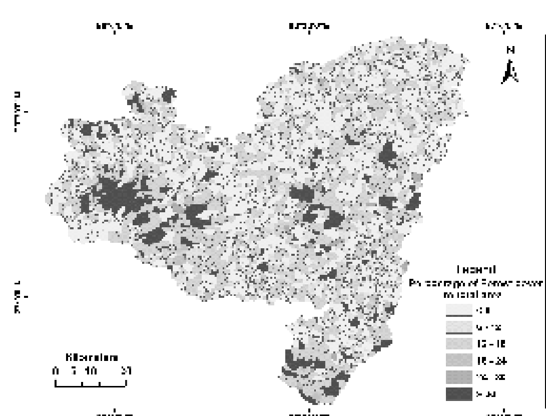


Figure 1

Agriculture land of Purulia

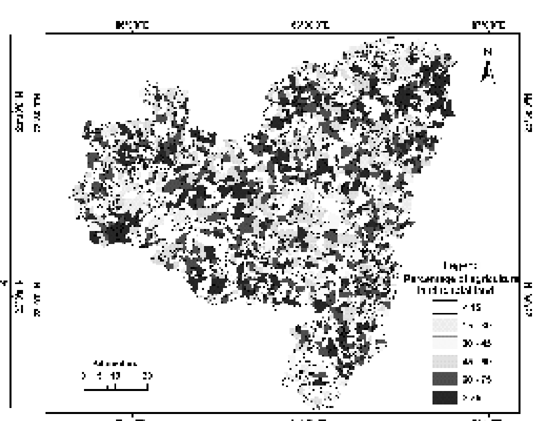


Figure 2

Double cropping area of Purulia

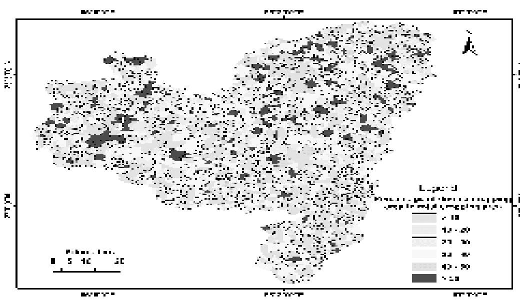
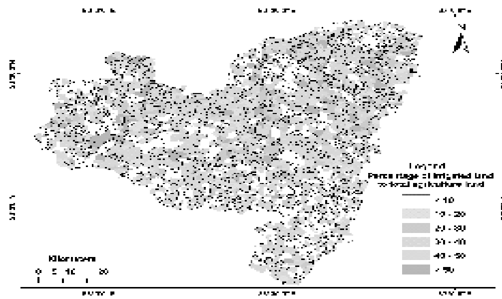


Figure 1

Irrigated land of Purulia



RESULT AND DISCUSSION

Land Degradation Vulnerability of Purulia District

In Purulia (Fig; 4.3.1) very high land degradation vulnerability (>150) (fig 4.3.1) areas are distributed in northern floodplain areas. It covers 1063sq.km. or 16.93% (table: 4.3.1) of the total area of the district. The flood plain areas are prone to soil erosion, low vegetation cover, high population density, agricultural population, and dependent population with intensive agriculture creates very high land degradation vulnerability. The high land degradation vulnerability (140-150) (table 4.3.1) areas are concentrated in large middle and plain northern areas of the district. It covers 3688sq.km. or 58.39% of the total area of the district. The medium slope with undulating topography, high drainage density and large deforestation creates threats to degradation. The medium land degraded vulnerability area (130-140) covers 1402sq.km. or 22.33% of the total area, distributed in southern parts, threats to degradation due to its physical nature low and very low land degradation vulnerable areas covers 145sq.km. and 3sq.km. or 2.3% and 0.02% of the area. This area distributed in dense forest areas.

Figure 1

Land degradation vulnerability map of Purulia District

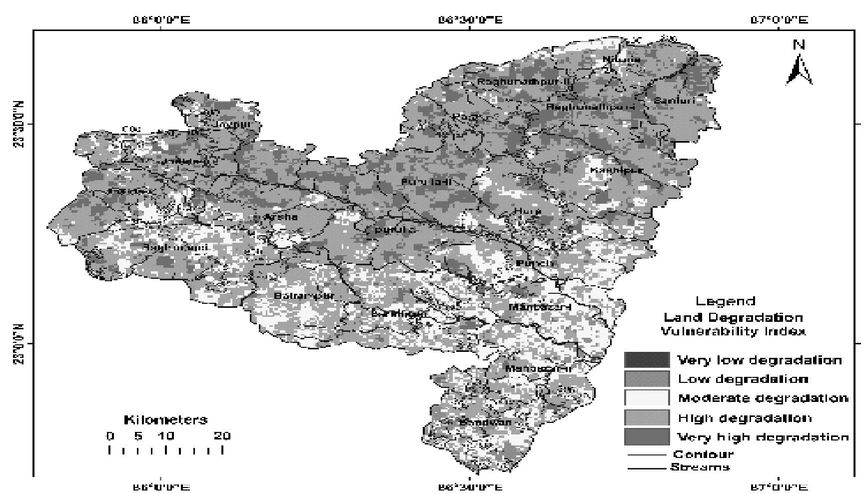


Table: 3
Area Of Different Land Degradation Vulnerability Index Of Purulia District

Land vulnerability degradation index	Value	Area (sq.km.)	Area (%)
Very low degradation	<120	03	0.0208
Low degradation	121-130	145	2.3154
Moderate degradation	131-140	1402	22.3339
High degradation	141-150	3688	58.3935
Very high degradation	>150	1063	16.9362

Conclusion

More than half of the global land are degraded due to different physical and human-induced processes. In study area the Granite-gneiss-schist geology of Purulia causes undulating landform, high relative relief, and shallow profile development. Productive works by anthropogenic activity also hindered in high relief and sloppy areas. The Dissected high land, crests of undulating plateau, denudational hills of Purulia and upper undulating plateau, dissected plateau, residual hillocks and mountains of district causes topographic hindrance in productivity. Very low ground water table in hilly upland areas and continuous declining in agricultural areas followed by large groundwater exploitation leads to water depletion. The high drainage density and frequency in undulating upland areas and large erosivity in sloppy areas causes high erosion. Decreasing rainfall and increasing aridity (low P/PET) causes water stress in ecological productivity of the area. In study area the different issues of anthropogenic processes of land degradation are increasing population density, large dependent population, a large no of population depends on primary occupation, heavy deforestation, expansion of agriculture land with double cropping area, large irrigation with increasing salinity. Out of total geographical of Purulia district, >65% area are prone to high land degradation vulnerability due to different physical and anthropogenic processes.

References

Atlas, W. (2010). Wastelands Atlas of India.

Bhunia, G. S., Samanta, S., Pal, D. K., & Pal, B. (2012). Assessment of Groundwater Potential Zone in Paschim Medinipur District , West Bengal – A Meso-scale study using GIS and Remote Sensing Approach, 2(5), 41–59.

Boever, M. De, Khlosi, M., Delbecque, N., Pue, J. De, & Ryken, N. (2013). Desertification and Land Degradation Degradation.

Fitzpatrick, R. W. (2002). Land Degradation Processes, (84), 119–129.

Gour, D., Soumendu, C., & Nilanjana, D. C. (2014). Weathering and Mineralogical Alteration of Granitic Rocks in Southern. International Research Journal of Earth Sciences, 2(4), 1–12.

Me&F. (2011). Elucidation of the 4 National Report submitted to UNCCD Secretariat, 1–121. Retrieved from http://envfor.nic.in/sites/default/files/unccd-report_0.pdf

Shit, P. K., & Maiti, R. (2012). Rill Hydraulics - An Experimental Study on Gully Basin in Lateritic Upland of Paschim Medinipur , West Bengal , India. Journal of Geography and Geology, 4(4), 1–11. http://doi.org/10.5539/jgg.v4n4p1

Stocking, M., & Murnaghan, N. (2003). What is lands degradation? Land Degradation - Guidelines for Field Assessment, 7–16. Retrieved from <http://archive.unu.edu/env/plec/l-degrade/index-toc.html>

Types, D., & The, D. (1976). hapter 2 - Types of land degradation.

Weekly, P. (2003). Land Degradation in India. Economic And Political Weekly, 38(44), 4700–4713.

5

Role of Cartography In Environmental Monitoring And Management To Appraise The Virtual Environments And Geographical Features

Balwant Kumar and Umesh Kumar Singh

Introduction

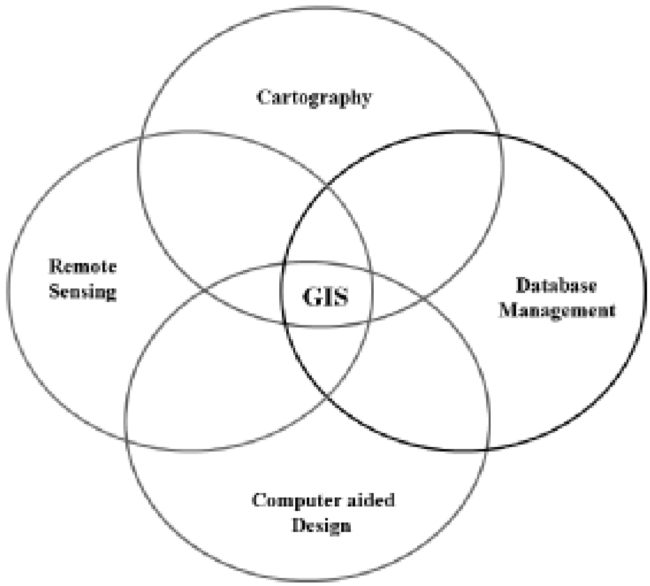
Environment is a most important dynamic system for our existence and first thing when we think about learning through interactions of a-biotic (soil, water, energy, space and air) and biotic (living organism) component (Lal 2001; Singh et al. 2008). These components always influence the adaptation of humans, animals, plants or working conditions. However, due to rapid growth of industrialization, urbanisation and economic development pollution level has increased in last few years (Zafar et al. 2010). Consequently, environmental pollution getting great attention throughout globe and it is great threat to social and sustainable development (Ishaq et al. 2010). These uncertainties have increased the challenges to maintain the sustainability between socioeconomic development and climate as well as global changes (Delpla et al. 2009). Therefore, it is necessary to understand how to conserve and restore the sustainable environment (Kabala et al. 2013). To understand and scientific management of environmental components, adaptive measures should be applied such as advanced information technology, interpretation of regular monitored data, transmission of data in scientific way and application of new noble technologies. In last few decades, advanced technologies have promoted the role of cartography in spatial and temporal analysis of environmental components (Cloud 2002). Cartography is scientific base technique to present the data in maps over the geographical coordinates. For the several centuries, it was very important to express the information visually through hand-drawn flat maps and charts (Harley 1987). In last few decades, expansion of digital computers and environmental softwares has promoted the spatial and temporal resolution and their data processing techniques for assessment of the virtual environments and geographical features. In the present scenario, application of relevant software based on cartography has been widely used for assessment and characterization of ocean and land surface including pollution and risk monitoring (Tanser and Sueur, 2002). Cartography is generally depending on the number of characteristics such as shape, size, image, tone, colour, pattern, shadow and texture of the particular objects. Shape of the object visualise structure of the surface area such as highways, buildings and river, natural landscape and geographical boundaries. Further, size determines the dimension and properties of the object to recognize the numerical properties of object such as unit of length on a map and the corresponding length on the ground. The role of image tone is very important for the identification of specific signatures of electromagnetic radiation of particular object. Another important characteristic is pattern, which is use for the systematic arrangement of natural vegetation. Similarly, shadow is useful to get a different view of an object for the identification of image problems. Lastly, texture is important character to display degree of coarseness or smoothness. It is also helpful in object interpretation such as comparing an area of grass and forest. Presently, applications of cartography have been widely used to develop various types of maps for **accident analysis, urban planning, road mapping and environmental impact analysis. It is also helpful to visualise the landslide hazard zones, land use, flood damage, agricultural area, and geology. Cartography technique also helpful to demonstrate the flooded area, forest cover, irrigational land and water bodies that will provide a platform for the better implementation of adaptive management plan in future prospective.** Therefore, role of cartography is very important with an interdisciplinary approach.

Numerous types of software are available to develop maps through employing of geographical information system (GIS) and satellite imaginary, which is helpful for the visualisation of maps with the high scale and accuracy. Several important softwares like ArcGIS, Surfer, ERDAS IMAGINE, Geo-Media, Map Info and QGIS, are available which is used for transformation and editing of imaginary file in informative way. These softwares are widely applied in the environmental research field to demonstrate scientific data in meaningful way such as slope characteristic, soil quality, agricul-tural practices, weather forecasts, environmental geology, petrology, hydrogeology, land use pattern and geographical features (Jeyaseelan 2004; Tsou 2004; Boumans et al. 2008; Kumar et al. 2011a; Avtar et al. 2011; Kumar et al. 2011b; Mukherjee et al. 2012; Krami et al. 2013; Mondal et al. 2014). In this study, ArcGIS-10.3 software developed by ESRI was employed to demonstrate grid-based map for spatial locations, geological characteristic and risk assessment with the help of geographical system coordinates. Mapping for the spatial variation of the parameters, data was transform though cringing linear method with reference to Ajay River. Moreover, all cartography techniques in this study were used based on the application of shape file in the thematic mapping and contouring though cringing linear method. This study is to respond to the need of maps including analytical tools, which will be helpful for scientific community. This study thoroughly discusses about following objectives (A) Thematic map formation for spatial location and characterisation of geological features with geographical coordinates (B) Environmental variables distribution over geographical coordinates and (C) Impact zone formation over interpolation line through contouring.

Geographical Information System (GIS)

Geographical information system (GIS) is an important computer based programme that has ability to capture, storage, retrieval, analysis, and display of spatial data. It is a scientific based new technology and emerging with several subjects such as geographical science, computer technology, remote sensing technology and information science (Clarke 1996). It has ability to collect, manage, analyze and visualize space data. Therefore, technological sound GIS softwares are one of the applications to investigate pollution monitoring and environmental resources protection. GIS mainly works on four major components viz. cartography, remote sensing, database management and computer aided design (Fig. 1).

Fig. 1
GIS and their major components for map formation



The research data can participate into GIS enabled softwares through existing digital computers. Each set of data must be allied with of geographical coordinates and satellite images in raster or vector format. In the GIS, scan map is also applicable to develop new maps after digitization and new layer formation. It has also ability to accomplish everything such as enter, edit data and modify information etc. (Bailey 1994; Elwood 2009). The storage data must be encoded into set of unique numbers for modification or editing of the maps. Similarly, maps can also be stored digitally using co-ordinate's information. It is very useful and more efficient to operate the map features without further processing. Data can also retrieve with the help of database manager by searching, reordering, and selecting of the data file (Tsou 2004). Lastly, display function is the visual output of the selected data in the form contours, symbols and shading or choropleth**.** There are several key functions, programme and sub programmes used to construct numerous types of maps. The role of cartography in GIS is very important to focus on data retrieval, categorization and symbolization.

Implementation of GIS software's especially ArcGIS and Surfer

ArcGIS software is one of GIS based computer programme where you can form maps. In the ArcGIS software, there are four major important tools such as ArcCatalog, ArcMap, ArcToolbox and Workspace. These tools have ability to transform data into different scientific maps. ArcCatalog is applied for data management that is the part of ESRI ArcGIS package. Similarly, ArcMap is used for editing and modification of the maps. It is also useful to visualise the maps with different nodes and open in layout mode where you can export or print the developed maps. ArcToolbox used as supporting tools to obtain shape-files, imaginary file, and polished data from web sources. Workspace mainly used to save the data in the computer drive.

In ArcGIS, imaginary files and base maps are firstly digitized and geo-referenced before further processing for the map formation. The image or shape-file obtained from the satellite imagery and ESRI web portal respectively are geo-referenced data. The projection of geo-referenced data is generally based on the UTM zone 11 WGS84. All the coordinates' data should be in X and Y series with the location name. Further, data file used to visualise the variables over the X (longitude) and Y (latitude) coordinates with different symbol styles.

Surfer is a surface modelling package, which is developed by American company named as Golden Software. This software has ability to transform the data into contour, surface, wireframe, vector, image, and shaded relief based on the geostatistical technique. Surfer is also helpful for the adjustment of interpolation and gridding of the data to assess the spatial variation. In the surfer software, data should be arranged in X, Y and Z column where X is longitude, Y is latitude and Z is concentration of the variable, which is shown in (Table 1). Data always saved as .dat file, which is used to convert the raw data based on statistical relation with measured points. Further, statistically converted data is used to develop contour line with different intervals.

Table 1

Data preparation for contour map

Longitude	**Latitude**	**Concentration**
X	Y	Z
86.5142	22.87613	1
86.8261	22.6133	2
87.35166	22.72831	3
87.22911	23.32466	4
87.07827	23.23791	5
86.67313	23.53537	6
87.3781	22.85733	7
86.79272	22.96576	8

Data Visualisation Techniques And Their Role In Environmental Research

The visual exposure of data elements like quantities or categories is generally expressed with the help of colouring, contouring and shape features. The visual interpretation of data illustrates the trends of analysed data such as spotting outliers, comparing sizes (minimum and maximum) and spatial distribution. Therefore, data visualization is an important and significant area for research-oriented work (Brath and Banissi, 2016). GIS and remote sensing give platform to visualisation of data including monitored as well as research data. Developed maps are used for identification of polluted areas, sensitive areas, metro cities, urban centres and ecologically fragile and sensitive areas. Map can also be helpful to mark out the monitoring stations, address, and important landmark. In study of river basin, GIS based maps are helpful to visualise drainage pattern, catchment area, water quality, flow, impact zones and source of pollutants.

Thematic Map Formation For River Basin With Monitoring Station

GIS techniques are very effective in topographical analysis of the river basin. It has capabilities of manipulation and analysis of individual layers of spatial data to analyse and model the interrelationships among different layers. The layers such as litho-stratigraphy, steepness of slope, drainage and lineament are generally formed by ESRI shape files. Data and geographical coordinates have been collected from Ajay River basin at nineteen different locations. The map of the area based on spatial analysis has been developed by the shape file followed though step by step approach such as digitization, editing, building topological structure and finally, polygonization for GIS overlay analysis. The targeted nineteen locations were indicated with their unique name and symbols based on the coordinates. Further, geographical boundaries of districts were employed to indicate exact targeted location. Similarly, Ajay River was employed to demonstrate the river catchment area and sampling points. This map also indicates sampling points, urban and industrial centres and rural areas along the Ajay River basin.

This map was developed with the help of ArcGIS 10.3 software. For the construction of river map, ESRI developed shape-files were used. In this process, blank template has been created with different size and frames. Further, gridding of the map has been developed according to the input coordinates of the study area. The polygons are representing the surface area and boundaries of districts along Ajay River. Each classes of the shape file integrated with Ajay River for the visualisation of the catchment's area. All levels are labelled with short legends and sampling points based on the input data.

Geological map formation

Geological map is very useful to understand the topographical shape and character of rock bodies (Brady, 2007). Geological map of Ajay River illustrates different geological attributes such as units, age, litho-logical and morphological description of the study area. In this study, geological map was developed for Ajay River basin. The study area lies between 24º 27' 763" to 23º 27' 342" N latitude and 86º 38'156" to 88º 07' 729" E longitude. Ajay River is an interstate river of Bihar, Jharkhand and West-Bengal. The river lies within three major geological setups viz. Archaean gneissic, Gondwana sedimentary rocks and recent alluvial deposits over rocks of tertiary age (Mukhopadhyay and Mukherjee 2005). Geological setting and other linear features of Ajay River basin are developed with geographical coordinates by ArcGIS 10.3 software.

For the formation of geological map, data has been collected from the Geological Survey of India (GSI), and ESRI developed shape-files. The obtained data has been converted and transformed into layer files and raster images through editing procedure with the help of ArcGIS software. Numerous features and information such as unit contacts (assigned symbols and characteristic), unit polygons (explanation of each unit geological shape-file), features (geologic features), data point (coordinates), overlay polygons (shape of numerous geology) etc were employed with the help of ArcGIS (DACF, accessed on 30.09.2016).

Distribution Pattern Of Environmental Variables Over Geographical Coordinates

To indicate the environmental data in the map is very effective to visualise assigned scores in a numeric scale. Data can be applied with their respective weights and units in a single map to visualise the concentration of variables. In this technique, data can be classified into numerous categories based on the water quality criteria such as Excellent, Very Good, Good, Poor and Very Poor. Therefore, this type of map has ability to provide specific information on the magnitude and characteristic of variables in the particular environment. In this study, the distribution of fluoride concentration in Indian states has been plotted with five classified groups according to the obtained values.

Multiple variables can also be visualised in the single map to demonstrate the distribution patterns of the variables. In this study, shape-file was collected from ESRI and symbolised by ArcGIS software according to fluoride concentration. Similarly, coordinates of the Indian states were obtained from the web source (Google Map).

Impact zone identification through contour map

Contour (isoline) is another feature of topographic map. Contour lines show the elevation and shape of the terrain based on the input data (Thrower 1999). It is useful to visualise the large data in one image with significant information. It has ability to demonstrate the statistical relation of data by spacing the contour interval, which is easy to understand spatial distribution of data. Contouring of the data was developed through the statistical gridding followed by cringing method with the help of Surfer software version (11)

This method is scientifically known as geo-statistic analysis**.** In this study, cadmium (Cd) data was used to demonstrate the spatial variation of Cd concentration. The study showed that the maximum concentration of Cd was obtained in the middle part of the Ajay River basin. Therefore, it is very important method for visual expression of the data of the study area in one map, which is easy to understand the spatial distribution pattern of the variables. Contour map can also overlap with comparable base maps**.** The contouring of heavy metal pollution index (HPI) value was overlapped with Ajay River base map with the help of Surfer software, which is shown in (Fig. 6). It demonstrates each point of contour level based on input variable (HPI value) which is easy to identify the highest risk prone area.

Conclusion

Cartography technique offers effective and meaningful solutions to the problem. It is very useful to demonstrate various types of scientific data in better manner. Interpretation of the large scientific data and imaginary analysis through GIS could be helpful for futuristic management plan. Similarly, numerous environmental parameters can be integrated in the cartography with the help of various softwares. For the proper visualisation of geomorphology, structure and spatial locations, cartography technique plays a major role in the GIS software**.** The integration of cartography in research area will be helpful for futuristic plans such as monitoring strategies, characterisation of sampling point, classification of zones and visualisation of research data in better way**.** This study also discussed about the mapping techniques, GIS software's and their role in the research field that will be helpful for scientific community.

Acknowledgement

Authors would like to thank University Grants Commission (UGC) Government of India, for financial grant through major research project. Authors would also like to thank 36th INCA International Conference (Visva-Bharati) for providing the platform to present this study.

References

Avtar R, Singh CK, Shashtri S, Mukherjee S (2011) Identification of erosional and inundation hazard zones in Ken – Betwa river linking area , India , using remote sensing and GIS. Environmental Monitoring and Assessment, 341–360. doi: 10.1007/s10661-011-1880-6

Bailey TA (1994) A review of statistical spatial analysis in geographical information systems. In: *Fotheringham S, Rogerson P. Spatial analysis and GIS*. London: Taylor and Francis 1994

Boumans L, Fraters D, Drecht G (2008) Mapping nitrate leaching to upper groundwater in the sandy regions of The Netherlands, using conceptual knowledge. *Environmental Monitoring and Assessment*, 137:243–249. doi: 10.1007/s10661-007-9756-5

Brady SR, Sinha AK, Gundersen LC (2007) Geoinformatics 2007—*Data to Knowledge, Proceed-ings:* U.S. Geological Survey Scientific Investigations Report 2007-5199, pp.1-104

Brath R and Banissi E (2016) Using typography to expand the design space of data visualization. She Ji: *The Journal of Design, Economics, and Innovation 2:59–87*. doi: 10.1016/j.sheji.2016.05.003

Clarke KC, McLafferty SL, Tempalski BJ (1996) *On Epidemiology and Geographic Information Systems: A review and discussion of future directions*. Emerging Infectious Diseases, 2(2): 85–92

Cloud J (2002) American Cartographic Transformations during the Cold War*. Cartography and Geographic Information Science, 29:*261-282

Delpla I, Jung A V., Baures E, Clement M, Thomas O (2009) Impacts of climate change on surface water quality in relation to drinking water production. *Environment International 35*:1225–1233. doi: 10.1016/j.envint.2009.07.001

Department of Agriculture, Conservation and Forestry (DACF) 22 State House Station 18 Elkins Lane Augusta, http://www.maine.gov/dacf/mgs/pubs/online/bedrock/bedrock.htm accessed on 30.09.2016.

Elwood S (2009) Geographic information science: emerging research on the societal implications of the geospatial web. *Progress in Human Geography, 34(3*):349-357 DOI: 10.1177/0309132509340711

Harley JB (1987) The Map and the Development of the History of Cartography, *The History of Cartography*, 1–42

Ishaq M, Khan MA, Jan FA, Ahmad I (2010) Heavy metals in brick kiln located area using atomic absorption spectrophotometer: A case study from the city of Peshawar, Pakistan. *Environmental Monitoring and Assessment, 166*:409–420. doi: 10.1007/s10661-009-1011-9

Jeyaseelan, AT. (2004) Droughts & floods assessment and monitoring using remote sensing and GIS, satellite remote sensing and GIS applications Sivakumar MVK, Roy PS, Harmsen K, Sah SK, Proceed-ings: "*Satellite Remote Sensing and GIS Applications in Agricultural Meteorology* "Dehra Dun, India, pp. 291–313

Kabala C, Bojko O, Medynska A, Szczepaniak A (2013). Spatial Variability And Temporal Changes In The Heavy Metal Content Of Soils With A Deep Furrow-And-Ridge Microrelief Formed By An Afforestation Plowing. *Environmental Monitoring and Assessment, 185*:5141–5150. doi: 10.1007/s10661-012-2931-3

Krami LK, Amiri F, Sefiyanian A, Shariff ARBM, Tabatabaie T, Pradhan B (2013). Spatial patterns of heavy metals in soil under different geological structures and land uses for assessing metal enrichments. *Environmental Monitoring and Assessment*, *185*:9871–9888. doi: 10.1007/s10661-013-3298-9

Kumar C, Satyanarayan S, Mukherjee S (2011)a Integrating multivariate statistical analysis with GIS for geochemical assessment of groundwater quality in Shiwaliks of Punjab, India. *Environmental Earth Science, 62*:1387–1405. doi: 10.1007/s12665-010-0625-0

Kumar C, Satyanarayan S, Mukherjee S, Kumari R, Avatar R, Singh A, Prakash R (2011)b Application of GWQI to assess effect of land use change on groundwater quality in lower Shiwaliks of Punjab/ : *Remote sensing and GIS based approach. Water Resource Management, 25*:1881–1898. doi: 10.1007/s11269-011-9779-0

Lal M (2001) Implementations for Indian water resources. *Journal of Indian Water Research Society,* 21:101-119

Mondal S, Chakravatry D, Bandayopadhyay J (2014) Cadastral maps for socio -economic data visualization and integration for land use in Raniganj mining areas. *International Refereed Journal of Engineering and Science (IRJES), 3*:55–63

Mukherjee P, Singh CK, Mukherjee S (2012) Delineation of Groundwater Potential Zones in Arid Region of India - A Remote Sensing and GIS Approach. *Water Resource Management*, 2643–2672. doi: 10.1007/s11269-012-0038-9

Mukhopadhyay S, Mukherjee M (2005) *Hydrological Characteristics of Flood: A Study in the Lower Ajoy River; A Socio-technical Approach*. ACB Kolkata, pp 51-58

Singh AK, Mondal GC, Singh S, Singh TB, Tewary BK, Sinha A (2008) Major ion chemistry, weathering processes and water quality assessment in upper catchment of Damodar River basin, India. *Environmental Geology*, 54745-758

Tanser FC, and Sueur DL (2002). The application of geographical information systems to important public health problems in Africa. *International Journal of Health Geographic,* 1-4. doi:10.1186/1476-072X-1-4

Thrower NJW (1999) Maps *and Civilization: Cartography in Culture and Society*, University of Chicago Press, 1972, revised 1996, page 97; and Jardine, Lisa Ingenious Pursuits: Building the Scientific Revolution, Little, Brown, and Company, 1999, page 31

Tsou M (2004) Integrated mobile GIS and wireless internet map servers for environmental monitoring and management. *Cartography and Geographic Information Science 31*:153–165

Zafar SI, Khattak AI, Nasir SM, Qurashi T, Durrani R (2010) Air pollution assessment in urban areas and its impact on human health in the city of Quetta, Pakistan. *Clean Technologies and Environmental Policy, 12*:291–299. doi: 10.1007/s10098-009-0209-4

6

Geomorphological Mapping of Kail Ganga River Basin using Geospatial And Field Techniques

Somit Mandal, Sucheta Mukherjee and V.C.Jha

Abstract

Geomorphological Mapping provides information about an area, which are very significant in planning and development.The geomorphic features have direct applications in settlement establishment,land occupancy and environmental management.The mapping techniques have changed from manual to digital providing more layers of information thereby opening up different aspects of application. With the advent of geospatial technology it has become easier to handle larger volume of data in a systematic and scientific form. However in geomorphological mapping the role of field techniques cannot be replaced by geospatial technology. Its importance at micro level like identification of geomorphic features is very significant.

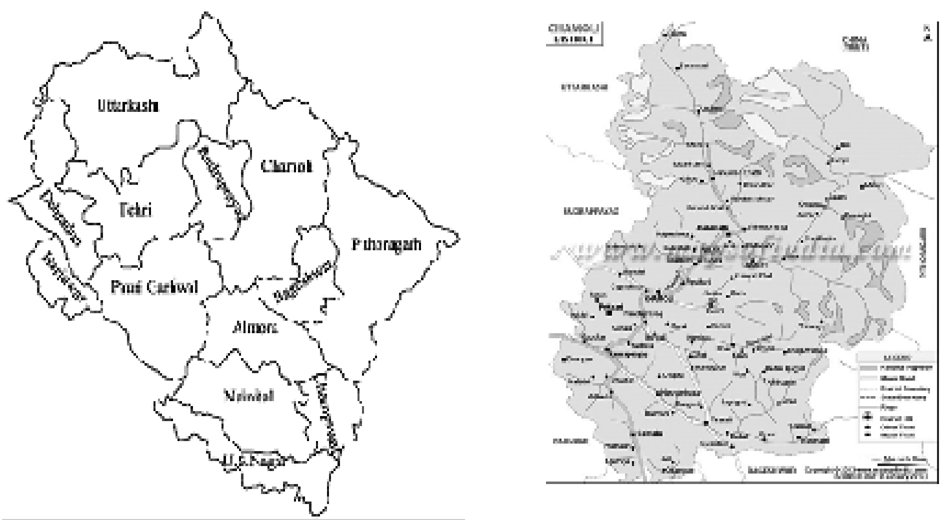
The morphometric aspects which are examined and analysed in this paper – linear ,areal and relief properties of this drainage basin alongwith slope morphology, is also taken into consideration.TheKail Ganga River Basin has been selected for study which is in the Chamoli district .It forms a part of Garwhal Himalaya ,Uttarakhand.It is the one of the important tributaries of Pindar River. The study area includes glacial, periglacial and fluvial landforms.In this paper an attempt has also been made to trace the stages of geomorphic development of the Kail Ganga River Basin using geospatial techniques.

Introduction :

The Kail Ganga is a left bank tributary of the Pindar river and it originates from Mulkotha glacier in the Chamoli District It meets the Pindar River at Talor(1290 m) .The length of the river is approximately 105 kms.A section of the Himalayan range in the Chamoli district is deeply cut into by the headwaters of the Alaknanda river, this trunk stream seeming to have reached a latter stage of development than its tributaries.TheKail Ganga is apart of the Alaknanda river system.There has been intense metamorphosis and there mostly instances of trellised drainage pattern predominating in the region with those streams emerging from snow covered peaks being in radial pattern.The Kail Ganga River basin is narrow with steep valley sides and is fed by several icy second order and first order streams on its left bank. The adjoining valley sides are grass covered during the summer months and locally are called *Bugyal* or alpine meadow pastures.Near its headwaters it exhibhits a dendritic pattern and river piracy in future cannot be ruled out given the movement of glacier with considerable erosive force during winter and the emerging and flowing of fast streams when the glacier tongue melts in summers.

Location of the Study Area :

a.TheKail Ganga River near the settlement of Timli .



b. Location map of Chamoli district in Uttarakhand,India and of Kail Ganga River Basin in Chamoli district. Source :www.maplanindia .in

KailGanga River is a Himalayan river, which is fed by Mulkotha Glacier in Chamoli district of Uttarakhand. The river has a length of 105 kilometres. The river crosses tiny hamlets and towns such asIchchali,Phaldiagaon,Dewal,before joining the Pindar River atTolar (1290 meter) .The Pindar River merges with River Alaknanda at Karnaprayag. The river flows as Alaknanda from here. The

Pindar river, before joining Alaknanda, is fed by Kailganga and Bheriganga.The basin areaof the Kail Ganga is made up of 396 sq.Km.approximately .It lies from 79°55' E to 79°25'E longitudinally and 30°05'N to 30°25'N latitudinally. The basin lies in the Chamoli district of Uttarakhand.TheChamoli district is situated in the north central part of this hilly state of India.Its northern borders touch Tibet,in the West are Uttarkashi and Tehri,in the south Pauri and in the west Almora districts.

The Southern part of the district lies in the middle Himalayas also known as Himachal while the northern part lies in the Himadri or the main Himalayan ranges.The temple town of Badrinath,the holy shrine of Kedarnath and the famous valley flowers of the Hemkund are part of this district.TheKail Ganga River flows through the Joshimath development block and extends till the IndoTibetan border in the north.To the south of Joshimath is the Okhimath development block and comprises the densely forested ridge between Okhimath and Gopeshwar.The famous mountain hamlets of Sonprayag,Gaurikund and Kund are part of this location.The headquarters of Chamoli district are located at Gopeshwar,a newly built town near the old town of Chamoli.Other important towns of this district are Karanprayag,Nandaprayag,Rudraprayag and Gauchar.

The Alaknandariver and its tributariesdrain a large part of the Chamoli district The main tributaries of Alaknanda River are Mandakini,Dhauliganga,Nandakini and the Pindar.TheKail Ganga is a tributary of the Pindar flowing down from North East and joining it at Tolar at 1290 meters.

The district of Chamoli consists of ten development blocks as stated below :

1.Okhimath 2.Joshimath 3.Dewal 4.Chamoli Ghat 5.Narain Bagar 6.Tharali 7.Gairsain 8.Karanprayag 9.Nagpur 10.Agastmuni.(Negi,1995)

The river originates in periglacial region of the upper Himalayas or the Himadri ranges and is formed from the melt waters of the Mulkothaglacier.It is in its youth and valley deepening is the primary function of the river here .

Climate and Natural Vegetation : The climate varies from Sub-tropical monsoon type (mild winter, hot summer) totropical upland type (mild winter, dry winter, short warm summer). The northern, northwestern, northeastern and western part of the district is perennially under snowcover, here the climate is sub-arctic type as the area is represented by lofty Himalayan Range. Severe winter and comparatively higher rainfall are thecharacteristic features of the northern part. The year may be divided into four seasons viz. the cold winter season, (December to February), the hot weather season (March to May), southwest monsoon season (June to September) followed by post monsoon season (October to November). The normal maximum and minimum temperature varies between 31 and –2.9ºC respectively.Larger part of the district is situated on the southern slopes of the outer Himalayas,monsoon currents can penetrate through trenched valleys, the rainfall reaches its maximal in the monsoon season that spans betweens June to September. Rainfall,spatially, is highly variable depending upon the altitude. In the Lesser Himalayan Zone (1000-3000m amsl) maximum rainfall occurs about 70 to 80% in southern half. August is the rainiest month. Rainfall rapidly decreases after September and it is the least in November. About 55 to 65% rainfall occurs in the northern half in Central Himalayan Zone. About 17% of the annual precipitation occurs in winter season. The winter precipitation is in association with the passage of the western disturbances and is mostly in the form of snowfall, particularly at higher elevations. The precipitation during the premonsoon month, which is about 7% of the annual total and the post-monsoon months, is frequently associated with thunderstorms. Its average normal annual rainfall is 1230.8 mm. The actual rainfall for the year 2003 is 986 mm. The relative humidity is high during monsoon season, generally exceeding 70% on the average. The driest part of the year is the pre-monsoon period when the humidity may drop to 35% during the afternoon. The normal annual average humidity is 64%during morning and 56% during evening.Skies are heavily clouded during the monsoon period and for short spells when the region is affected by the passage of western disturbances. During the rest of the year the skies are generally clear to lightly clouded. The normal annual average wind speed is 5.2 kmph.

The effectiveness of the rains is, among others, related to low temperature which means less evapo-transpiration and forest or vegetation cover. However, the effectiveness is neither uniform nor even positive in areas where either the vegetational cover is poor or / and has steep slopes or the soils have been so denuded that their moisture absorption capacity has become marginal.

Winds - Owing to the nature of terrain local affect are pronounced and when the general prevailing winds not too strong to mask these effect, there is a tendency for diurnal reversal of winds, the flow being anabatic during the day and katabatic at night, the latter being of considerable force. The region is characterized by a large variety of micro-climates,varying from sub-tropical in low river valleys to temperate on slopes andpeaks of moderate to high elevation and alpine at very high altitudes.

Undulating topography creates diversity in temperature and precipitationwithin relatively short distances. The study area has been categorized into the following climatic zones:

i)warm sub-tropical zone: found at elevations 600 – 950 mts;

meanannual temperature: 18.9ÚÆ – 21.1ÚÆc

(ii) Warm temperate zone: 950 – 1830 mts; 13.9° - 18.9°c

(iii) Cool temperate zone: 1830 – 2440 mts; 10.3° - 13.9°c

(iv) Cold zone: 2440 – 3000 mts; 4.5° - 10.3°c

Cloudless sky, transparent atmosphere, calm nights, heavy dew and great temperature variations etc are the main characteristics of the autumnand winter seasons in the study area. The mean monthly temperature falls below the freezing point sometimes at several places. By the end of December, northern dry winds are well-established and produce much snowfall at higher elevations. Sometimes they result into severe blizzards.

Forests occupy nearly 58% area of the district. Changing thermal conditions and varying relief control the distribution of natural vegetation. The forests have plenty of broad-leaved evergreen plants like Baanz, Buransh. Higher altitudes have Deodar forests. But in recent years Pine forests are growing rapidly which is not favourable for the environment. Another problem facing the natural vegetation is the rapid depletion on account of the growing demands of the ever-growing population. Major forest areas are converted into farmland to support the basic food supply of the people. Absence of the alternate occupational opportunities is also responsible for this transformation. Pine and Oak are the main trees, Kaphal, Buransh, Deodar, Uttis,Ayaretc are other main species. Ghingaru, Kurie (lantana) Cactus & grass are found in dry areas. Changing thermal conditions and varying relief control vertical distribution of natural vegetation.(Kashyap.2015)

The River traverses the Pindarpar reserve forest which is a fairly mixed jungle with mainly Banzvariety of trees predominating.

Geological Background : The Kail Ganga River lies in a region of tectonic or folded and overthrust mountain chains, has strata are structurally marked by complex folds, reverse faults, overthrusts and nappes of great dimensions, all these as well as frequent earthquake of varying intensity give region to believe that the region is still unstable. Although any movement or tremor of the Earth's crust in the district is not produced by volcanic activity, the Chaukhamba peak a pair to be the crater of an extinct volcano.

The geology of the region shows that the Himalayas are the young fold mountains in the world. During early Mesozoic times, or the secondary geological period, the land mass now covered by them was occupied by the great geosynclinal Tethys sea. The probable date of the commencement of the elevation of the Himalayas is about the close of the Mesozoic period.They include ancient and relatively recent crystalline intrusive, rocks and sediments allied to the peninsular part of India In some parts uplift has been considerable since the mid-pleiscetocene period, in others there are great stretches of high but subdued topography and elsewhere there are the deepest gorges. The direction of folding in these mountain masses is generally North to South. The geological feature of the district form two major divisions which lies North and south of an imaginary line extending east-southeast between the villages of Hilang in Joshimath and Loharkhet in the adjoining District of Pithoragarh. The Northern division, which is occupied by higher ranges and snow-covered peaks consist entirely of medium to high grade metamorphic rocks and is intruded by later volcanic rocks. The Division to the South, occupied by ranges of lower altitude, consists essentially of sedimentary and low grade metamorphic rock also intruded by later volcanic rocks. Geologically very little is known of the first division which consists of rocks such as quartzites, marbles and various types of micaceousschists and gneisses which a few sporadic occurrences of garnet, graphite, iron, kyanite, mica and vein quartz. The division to the south of the imaginary line is better known geologically and consists of rocks such as gneisses, limestone, phyllites, quartzite, sericite-biotiteschists and slates.

Soils are the reflection of geological setting, relief, climate and natural vegetation and thus characterize the personality of region. Our study areahas at some places very thick, well drained soils formed in a loamy mantleand sandy or gravelly outwash sediments. These soils are on till plains,moraines, stream terraces, and outwash plains. They have moderatepermeability in the upper part and rapid permeability in the lower part. Slope gradient range from 0 to 18 percent.In general, the soil cover of mountainous parts of the region is thin.Thick layers of soils are distributed mainly in the valleys and broad river tracts. Absolute rock exposures are the prominent features of crystalline basements, particularly in the high altitudes of Himadri.

Mainly on the basis soil regions.

(i) Meadow Soils

(ii) Red Looms

(iii) Podzol Soils

(iv) Brown Forest Soils

(v) Mountain Meadow and Glacial Soils

Methodology : SOI topographical sheets for 53 N/12 and 53N/16 were used along with google satellite imagery from the following website:Imagery copyright 2017CNES/ Airbus.Mapdatacopyright 2017 United Stateswww.Googlemaps.co.in/maps 2000 ft.

Field data as well as map interpretation and identification of geomorphological units were done extensively to identify the physical features .Various literature pertaining to the study area were consulted and have been quoted were necessary.Geospatial techniques have been used to prepare a geomorphic units map to assess the risk of landslides ,slope failure and bank failure.Satellite imagery from have been extensively used to study those areas where accessibility is not possible . The greyish to brownish tone of the terrain denotes periglacial conditions around the Mulkotha glacier.

Geomorphological Aspects :

"Before such features as block fields,rock streams and talus slopes are interpreted as evidence of former periglacialconditions,there should be evidence that they are stable at present .Evidence of stabilization consists of : growth of lichens on rock surfaces,growth of tress or bushes between rocks ;secondary weathering effects upon rock blocks so as to indicate breakdown in place;the beginning of soil profile;and the presence of overlying deposits in an undisturbed state" (Thornbury,1986). Glaciers, horned peaks, cirques, hanging valley etc, sculpture this zone. The morainic materials occupy the valleys areas. The prevalent landforms are lateral moraines, end moraines, U-shaped glacier valleys, V-shaped fluvial valleys, river terraces and Denudational Structural Mountain.

The riverine tract shaped from the meltwaters of the Mulkotha Glacier traverses a rocky path where valley deepening is the primary erosive action of the river. An upliftment during the mid Pleiscetocene period has resulted in a pair of terraces on both banks of the river near the settlements of Suiya and Gula.TheKail Ganga River is a third order channel .The glacial features noted in the region are

a. Morraines – Chiefly lateral and terminal moraine.Lateral moraine is noticed along the valley sides deposited during the melting of the glacial waterwherein they drop their load and terminal moraine at the glacial snout from where the Kail Ganga emerges. Further up north median moraine is found after it has left its snowfield.

b. Hanging valleys – On both sides of the Mulkotha glacier hanging valleys are found which feed it with snow from its sides.Lateral moraine accumulates as the tributary glaciers leave their valleys to merge with the Mainstream Mulkotha glacier.

c. Potholes - The valleysides near the meltwatersof the glacier has evidences of potholes filled with water where glacial meltwaters have accumulated near the snout .

d. Stream eroded surface – This is littered with moraine which are rough sided and greyish in colour.

e. Rocks broken due to frost splitting – There are breaking down of rocks along their cleavage plain due to intense frost action and hence the pieces have sharp edges .As they are covered by snow thawing for a brief time during the late summer does not smoothen their edges.The stream eroded surfaces are aggraded or strewn over by rock pieces al not of the same size,brought down by the glacier.

The Kail Ganga river flows with great force in steep and narrow channels often resulting in excessive erosion and collapse of the banks.

f. River Piracy – The initial stages of river piracy is clearly noticed between the two adjoining streams of Kail Ganga River and the another to its southeast .The Kail Ganga originates at the mouth of a glacier and the one to its south east originates from a vast snowfield which tilts north.

Results and Discussions : Distinct 'U' shaped glacial troughs, hanging valleys, moraines and other landforms indicated a major phase of glacial activity in the area during Pleistocene. The interglacial phase was dominated by fluvial activity washing out considerable amount of glacial waste and depositing it in a number of valley floor basins formed by the blockade of the valley side deposits of the Kail Ganga river. The erosive fluvial activity assisted by rock structure is also responsible for the formation of several gorges in the main valley. The valley side slopes are steep and are covered with morainic deposit. The Alaknanda River possesses depositional terraces with Quaternary sediments . The Kail Ganga river occupies an antecedent gorge, which is deep,and has a trellised drainage pattern with some of its first order streams emerging from peaks in radial pattern before confluence with Pindar River. The tributaries generally follow along strike direction. Very steep to steep hills and Glacio-fluvial valleys are dominantly occupied with very shallow to moderately shallow excessively drained, sandy-skeletal to loamy-skeletal,neutral to slightly acidic with low available water capacity soils. They have been classified as Lithic/TypicCryorthents. These soils are in general under sparse vegetation.Intermittent sparse patchy terraced cultivation is also practiced on fairly steep hill slopeswhereas dry and wet cultivation are prevalent on the uplands and low-lying valleysrespectively. The broader valley slopes dominantly have deep, well drained, fine-loamy,moderately acidic and slightly stony.(Kashyap,2015)

Conclusion : The Kail Ganga River basin has distinct glacial and periglacial geomorphic features .The river being a third order stream has carved out a deep ravine like valley with the upper part being U shaped. The soil cover is thin and supports meadow for grazing during the summer months.The older valleys with alluvial soil brought down by the river in the lower reaches near the village of Suiyan support growth of trees with deep soil cover. Settlements are few and some terrace farming is done by the residents for subsistence.

References :

1. Kashyap.A. (2015) : Land and People of Uttarakhand , shodhganga.inflibnet.ac.in/bitstream/10603/40037/2/chapter2.pdf
2. Negi,Sharad Singh,(1995): Uttarakhand : Land and People pub MD Publications Private Limited ,New Delhi, Daryaganj,110002 pp
3. Chamoli ; A Brief Industrial Profile. Ministry of MSME, Uttarakhand, Govt . of India http://msmedihaldwani.gov.in Industrial Profile of District Chamoli. MSMEDevelopment Institute, Kham Bangla, Kaladhungi Road, Haldwani, Nainital, Uttarakhand, India
4. Thornbury,W.D.(1985): Principles of Geomorphology ,Second Edition Pub:Wiley Eastern Limited pp 401 – 404.
5. Wikipeadia: Chamoli,Uttarakhand
6. Imagery copyright 2017CNES/Airbus.Mapdatacopyright 2017 United Stateswww.Googlemaps.co.in/maps 2000 ft.
7. www.maplandia.com: google maps world gazetteer

7

Assessment of Seasonal Sediment Distribution Zones of Estuarine Sections and Near-shores using Landsat 8 Digital Data : A Case Study of Subarnarekha Delta

Amrit Kamila, Ashis Kumar Paul and Jatisankar Bandyopadhyay

Introduction

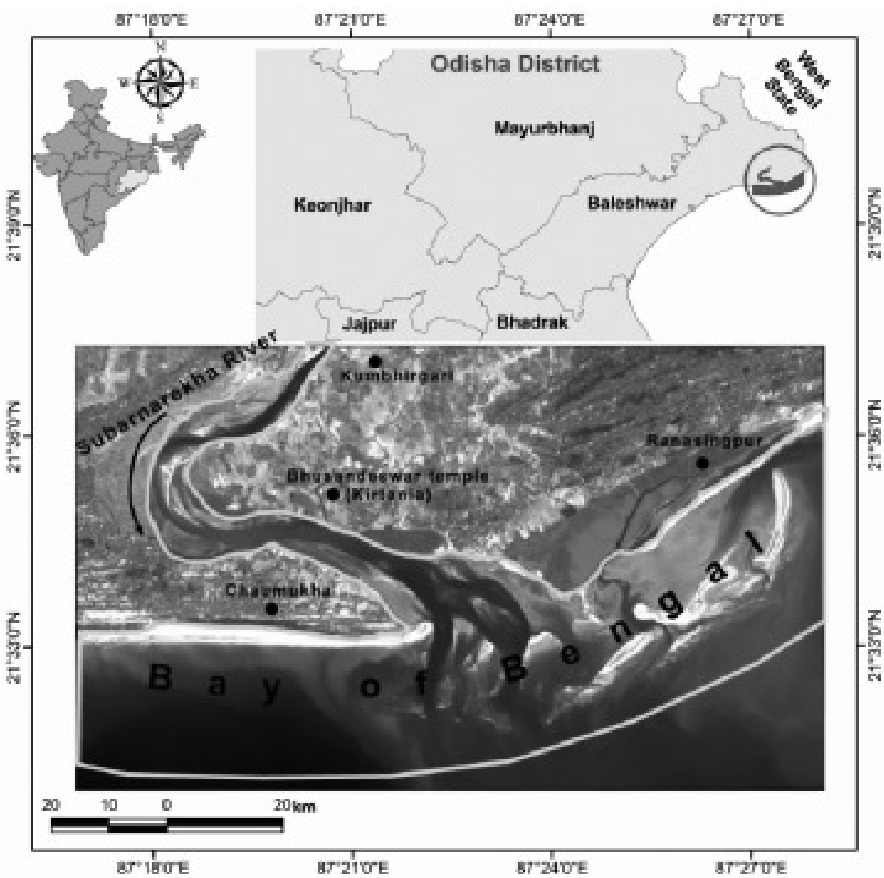
A relative measurement of reduced realistic clarity with respect to a calibrated standard means turbidity. In other words turbidity measures the “cloudiness” of water; i.e., it measures the extent to which light is scattered and absorbed by suspended sediment, dissolved organic matter and also by plankton and other microscopic organisms [1]. Therefore, more attendance the particles in the water the turbidity is gradually increased. An intensifying in stream flow due to heavy rains or a decrease in stream-bank vegetation can speed up the process of soil erosion, which adds suspended particles, such as clay and silt, in the water. Runoffs including agricultural and industrial wastes, water treatment plant effluent, and urban runoff from parking lots, roads, and rooftops often contain suspended soil particles. Bottom-dwelling aquatic organisms, such as catfish, can contribute to the turbidity of the water by stirring up the sediment that has built up on the bottom of the stream [2]. Moreover algal bloom may also lead to higher turbidity measure. Human activities like construction and direct influences of the people, animals and boats disturb the water column (waterbed) [3].

There are various effects of water being highly turbid. It decreases the photosynthesis rate by not allowing the sunlight to enter the water and reducing the concentration of dissolved oxygen, which is necessary for the survival of fish and other aquatic lives. Reduced clarity, though not harmful directly, makes the water less aesthetically pleasing and is certainly undesirable for many water uses. Increased cloudiness in water can lead to various problems associated with increased temperature levels. This occurs because the suspended particles in the water absorb the sunlight and makes it warm. As a solid matter settles, it may cover and harm bottom-dwelling plants, animals and spawning beds for fish such as trout. While highly turbid water can be detrimental to an aquatic ecosystem, it is not correct to assume that clear water is always healthy. Clear water could contain unseen toxins or unhealthy levels of nutrients so slightly turbid water can be perfectly healthy [2].

Study Area

The area is a coastal alluvial tract with unconsolidated substrates and this extend of the coastline is geomorphologically very dynamic; and at the same time the area is influenced by different types of hazards such as tropical cyclone-induced tidal waves, storm surges and consequent coastal flooding. This expanding coastal plain is made up of sand and mud which is deposited by the fluvial, fluvio-marine, tidal and Aeolian processes, and it extended up to the area is concentrated western division of Kanthi Coastal Plain. The study area is characterized by high turbid and saline sea water influences. The study area lies in between 21°32’01" N to 21°37’22" N Northern Latitude and 87°16’54" E to 87°23’29" E Eastern Longitude. The estuary of the river Subarnarekha has been always very dynamic for the presence of long shore current and active dynamic diversion of tides with seasonal freshets in the mouth. The depositional bar of the Subarnarekha delta region increases rapidly for the agglomeration of the sediment carried by rivers and always alters the river mouths.

Figure 1
Geographical Location of the Study Area



Data and Methods

Data

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) image consists of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. New band 1 (ultra-blue) is useful for coastal and aerosol studies. New band 9 is useful for cirrus cloud detection. Imagery path is 139 and the row is 45.

Table 1

Landsat 8 OLI Band Information (Date: 08.02.2015 & 06.10.2015)

Landsat- 8 Operational Land Imager (OLI) & Thermal Infrared Sensor (TIRS)	Bands	Wavelength (micrometers)	Spatial Resolution (meters)
	Band 1 (Coastal aerosol)	0.43 - 0.45	30
	Band 2 (Blue)	0.45 - 0.51	30
	Band 3 (Green)	0.53 - 0.59	30
	Band 4 (Red)	0.64 - 0.67	30
	Band 5 [Near Infrared (NIR)]	0.85 - 0.88	30
	Band 6 (SWIR 1)	1.57 - 1.65	30
	Band 7 (SWIR 2)	2.11 - 2.29	30
	Band 8 (Panchromatic)	0.50 - 0.68	15
	Band 9 (Cirrus)	1.36 - 1.38	30
	Band 10 Thermal Infrared (TIRS-1)	10.60 - 11.19	100 * (30)
	Band 11 Thermal Infrared (TIRS -2)	11.50 - 12.51	100 * (30)

Methods

The multi-spectral satellite imagery is used as a numerical basis to identify the sedimentation zone of the Subarnarekha river mouth area and it digitally represents the turbidity zone towards the river and along the shore. Before using this satellite data, the radiometric correction of the image is enhanced due to some logarithmic operation. The DN value of the image is converted in radiance to spectral reflectance and the Dark Object Subtraction (DOS) atmospheric correction is concerned to suppress the pixel transparency. Several band math equations have been used to instigate the models of different component of suspended materials which is present in water bodies. The Normalized Suspended Material Index (NSMI) is generated to identify the suspended material of water from Landsat 8 OLI sensor's data. This model is calibrated in three spectral bands such as Blue, Green and Red, so the equation follows as [4]:

Blue region replicates the peak reflectance in clear water, while the existence of suspended material supports increasing of reflectance in the whole visible spectrum; particularly clear water has a tendency to absorb radiation in green and red region [4]. For the authentication the strength of the NSMI, this result is compared with the following two equations. Several authors [5] have been used Normalize Difference Suspended Sediment Index (NDSSI) method to develop suspended sediment models of in rivers, lakes, estuaries and many other water bodies using this spectral index.

$$\mathrm{NDSSI} = \frac{\mathrm{Blue} - \mathrm{NIR}}{\mathrm{Blue} + \mathrm{NIR}}$$

When the suspended particles of water have increased the level of turbidity is gradually enhanced in the water, so the reflectance of the red band is more than that of the green band [6]. So, the Normalized Difference Turbidity Index (NDTI) is used to categorize the Turbidity Maximum Zone (TMZ). This index formula is provided by 'J. P. Lacaux' [7].

$$\mathrm{NDTI} = \frac{\mathrm{Red} - \mathrm{Green}}{\mathrm{Red} + \mathrm{Green}}$$

The values of Standard Deviation and Mean are calculated by the statistics of the image with the help of the software. Low, Moderate and High turbidity zones are considered using the following formulas: Low is the Mean – Standard deviation; Moderate is the Mean + Standard Deviation; High is the more than moderate

Accordingly, low, moderate and high values were assigned to the image and converted in GIS environment. After bear out the Normalized Suspended Material Index, finally the NSMI deliberation appears to be successful discriminating between clear water and suspended material.

Results and Discussions

Normalized Suspended Material Index (NSMI)

NSMI is developed for measuring the suspended materials in the water. The equation is retrieved by accumulating the spectral consequence of the Red and Green bands and subtracting it from the Blue band, after dividing the above operation the sum of the Red, Green and Blue bands are stabilized the ultimate result. The equation value fluctuates from -1 to +1. Lower values communicate with clear water. It is noted that, when the blue band has a higher value than the sum of red and green band, the equation provides a negative value, which is indicating the attendance of the clearest water. Higher values signify the more suspended materials in the water.

Figure 2

Normalized Suspended Material Index (NSMI) of Subarnarekha Estuary (8th February, 2015

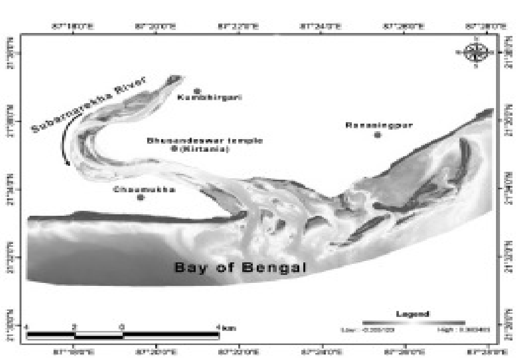
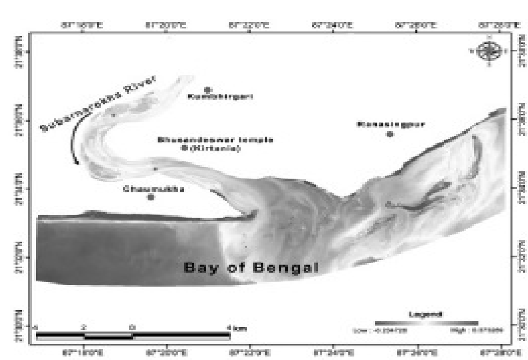


Figure 3

Normalized Suspended Material Index (NSMI) of Subarnarekha Estuary (6th October, 2015)



4.2 Normalize Difference Suspended Sediment Index (NDSSI)

It is practiced that the Landsat 8 OLI imagery is more responsive to water intelligibility on the blue and near infrared bands [5]. This index is applied by subtracting the near infrared band from the blue band and finalizes the result by divining the sum of both bands. The range of NDSSI from -1 to +1 where the higher value indicates the presence of clearest water and lower value signifies the presence of more turbid water or land [5].

Figure 4

Normalize Difference Suspended Sediment Index (NDSSI) of Subarnarekha Estuary (8th February, 2015)

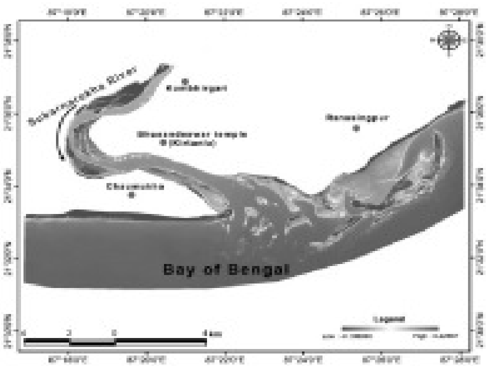
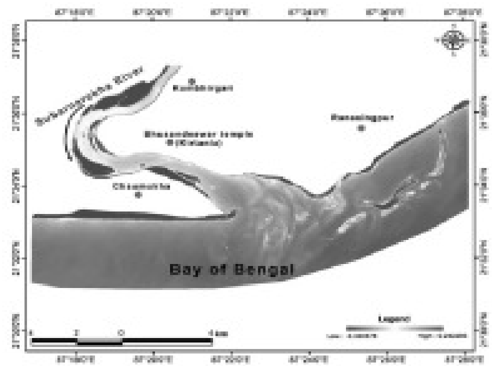


Figure 5

Normalize Difference Suspended Sediment Index (NDSSI) of Subarnarekha Estuary (6th October, 2015)



Normalized Difference Turbidity Index (NDTI)

NDTI have been deliberating for both pre and post monsoonal satellite imagery to identify the clearance of water. This index is combined to enhance the suspended materials in estuarine water. This spectral response of the turbid water can be used for the revealing of turbid water pixels and it has been arrested in the (NDTI) Normalized Difference Turbidity Index. In view of the fact that the radiometric values of the red band are much larger than the green band, subsequently the relationship is inverted between the green and red wavelengths [8].

Figure 6

Turbidity Zones of Subarnarekha Estuary (8th February, 2015)

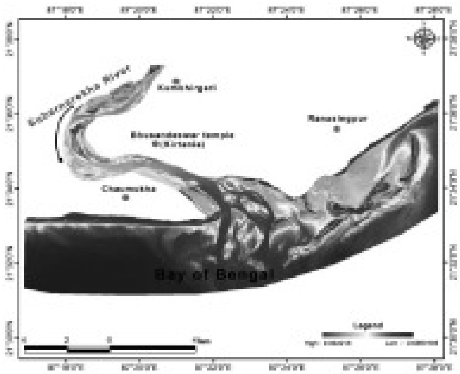
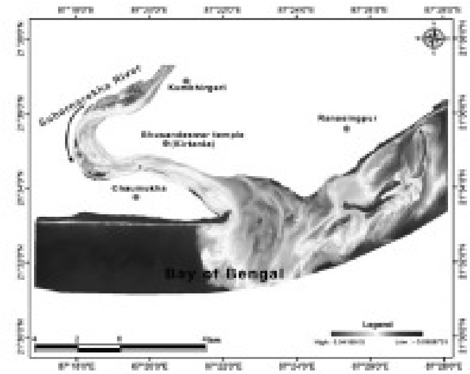


Figure 7

Turbidity Zones of Subarnarekha Estuary (6th October, 2015)



Turbidity map is generated on the basis of suspended solids pixel, wherein mean and standard deviation values are calculated in the image. The range of high, medium and low turbidity zones are allocated of an image on the basis of image statistics deliberation. The Values of the mean and standard deviation are -0.0542 & 0.0242 on October image and The Values of the mean and standard deviation are -0.0498 & 0.0298 on February image.

Figure 8
Zone of Sediment with Emerged Bars of Subarnarekha Estuary (8th February, 2015)

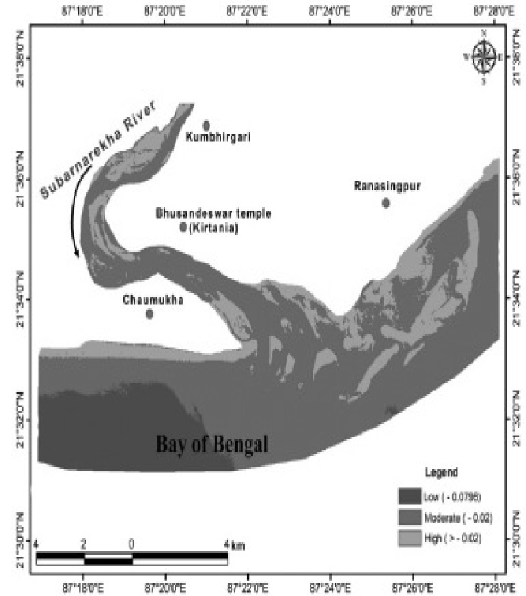
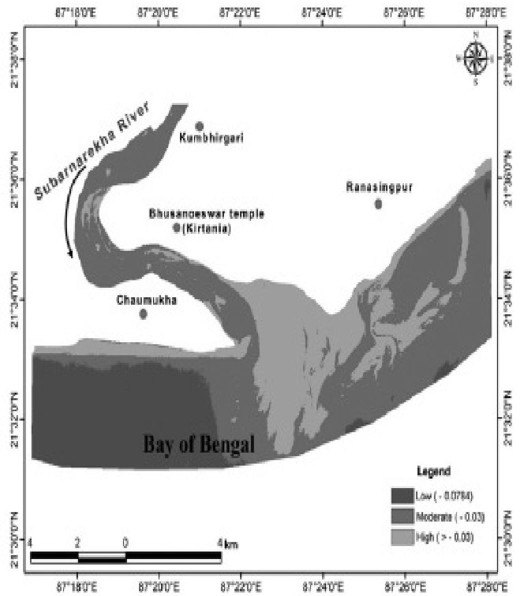


Figure 9
Position of Monsoon Peak Sediment Plume of Subarnarekha Estuary



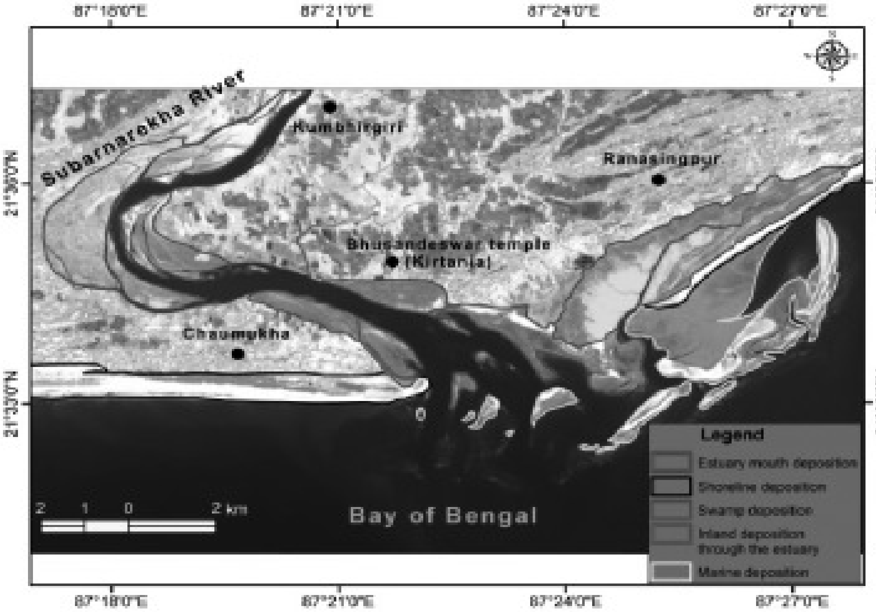
So the different formulas were used for calculating high, medium and low range of turbidity. In the month of February Mean is the – 0.0498 and Standard deviation is the 0.0292. So the low concentration pixels are (Mean – Standard deviation) = -0.0796; Moderate concentration pixels are (Mean + Standard Deviation) = -0.02 and High concentration pixels are (more than moderate pixel) = > -0.02. In the month of October Mean is the – 0.0784 and Standard deviation is the 0.0242. So the low concentration pixels are (Mean – Standard deviation) =-0.0784; Moderate concentration pixels are (Mean + Standard Deviation) = -0.03 and High concentration pixels are (more than moderate) = > -0.03.

4.4 Sediment Concentration zones and Transportation Paths

The present study reveals that there is a seasonal concentration of sediment deposition zones in the mouth of the Subarnarekha river estuary, particularly at the monsoon month (October). The areas dominated by sediment plumes are recorded through the analysis of Landsat 8 digital data of this study area.

Figure 10

Sediment Transportation Paths



However, in the month February concentrated sediment distribution zones are usually fragmented into several micro sediment sinks or pockets by dynamic diversion of up rushing tide and active long shore current transport into the coastal zones. Such concentration of seasonal mouth sediments and their redistribution process modify the morphology of the submerged bars, emerged bars, tidal shoals, tidal mud flats, tidal sand banks and island in this estuarine and barrier built coasts.

Conclusions

Following conclusions may be drawn on the basis of the study. Turbidity zones and sediment concentration zones can be studied by the method of NDTI based on analysis of the Landsat 8 digital data of the estuarine and near-shore areas of the coastal belt. Reduction of the sediment supply in the low to moderate flood peaks and active presence of long shore currents and tides redistributes the sediments into fragmented bars in the near-shores and along the sections of the estuary on the deltaic alluvium coast. The entire amount of sediments is distributed into sea beaches, near-shores, tidal basin, mangrove swamps, inner estuarine sections and island platforms of the Chenier delta.

References

Turbidity Technical Review; Summary of Sources, Effects, and Issues Related to Revising the Statewide Water Quality Standard for Turbidity; Oregon Department of Environmental Quality; 811 SW 6th Avenue Portland, OR 972041-800-452-4011; www.oregon.gov/deq

Gower-Rousseau, C., Dauchet, L., Vernier-Massouille, G., Tilloy, E., Brazier, F., Merle, V., & Lerebours, É. (2009). The natural history of pediatric ulcerative colitis: a population-based cohort study. *The American journal of gastroenterology*, *104*(8), 2080-2088.

Stewardship, M. W. (2011). Red River Floodway Operation Report Spring 2011.

Montalvo, L. G. Spectral analysis of suspended material in coastal waters: A comparison between band math equations.

Hossain, A. K. M. A., Jia, Y., & Chao, X. (2010, September). Development of remote sensing based index for estimating/mapping suspended sediment concentration in river and lake environments. In *Proceedings of 8th international symposium on ECOHYDRAULICS (ISE 2010)* (pp. 578-585).

Islam, M. M., & Sado, K. (2006). Analyses of ASTER and Spectroradiometer Data with in Situ Measurements for Turbidity and Transparency Study of Lake Abashiri. *International Journal of Geoinformatics*, *2*(1).

Lacaux, J. P., Tourre, Y. M., Vignolles, C., Ndione, J. A., & Lafaye, M. (2007). Classification of ponds from high-spatial resolution remote sensing: Application to Rift Valley Fever epidemics in Senegal. *Remote Sensing of Environment*, *106*(1), 66-74.

Somvanshi, S., Kunwar, P., Singh, N. B., & Kachhwaha, T. S. (2011, January). Water turbidity assessment in part of Gomti River using high resolution Google Earth's Quickbird satellite data. In *Geospatial World Forum* (pp. 18-21).

8

Recent Scenario of Rajghat Dam Reservoir of District Sagar, Madhya Pradesh, India and Their Health Impact

Abhilasha Chourasia and R.K. Rawat

Introduction:

The availability of a water supply adequate in terms of both quantity and quality is essential to human existence. The demand for water has increased over the years and this has led to water scarcity in many parts of the world. The situation is aggravated by the problem of water pollution or contamination. India is heading towards a freshwater crisis mainly due to improper management of water resources and environmental degradation. This leads to lack of access to safe potable water supply to millions of people. This freshwater crisis is already evident in many parts of India, varying in scale and intensity depending mainly on the time of the year. (K. Sundara Kumar et.al 2010).

Groundwater is controlled by factors such as precipitation, evapotranspiration, mineralogy, type of aquifers, climate, topography and also pumping rates. The combinations of these factors create diverse water types that change groundwater composition spatially and temporally (Chenini and Khemiri, 2009; Gholami et al., 2009; Praveena et al., 2011). Therefore, quality of groundwater varies from place to place, with depth of water table and from season to season (CPCB, 2008).

Groundwater is an important source of water supply throughout the world. The quantity and the suitability of groundwater for human consumption and for irrigation are determined by its physical, chemical and bacteriological properties. Its development and management plays a vital role in agriculture production, for poverty reduction, environmental sustenance and sustainable economic development. In some areas of the world, people face serious water shortage because groundwater is used faster than it is naturally replenished. Human development and population growth exert many and diverse pressures on the quality and the quantity of water resources and on the access to them. Water quality monitoring and assessment is the foundation of water quality management; thus, there has been an increasing demand for monitoring water quality of many rivers and ground water by regular measurements of various water quality variables. (Mangukiya Rupal et. al. 2012).

Study area

The Rajghat dam is rock and earth fill type of dam. This dam is 1680.0 m long with 400.0 m masonry spillway, and which get water from Bewas River, Parkul River, and Jamunia River junction at Hinota village. Bewas River is 53.03 kms, Parkul River is 33.93 kms, and Jamunia River is 18.05 kms long at the dam site. The catchment area of Bewas river at the dam site is 472 sq.

kms is located between 23° 22' 0" N to 23° 48' 0" N latitude and 78° 28' 0" E to 78° 50' 0" E longitude. The total water capacity of dam is 96.0 million cubic meter with 80.0 live storage, and 16.0 dead storage. Bed level of river is 495.0, minimum sill level is 509.0 m, maximum water level is 518.0 m, and maximum bed level is 520.0 m at dam site. The Bewas River originates from the northeast part of Raisen district located at about 720 meter near the Pipalia Katan. The study area falls in Survey of India (1:50,000) top sheets No. 55I/9, 55I/10, 55I/11, 55I/13 and 55I/14 (Fig.1). The normal annual rainfall of the study area is 1371.6 mm about 90% of the annual rainfall takes place during the southwest monsoon period i.e. June to September only 5.5% of annual rainfall takes place during winter and about 4.5% of rainfall occurs during the summer months. Last of December to January end is the coldest months with the temperature falling as low as 4.6^0 C and max. up to 24.5^0 C, and in the month of May, the temperature goes up to 48.7^0 C. (Chourasia A. et.al 2015 & Rawat R.K. et. al 2013)

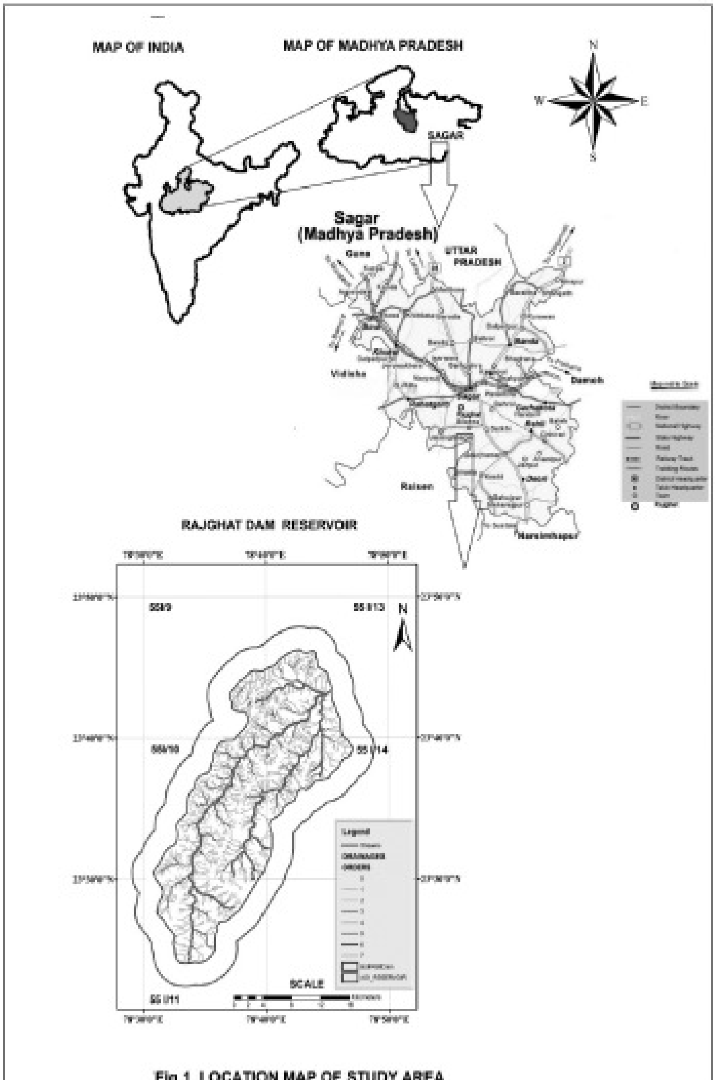


Fig.1. LOCATION MAP OF STUDY AREA

Materials and Methods

Remote sensing has become an important tool applicable to developing and understanding the global, physical process affecting the earth. Recent development in the use of satellite data is to take advantage of increasing amount of geographical data available in conjunction with GIS to assist in interpretation. GIS is an integrated system of computer hardware and software capable of capturing, storing, retrieving, manipulating, analyzing and displaying geographically referenced (spatial) information for the purpose of aiding development oriented management and decision making processes.

The present investigation was based on field observations as well as laboratory analysis. There are seven samples are collected from the reservoir catchment area. These samples are collected for physic-chemical analysis during pre- monsoon and post monsoon season in year 2015. Temperature, pH, Turbidity and Conductivity were measured on-site using digital meter kit. The others parameters like Total Alkalinity, Chloride, Nitrate, Sulphate, Total hardness, Calcium, Magnesium, Total Dissolved Solid (TDS), Iron, Sulphate, Fluoride, Copper, Manganese and Chromium were analyzed in the laboratory by collected samples in sample containers.

Water Quality Index (WQI) is calculated from the point of view of suitability of groundwater for human consumption. The standards for drinking purposes as recommended by BIS 10500 (2012) have been considered for the calculation of WQI. For computing WQI three steps are followed: (Vasanthavigaret al., 2010).

In the first step, each of the 17 parameters (Temp., Turbidity, pH, Conductivity, Total Alkalinity, Cl^-, NO_3^-, Total Hardness, Ca^{++}, Mg^{++}, TDS, Fe_2^+, SO_4^{--}, F^-, Cu, Mn, Cr_6^+) has been assigned a weight (*wi*) according to its relative importance in the overall quality of water for drinking purposes. In the second step, the relative weight (*Wi*) is computed from the following equation:

(1)

$$Wi = wi / \sum_{i=1}^{n} wi$$

where,

Wi is the relative weight

wi is the weight of each parameter

n is the number of parameters

In the third step, a quality rating scale *(qi)* for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS 10500 (2012) and the result is multiplied by 100:

$qi = (Ci/Si) \times 100$

where,

qi is the quality rating

Ci is the concentration of each chemical parameter in each water sample in milligrams per liter

Si is the Indian drinking water standard for each chemical parameter in milligrams per liter according to the guidelines of the BIS 10500 (2012).

For computing the WQI, the SI (Sub-Index) is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$SIi = Wi \times qi$

Then, WQI = " SI*i*

where

SIi is the sub-index of ith parameter

qi is the rating based on concentration of ith parameter

n is the number of parameters

According to Ramakrishnaiah et al. (2009), Vasanthavigar et al.(2010) and Yidana and Yidana (2010); Computed WQI values are classified into five categories as follows (Table 3):

Salinity based classification of water, as given by Davis and DeWiest, 1967, is also adapted for present study (Kumar et al., 2006) (Table 4):

FIG 2. LOCATION OF SAMPLES

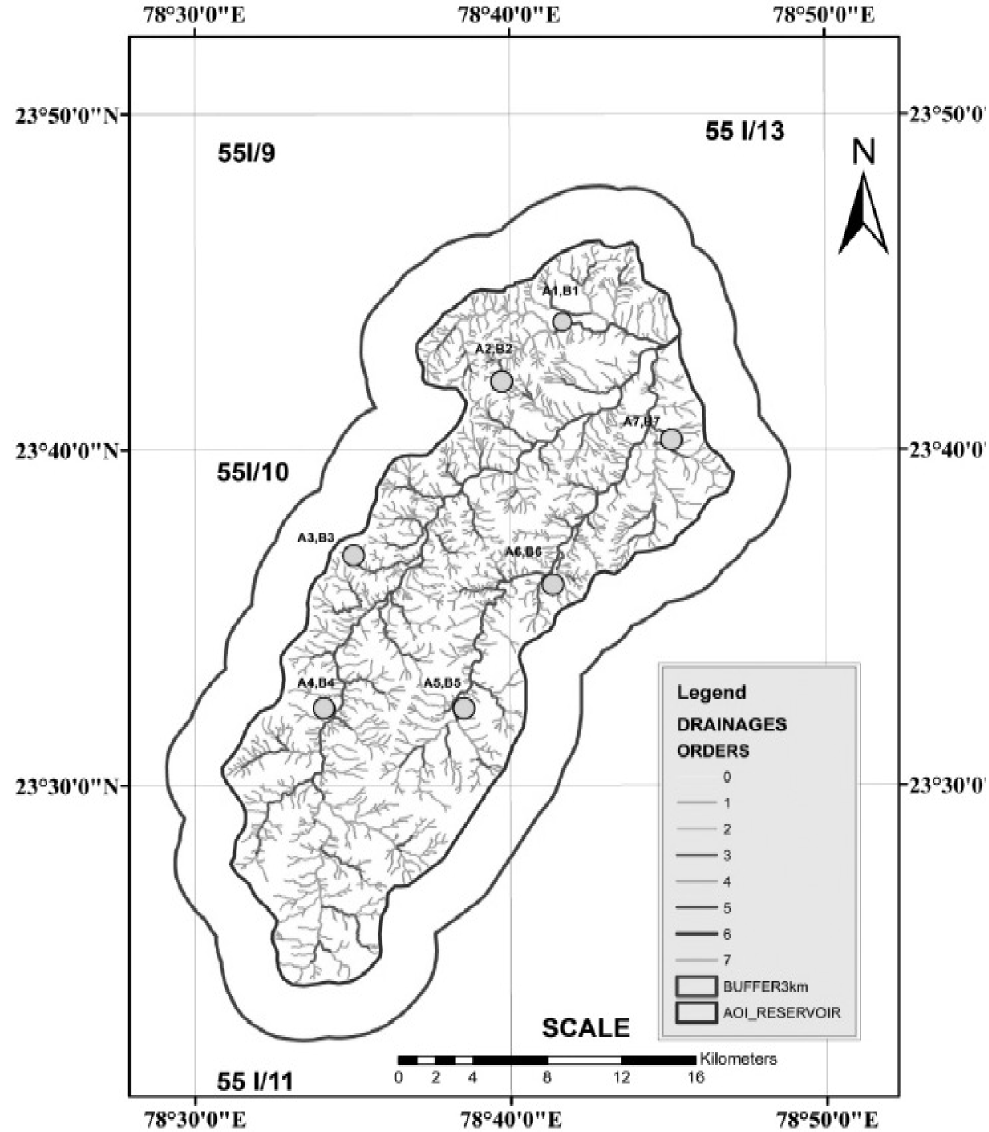


Table 1

Location of sample in study area

SAMPLE NO.	LOCATION	LONGITUDE	LATITUDE	ALTITUDE(m)
A1, B1	PARKUL RIVER	E78^{0}45’14.1"	N23^{0}43’37.7"	1720
A2, B2	BILEHRA FIELD SITE RIVER	E78^{0}44’17.3"	N23^{0}43’26.3"	1718
A3, B3	JAISINAGAR RD. BRIDGE 3	E78^{0}42’37.6"	N23^{0}43’30.4"	1748
A4, B4	BILEHRA VILLAGE	E78^{0}43’03.3"	N23^{0}36’53.1"	1724
A5, B5	BILEHRA VILLAGE	E78^{0}44’18.6"	N23^{0}40’37.3"	1712
A6, B6	JAISINAGAR RD. BRIDGE 2	E78^{0}42’53.9"	N23^{0}43’55.0"	1760
A7, B7	JAISINAGAR BILEHRA RD.	E78^{0}40’07.4"	N23^{0}39’42.4"	1789

Table 2

Drinking Water quality standards by BIS 10500; 2012

S.NO.	CHARACTERISTICS	UNIT	As Per BIS-10500:2012For Drinking Water	
			Desirable Limit	Permissible Limit
1.	Temperature	^{0}C	————-	————-
2.	*p*H	*p*H scale	6.5 to 8.5	6.5 to 8.5
3.	Turbidity	NTU	1.0	5.0
4.	Conductivity at 25^{0}C	µ&!/cm	————-	————-
5.	Total Alkalinity as $CaCO_3$	mg/l	200	600
6.	Chloride as Cl	mg/l	250	1000
7.	Nitrate as NO_3	mg/l	45.0	45.0
8.	Total Hardness as $CaCO_3$	mg/l	300	600
9.	Calcium as Ca^{++}	mg/l	75	200
10.	Magnesium as Mg^{++}	mg/l	30	70
11.	Total Dissolved Solids	mg/l	500	2000
12.	Iron	mg/l	0.3	1.0
13.	Sulphate as SO_4	mg/l	200	400
14.	Fluoride as F	mg/l	1.0	1.5
15.	Copper as Cu	mg/l	0.05	1.5
16.	Manganese as Mn	mg/l	0.1	0.3
17.	Chromium as Cr^{6+}	mg/l	0.05	0.05

Table 3

Classification of water based on WQI values

WQI values	Water Quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very Poor
>300	Unsuitable for drinking

Table 4

Classification of water based on TDS values

TDS (mg/l)	Types of Water
0-1000	Fresh
1000-10,000	Brackish
10,000-100,000	Salty
>100,000	Brine

Results and Discussions

Table 5

Concentration Of Chemical Parameters And WQI Values Of Pre- Monsoon Water Samples

CHARACTERISTICS	UNIT	RESULTS						
		A1	A2	A3	A4	A5	A6	A7
Temperature	^{0}C	33.0	33.0	33.0	33.0	32.0	33.0	33.0
*p*H	*p*H scale	7.7	7.4	7.5	7.6	7.4	7.5	7.6
Turbidity	NTU	16.0	10.0	18.0	12.0	10.0	18.0	12.0
Conductivity at 25^{0}C	µ&!/cm	390	340	1250	640	460	1250	640
Total Alkalinity as $CaCO_3$	mg/l	140	160	114	240	164	114	240
Chloride as Cl	mg/l	25.0	22.0	430	70.0	40.0	430	70.0
Nitrate as NO_3	mg/l	nil	14.2	48.2	58.0	59.0	48.2	58.0
Total Hardness as $CaCO_3$	mg/l	121	127	450	198	180	450	198
Calcium as Ca^{++}	mg/l	31.2	36	104	31.2	31.2	104	31.2
Magnesium as Mg^{++}	mg/l	10.3	8.9	45.6	28.8	24.4	45.6	28.8
Total Dissolved Solids	mg/l	234	204	750	384	276	750	384
Iron	mg/l	3.2	0.8	1.5	1.2	2.8	1.5	1.2
Sulphate as SO_4	mg/l	32.0	44.8	64.0	19.2	26.8	64.0	19.2
Fluoride as F	mg/l	0.14	0.13	0.14	0.45	0.35	0.14	0.45
Copper as Cu	mg/l	0.137	0.173	0.112	0.094	0.104	0.112	0.094
Manganese as Mn	mg/l	0.123	0.231	0.233	0.171	0.106	0.233	0.171
Chromium as Cr^{6+}	mg/l	0.196	0.169	0.227	0.102	0.111	0.227	0.102
WQI values		**24.91**	**19.78**	**31.26**	**23.62**	**21.52**	**31.26**	**23.62**

Table 6

Concentration of chemical parameters and WQI values of post- monsoon water samples

CHARACTERISTICS	UNIT	RESULTS						
		B1	B2	B3	B4	B5	B6	B7
Temperature	^0C	26	26	26	26	26	26	26
*p*H	*p*H scale	7.96	7.94	7.94	7.72	7.94	7.84	7.72
Turbidity	NTU	3.5	3.0	2.0	3.5	3.0	12.0	3.0
Conductivity at 25^0C	µ&!/cm	265	334	572	399	334	334	409
Total Alkalinity as $CaCO_3$	mg/l	138	174	220	212	174	240	224
Chloride as Cl	mg/l	15	13	105	30	13	55	25
Nitrate as NO_3	mg/l	17.7	41.1	31.4	38.8	41.1	27.7	19.9
Total Hardness as $CaCO_3$	mg/l	130	162	280	200	162	210	200
Calcium as Ca^{++}	mg/l	88	110	164	124	110	160	116
Magnesium as Mg^{++}	mg/l	42	52	116	76	52	50	84
Total Dissolved Solids	mg/l	136	172	297	206	172	172	211
Iron	mg/l	0.05	0.06	0.1	0.04	0.06	0.05	0.08
Sulphate as SO_4	mg/l	6.4	12.8	9.6	22.4	12.8	5.4	3.2
Fluoride as F	mg/l	1.0	0.8	0.7	0.9	0.8	0.6	0.7
Copper as Cu	mg/l	0.075	0.104	0.173	0.094	0.104	0.137	0.112
Manganese as Mn	mg/l	0.097	0.106	0.231	0.171	0.106	0.123	0.233
Chromium as Cr^{6+}	mg/l	0.101	0.111	0.169	0.102	0.111	0.196	0.227
WQI values		**13.99**	**14.72**	**16.71**	**16.03**	**14.72**	**22.58**	**15.63**

Table 6

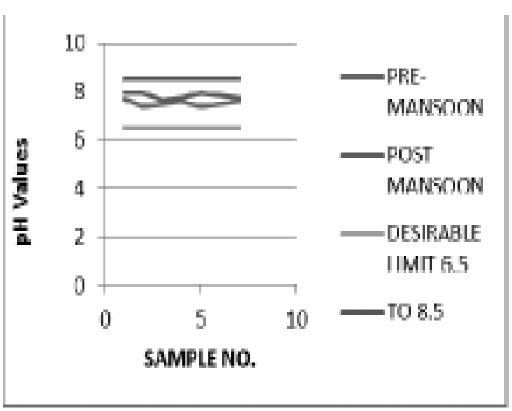
Safe limits in PPM (as per BIS, WHO, ICMR, APHA) & Minimum Acceptable & Maximum Acceptable limits for drinking purpose use of Ground Water & Adverse effect on wring Bodies

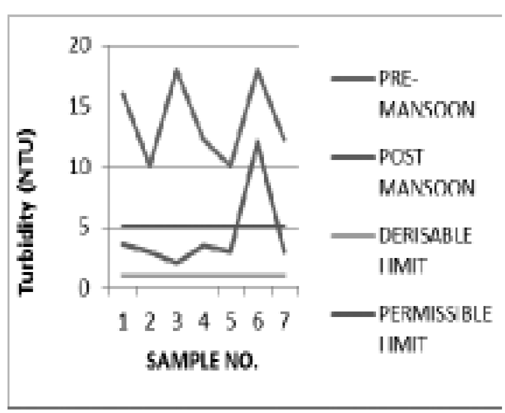
S.No	Parameters	Groundwater in mg/l		Effect on lifting
		Max.	Min.	
1.	Fluoride	1.5	1.0	Fluoride is essential for human beings as a trace element and higher concentration of this element causes toxic effects. Concentration offluoride between 0.6-1.0 mg/l in potable water protects tooth decay and enhances bone development.

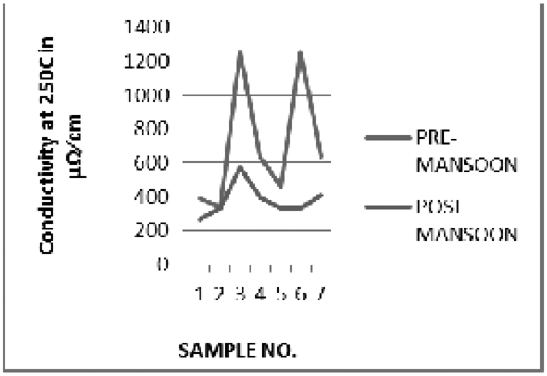
2.	Sulphate	400	200	The presence of sulphate has less effect on the taste of water compared to the presence of chloride. The high concentration of sulphate may induce diarrhea and intestinal disorders. Excess amount of sulphate in water has cathartic effect of human health.
3.	Iron	1.0	0.3	Promote Iron Bacteria in water, bad Taste, In trace is nutritional. Excess causes reduced metabolism of iron to form Hemoglobin.
4.	Copper	0.05		Astringent taste but essential elements for metabolism, deficiency results is anemia in infants, excess may results in liver damage.
5.	Manganese	0.1		Produces bad taste, essential as cofactor in enzyme system & metabolism process. Excess causes reduced metabolism of iron to form Hemoglobin.
6.	Chromium	0.05		Carcinogenic acuity (cancer), can produce coetaneous and nasal mucous membrane ulcer & Dermatitis, Hexavalent Cr causes lung tumors units in mg/l Jinwal et.al 2009 & Kataria et.al. 2011

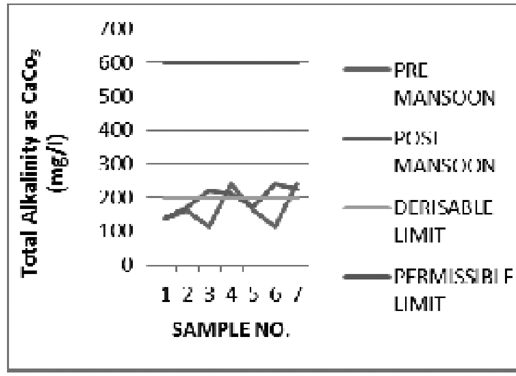
Fig 3.

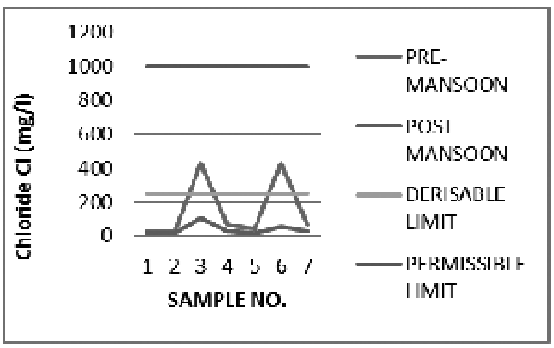
Figures of different parameters representing compliance with BIS satandards, a)*pH,* ***b)****Turbidity,* ***c)****Conductivity,* ***d)****Total Alkalinity,* ***e)****Chloride,* ***f)****Nitrate,* ***g)****Total hardness,* ***h)****Calcium,* ***i)****Magnesium,* ***j)****Total Dissolved Solid (TDS),* ***k)****Sulphate,* ***l)****Fluoride,* ***m)****Iron,* ***n)****Copper,* ***o)****Manganese and* ***p)****Chromium*

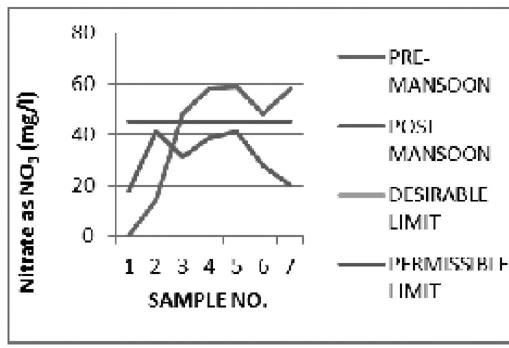


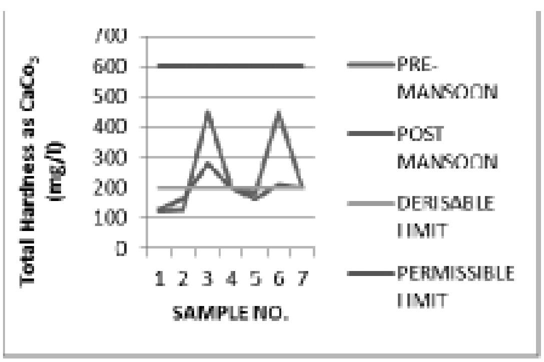


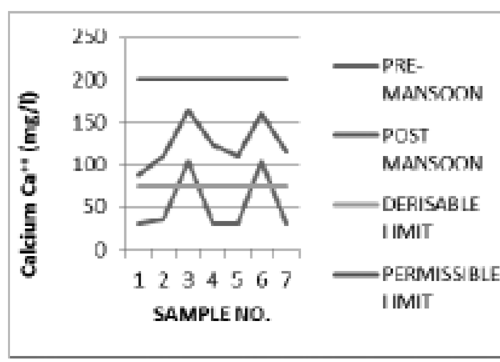

Conductivity at 250C in μΩ/cm
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE-MANSOON
POST MANSOON

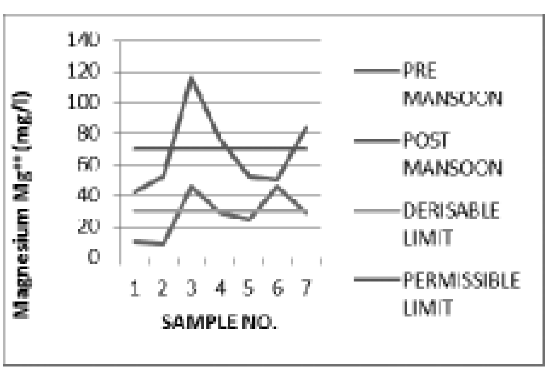

Total Alkalinity as $CaCo_3$ (mg/l)
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE MANSOON
POST MANSOON
DERISABLE LIMIT
PERMISSIBLE LIMIT

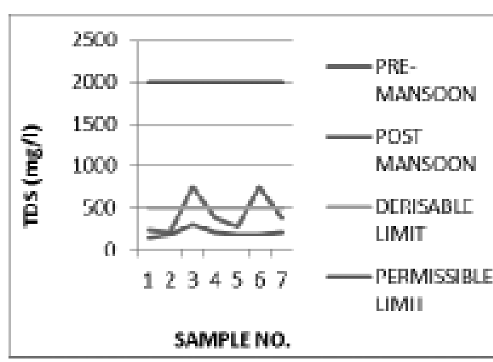

Chloride Cl (mg/l)
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE-MANSOON
POST MANSOON
DERISABLE LIMIT
PERMISSIBLE LIMIT

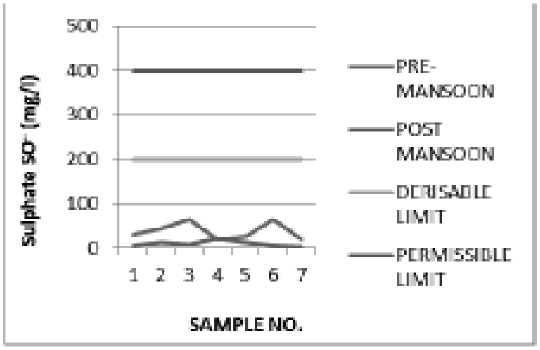

Nitrate as NO_3 (mg/l)
80
60
40
20
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE-MANSOON
POST MANSOON
DESIRABLE LIMIT
PERMISSIBLE LIMIT

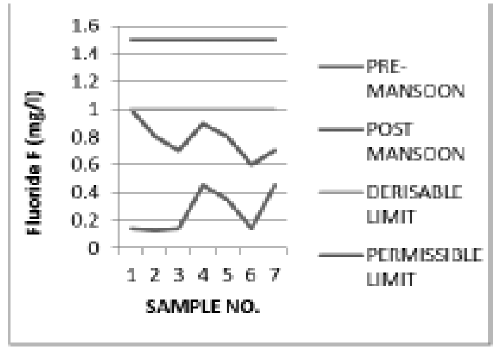

Total Hardness as $CaCo_3$ (mg/l)
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE-MANSOON
POST MANSOON
DERISABLE LIMIT
PERMISSIBLE LIMIT

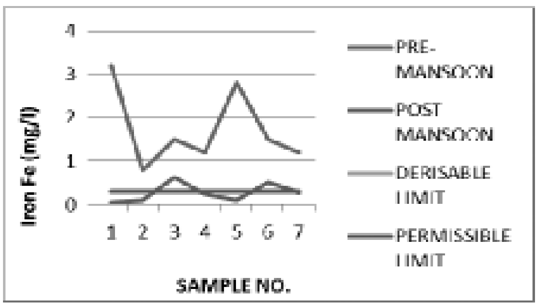

Calcium Ca^{++} (mg/l)
250
200
150
100
50
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE-MANSOON
POST MANSOON
DERISABLE LIMIT
PERMISSIBLE LIMIT

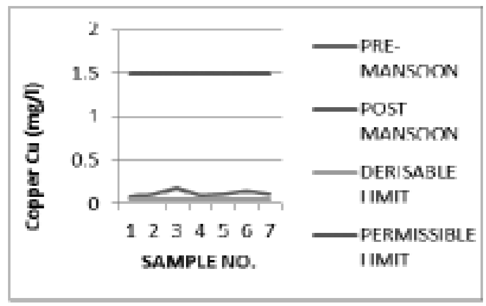

Magnesium Mg^{++} (mg/l)
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE MANSOON
POST MANSOON
DERISABLE LIMIT
PERMISSIBLE LIMIT

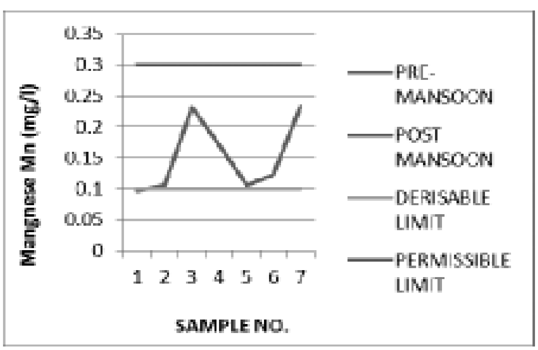

TDS (mg/l)
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7
SAMPLE NO.
PRE-MANSOON
POST MANSOON
DERISABLE LIMIT
PERMISSIBLE LIMIT

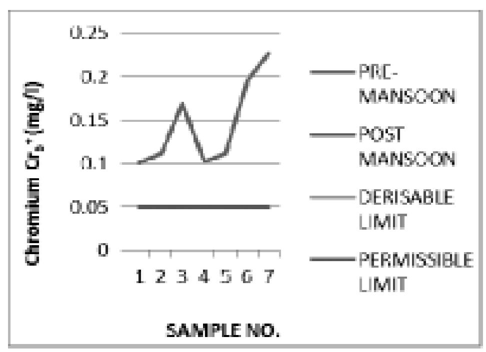












Variation in water quality

i) *pH*: *pH* was found in the range of 7.4 to 7.96 from all the study sites, which shows that the groundwater in the study area is more alkaline in post- monsoon season than in pre- monsoon.

ii) Turbidity: Turbidity was found in between 2 to 18 NTU where high in pre- monsoon and low in post monsoon season. But the most of pre- samples were range between 10 to 18 NTU which is inappropriate for drinking purpose. Hence special care must be taken while disinfecting the water before supplying to the public.

iii) Chloride: All values for Chloride were within desirable limit while chloride values of sites A3 was above desirable limit. High chloride values in pre-monsoon was reported by (Vasanthavigar et al. 2010) which can be due to leaching from upper soil layers derived from domestic activities and dry climate. Chloride content increases with increase in mineral content. The large variation of chloride concentration indicates recharge and discharge zones of lateral flow regime as local recharge to the unconfined aquifer is more dominant than recharge from lateral flow.

iv) Nitrate: Nitrate is permissible limit of 45 mg/L as per Indian standards. All values for Nitrate were within desirable limit while nitrate values for sites A3, A4, A5 were above desirable limit. Nitrates themselves are relatively nontoxic. Nitrogen essential component of amino acids, and therefore all proteins and nucleic acids, and therefore needed for all cell division and reproduction. Nitrogen is contained in all enzymes essential for all plant functions. However, when swallowed, they are converted to nitrites that can react with hemoglobin in the blood, oxidizing its divalent iron to the trivalent form and creating methanoglobin. Thus, Nitrate compounds can prevent hemoglobin from binding with oxygen at levels above the permissible limit. Thus the drinking water that is contaminated with nitrates can prove fatal especially to infants as it restricts the amount of oxygen that reaches the brain causing the 'blue baby' syndrome.

v) Hardness: Total Hardness was found in all sites of catchment area is falls under acceptable limit except site A3 exceed permissible limit. High values of hardness in pre-monsoon were observed due to dissolution of minerals by infiltration of young groundwater into the aquifer system. Six out of seven samples viz. 1, 2, 4, 5, 6 and 7 exceed desirable limit for magnesium.

vi) Magnesium: Mg concentration at site A1, A2 was reported below desirable limit in reservoir area. For site B3, B4, B7 magnesium concentration was reported above permissible limits. High magnesium values in groundwater samples, which might have been derived from dissolution of magnesium calcite, gypsum and dolomite from source rock (Garrels and Christ, 1965).

vii) TDS: Total Dissolved solids refer to any minerals, salts, metals, cations or anions dissolved in water. This includes anything present in water other than the pure water (H_2O) molecule and suspended solids. (Suspended solids are any particles/substances that are neither dissolved nor settled in the water, such as wood pulp.) TDS was found in the range of 136 to 750 mg/L. Groundwater TDS varies considerably in different geological regions owing to difference in solubility of minerals. In the present study, like TDS, EC was found in the range of 265 to 1250 ìS/cm appropriate for drinking purpose and in range of 0 to 1000 mg/l. Hence the water is fresh and it falls under desirable limit.

viii) Sulphate: All values for Sulphate were within desirable limit. Sulphate is relatively minor constituents of basalts. It is mainly comes from atmospheric precipitation and magmatic gases. It is also contributed to the groundwater because of breakdown of organic substances in the soil and sulphate rich fertilizers.

ix) Fluoride: Flouride is the permissible limit of 1 mg/L as per Indian standards. The variation of fluoride is dependent on a variety of factors such as amount of soluble and insoluble fluoride in source rocks, the duration of contact of water with rocks and soil temperature, rainfall, oxidation-reduction process. Easy accessibility of circulating water to the weathered products during irrigation dissolves and leaches the minerals, including fluorine, contributing flouride to the surface water and groundwater. The health issues body pain, knee pain and back pain were prevalent among people who consumed water containing excess fluoride. The presence of small quantities of fluoride in drinking water may prevent tooth decay. Fluoride is poisonous at high levels, and while dental fluorosis (mottled teeth) is easily recognized, skeletal damage may not be clinically obvious until advanced stages have occurred. Often, ground waters will contain less amount of fluoride to 1 mg/l and in these cases, the water is good for drinking purpose (Mangukiya Rupal et.al 2012).

x) Iron: Iron concentration in the groundwater sample is the permissible limit of 0.3 mg/l as per Indian standards. All sites were shown very high concentration of iron in water. The ground water samples exhibited high Iron contamination which is an indication of the presence ferrous salts that precipitate as insoluble ferric hydroxide and settles out as rusty silt. Iron is an essential element in human nutrition. Toxic effects have resulted from the ingestion of large quantities of iron, but there is no evidence to indicate that concentrations of iron commonly present in food or drinking water constitute any hazard to human health. At concentrations above 0.3 mg/l, iron can stain laundry and plumbing fixtures and cause undesirable tastes. Iron may also promote the growth of certain microorganisms, leading to the deposition of a slimy coat in piping.

xi) Copper: Copper concentration in the groundwater sample is the permissible limit of 0.05 mg/l as per Indian standards. All sites were shown very high concentration of Copper in water. It has taste like astringent but essential element for metabolism, deficiency results is anemia in infants. Due to high concentration may cause liver damage.

xii) Manganese: Manganese Mn concentration in the groundwater sample is the permissible limit of 0.1 mg/l as per Indian standards. All sites were shown very high concentration of Manganese in water. It can produce bad taste and essential as cofactor in enzyme system & metabolism process. Excess causes reduced metabolism of iron to form Hemoglobin.

xiii) Chromium: Chromium concentration in the groundwater sample is the permissible limit of 0.05 mg/l as per Indian standards. All sites were shown very high concentration of Chromium in water. Carcinogenic acuity (cancer), can produce coetaneous and nasal mucous membrane ulcer & Dermatitis, Hexavalent Cr causes lung tumors.

Conclusions

According to the calculation of physico-chemical parameters of groundwater, Water Quality Index (WQI) for 7 groundwater samples range varies from 13.99 to 31.26. Therefore, the water quality index (WQI) values for all sites, when arranged in ascending order, are found to be:

In pre- monsoon season, **A2<A5<A7<A4<A1<A3<A6**

In post monsoon season, **B1<B2<B5<B7<B4<B3<B6**

Hence, the overall water quality of groundwater is excellent while in case of analysis of Rajghat catchment area groundwater samples are affected by the studied trace elements. Atleast 70% of the population is still consuming groundwater. According to the analysis the study area were found Copper, Manganese and Chromium beyond the limit which contaminated water. Chromium enriched refuge should be properly treated and then disposed off. Construction of groundwater structure on dumping sites or its immediate vicinity should be avoided as Cr pollution relates to point sources. In agricultural excessive use of pesticides should be avoided so that it does not leach down to the groundwater and deteriorate its quality. Mass awareness should be generated about the over use of fertilizer, its harmful effects on quality of water and human health.

References:

Bathrellos, G. D., Skilodimou, H. D., Kelepertsis, A., Alexakis, D., Chrisanthaki, I. and Archonti, D. 2008. Environmental research on groundwater in the urban and suburban areas of Attica region, Greece. *Environmental Geology*, 56, pp.11-18.

BIS (Bureau of Indian standards) 10500; 2012. Indian Standard drinking water-specification.

Chenini, I. and Khemiri, S. 2009. Evaluation of groundwater quality using multiple linear regression and structural equation modeling. *International Journal of Environmental Science and Technology, 6*, pp.509-519.

Chourasia Abhilasha, Rawat R.K. and Thomas. H., 2015. Drainage network analysis of Rajghat dam reservoir, district Sagar, M.P., India using Remote sensing techniques. *International Journal of Engineering Science and Innovative Technology (Online*) www.ijesit.com, vol.4, Issue 2 March 2015.

Davis, S. N. and DeWiest, R. J. M. 1967. *Hydrogeology.* Wiley, New York.

Garrels, R. M. and Christ, C. L. 1965. *Solutions minerals and equilibria*. New York: Harper and Row, 450.

Gholami, V., Yousef, Z. and Rostami, H. Z. 2009. Modeling of groundwater salinity on the Caspian southern Coasts. *Water Resource Management*, 24, pp.1415-1424.

Jindwal. A., Dixit S., Malik. S., 2009. Some Trace Elements Investigation in Groundwater of Bhopal and Sehore District in Madhya Pradesh: India. *Journal of Applied Science and Environmental Management, December, 2009, vol.13(4),* pp.47-50.

Kataria. H.C., Gupta Manisha, Kumar Mukesh, Kushwaha Sandhya, Kashyap Sherwati, Trivedi Sonal, Bhadoriya Rani, and Bandewar Naval Kumar, 2011. Study of Physico-chemical Parameters of Drinking Water of Bhopal city with Reference to Health Impacts, *Current World Environment, 6(1*), 95-99.

K. Sundara Kumar, P. Sundara Kumar, M.J. Ratnakanth Babu, Ch. Hanumantha Rao, 2010. Assessment and Mapping of Groundwater Quality using Geographical Information Systems, *International Jounral of Engineering Science and Technology, Vol. 2(1),* pp. 6035-6046.

Kumar, M., Ramanathan, A. L. and Rao, M. S. 2006. Identification and evaluation of hydrogeochemical processes in the groundwater environment of Delhi, India. *Environmental Geology, 50*, pp.1025-1039.

Mangukiya Rupal, Bhattacharya Tanushree and Chakraborty Sukalyan, 2012. Quality Characterization of Groundwater using Water Quality Index in Surat city, Gujarat, India. *International Research Journal of Environmental sciences, 1(4),* 14-23.

Pareta. K., 2011. Geo-Environmental and Geo-Hydrological Study of Rajghat Dam, Sagar (M.P.) using Remote Sensing Techniques. *International Journal of Scientific & Engineering Research (IJSER, 2011), vol.2, Issue 8*.

Praveena, S. M., Abdullah, M. H., Bidin, K. and Aris, A. Z. 2011. Understanding of groundwater salinity using statistical modeling in a small tropical island, East Malaysia. *Environmentalist, 31*, pp.279-287.

Ramakrishnaiah, C. R., Sadashivaiah, C. and Ranganna, G. 2009. Assessment of Water Quality Index for the groundwater in Tumkur Taluk, Karnataka state, India. E-Journal of Chemistry, 6(2), 523-530.Rodriguez-Iturbe, I. 2000. Ecohydrology: a hydrologic perspective of climate-soil-vegetation dynamics. *Water Resource Research, 36(1)*, pp.3-9.

Rawat. R.K. and Chourasia. A. 2013. Geoenvironmental evaluation of Rajghat dam, dist. Sagar (M.P.) using geo-informatics techniques*. XXXIII INCA International Congress on Integrated Decentralized Planning: Geospatial Thinking, ICT and Good Governance 33,* 370-372.

Vasanthavigar, M., Srinivasamoorthy, K., Vijayaragavan, K., Rajiv Ganthi, R., Chidambaram, S., Anandhan, P., Manivannan, R. and Vasudevan, S. 2010. Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India. *Environmental Monitoring and Assessment, 171,* pp.595-609.

Yidana, S. M. and Yidana, A. 2010. Assessing water quality using water quality index and multivariate analysis. *Environment Earth science, 59,* pp.1461-1473.

9

Submergence Of Ghoramara Island Of Sundarban Region: Challenges And Crisis

Deblina Choudhury, Kalikinkar Das and Arijit Das

Introduction

The coastal area is a transition zone between terrestrial and marine life. This zone refers to a broad geographical area where the terrestrial and marine factors are mixed to produce dynamic/ sensitive ecosystems (Das *et.al.*2013; Marfai*et.al.* 2007; Jayappa*et.al.* 2006; Chert and Rau, 1998). The shoreline, interface between land and sea (Adarsa*et.al.*2012; Alesheikh et.al. 2007; Boak and Turner, 2005), is very dynamic feature of the coastal zone (Adarsa*et.al.*2012; Alesheikh*et.al.* 2007).

The Sundarban region is located in the south eastern part of West Bengal, is very much unstable as the erosion and accretion processes are continuously affected the region. This region has become vulnerable. The Sundarban region is composed of chain of islands. Ghoramara Island, as a part of Sundarban region is shrinking rapidly and losing its terrain day by day. This is exposed to strong river currents, storm surge, cyclones etc. As the erosion is increasing continuously the two third population of Ghoramara Island have already moved out of the Island. So now Ghoramara has become an endangered Island. The overall land use land cover has changed because of rapid submergence of this island. The shoreline of this island has also changed through time because of continuous submergence of Ghoramara Island. In the past three decades the land of this island has been lost drastically. Maximum land loss has been taken place in the decade of 1998-2008. Among the villages of this island Khasimara Char, Khasimara and Chunpuri has lost its land area the most because of its location. The whole Island becomes unstable and it directly affects the quality of life of the inhabitants. They feel insecure in their own homeland. Due to differcial erosion their land in terms of agriculture, vegetation has been lost day by day. Those who are cultivator has shifted their occupation as fisherman or permanently become inactive. The present study aims to understand island erosion and land use land cover change and changes in shoreline pattern over almost three decades. The land use land cover of this island drastically changed.

At present Ghoramara Island is on the verge of extinction. This paper, tries to establish the relationship between island erosion and landuse-landcover change, shows the shoreline change of this island over three decades, identifies the village wise areal reduction of Ghoramara Island as well as the soil erosion risk zone and studies the occupational shifting of the dwellers due to island erosion.

Study Area

Ghoramara Island is a part of Sagar block, West Bengal, India. This island is surrounded by Muriganga River in the east and Hoogly River in the west. It is located 18.36 nautical miles southeast of Haldia dock (Adarsa*et.al.*2012). The latitudinal and longitudinal extensions of Ghoramara Island are 21°53'56"N to 21°55'30"N and 88°06'30"E to 88°09'E. A couple of years ago Ghoramara Island was a part of Sagar Island, but due to tidal erosion, river currents of Hooghly River, tsunami etc. the island has separated by Hoogly River from the main island, Sagar. The Island cover an area of 4.04km^2. The present available village on the island are Khashimara Char, Khashimara, Chunpuri, Baghpara and Raipara. Some village namely Laxminarayanpur and Hathkhola are totally submerged in water in last two decade. Mean elevation of the island is 6.5 m above the mean sea level (Mukherjee 1983). Now in evert year sea level is rise caused by some natural as well as man-made causes like global worming (Adarsa*et.al.*2012). The average sea level rise of the island estimated as 2.6 mm per year (Gopinath2010; Ghosh *et.at.*2001; Baksi*et.al.*2001). Total population of the island is 5193 (Census of India 2011) but due to the gradual submergence people leave the place (Das *et.al.*2013), at present total population is about 3000 (Wikipedia 2016). The climate in the island is generally distinguished as pre-monsoon (February–May), monsoon (June–September) and post-monsoon (October–January) season respectively. Almost 70–80 % of the annual rainfall occurs during the summer monsoon (Hazra*et.al.*2016; Mukhopadhyay*et.al.*2006).

Data Used

In the present study, four satellite imageries were taken into consideration over the 27 years' time period (1988–2015). The datasets were acquired from the USGS website http://glovis.usgs.gov. Multi resolution satellite data such as Landsat TM, Landsat ETM+ and Landsat OLI TIRS were used in this study because of the unavailability of same resolution imagery over the chosen period. The details of the satellite imagery, acquisition details and resolution are given bellow.

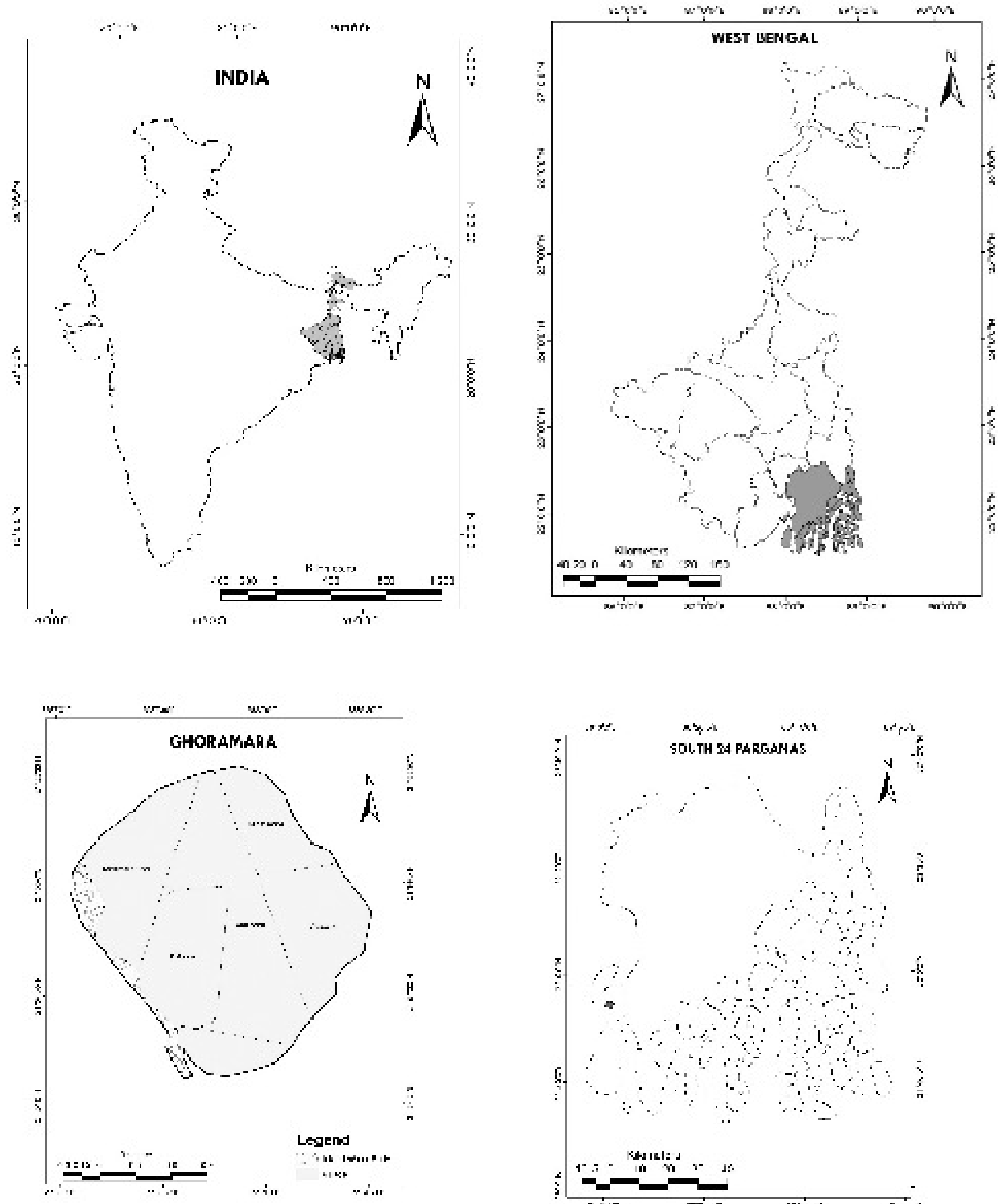
Satellite Data	Path/Row	Date of Acquisition	Spatial Resolution	No. of Bands
Landsat TM	138/45	25th January, 1988	30 m	7
Landsat TM	138/45	9th March, 1998	30 m	7
Landsat ETM+	138/45	28th March, 2008	30 m	7
Landsat OLI TIRS	138/45	8th March, 2015	30 m	11

Some population related data are collected from Census of India and Wikipedia.

Satellite Data Processing

The multi-temporal satellite imageries (for the year 1988, 1998, 2008 and 2015) were utilized to identify the morphological change. Landuse-Landcover maps are also created for 1988 and 2015 with the help by software. The method used for this is unsupervised classification. Firstly, fifteen classes are created for landuse and then all classes are rearranged into five classes they are namely Water Body, Settlement, Vegetation, Agricultural Field and Barren Land.

Fig: 1
Location of Study area

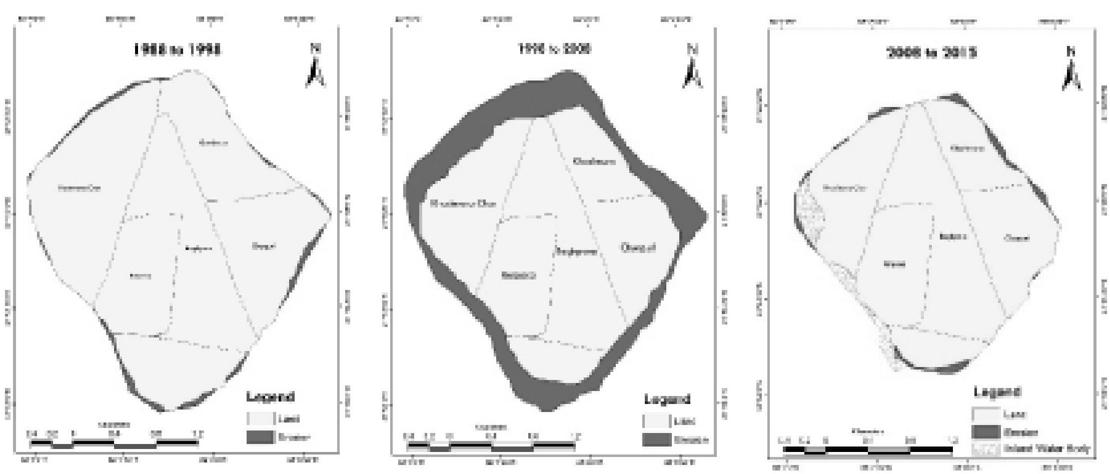


Result and Discussion

The time series analysis is showing a considerably higher areal loss of Ghoramara Island. Satellite images of 1988, 1998, 2008 and 2015 have been used for this change detection study. The time series analysis shows that total area of Ghoramara was 5.84sq. KM in 1988, decreased substantially to 4.04 sq. KM in 2015 which clearly indicates the severity of erosion. Erosion was higher during 1998–2008. Total area of the Island is 5.72 sq. KM in 1998 which become only 4.34 sq. KM in 2008 i.e. 1.38sq. KM (24.13%) of the Island has erode away in this decade. During this decade the north-western portion of this island has been adversely affected. 0.12 And 0.20 sq. Km area has been loss respectively during 1988 to 1998 and 2008 to 2015. From this mapping we can show that the rate of erosion is much higher than the accretion rate. At this time maximum erosion is occurred due to the occurrence of Tsunami in 26th December, 2004. But later rate of erosion is slower than previous decade. People of the island are very frightened and some of the villagers leave this place as soon as possible those who have the ability to own or rent a house in other area. But those who don't have the ability to do this have to adjust with the present condition of the island and lives with fear.

Fig: 2

Time series analysis to show the Areal reduction of Ghoramara Island in different decades (From 1988 to 2015)



The effect of changes of village area is different, respect to their position. Highest affected village is Khashimara Char situated in the North-West followed by Khashimara in North-East and Cable House in South. Baghpara is remaining same in their area due to central location. Raipara is also a village remain unchanged in their area located in the South-Western part of the Island i.e. North West part of the island is more erosive followed by north eastern part and the rest part are less erosive than above two. People living in the coastal part leave their house and settle in middle part of the island. So, those people are engaged in fishing at saline water become engaged at inland water body. People engaged in agriculture are also sifted their occupation to fishing and household industrial labour.

Fig: 3

Changes Of Area Of Different Villages In Different Decades

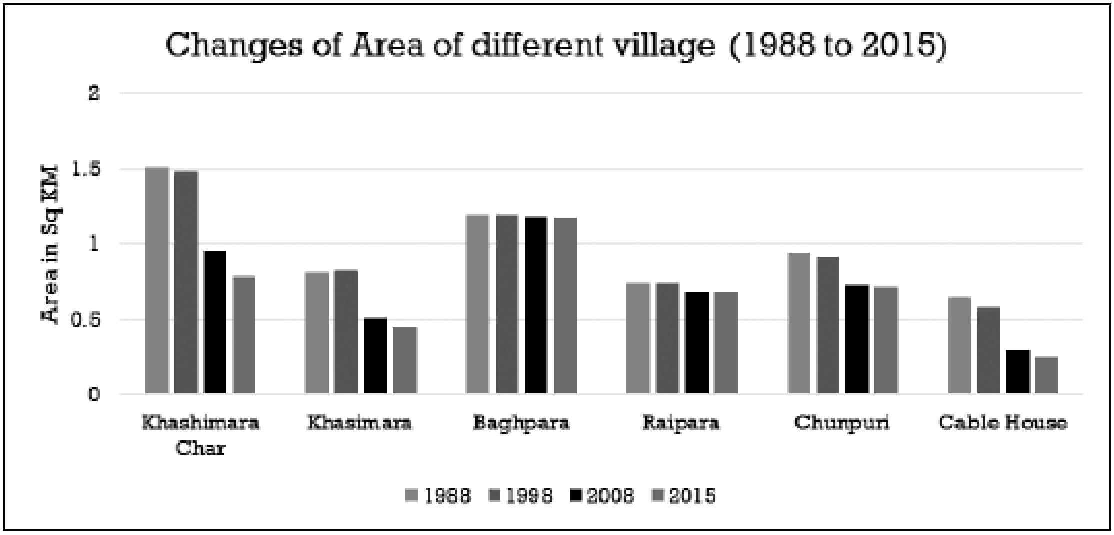
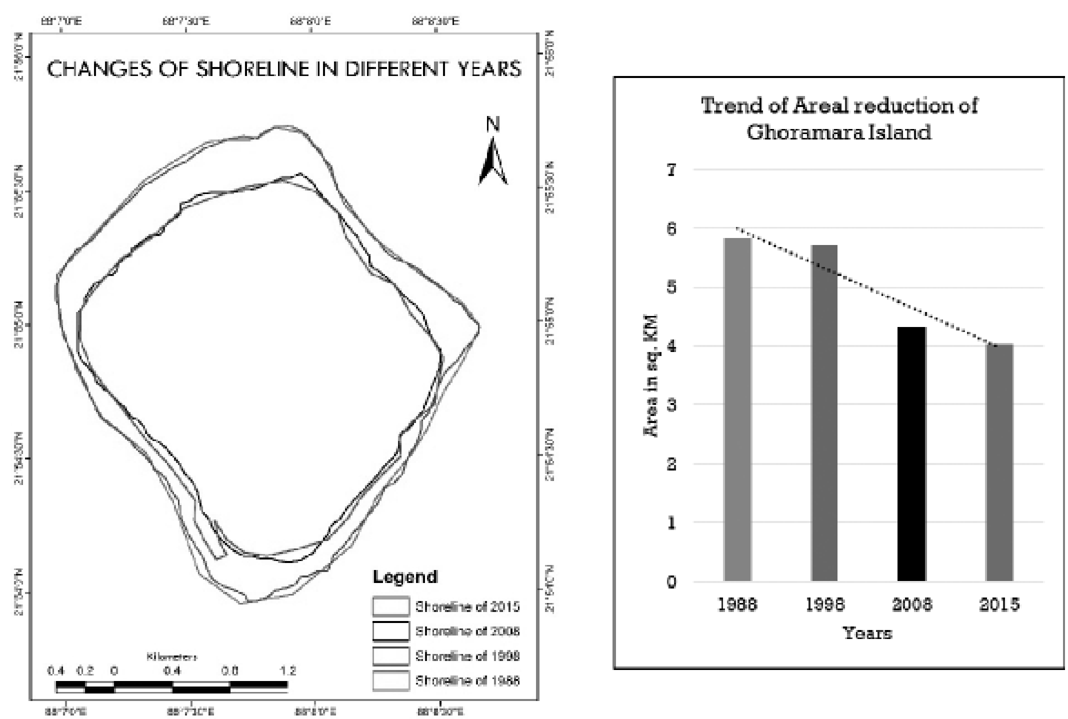


Fig: 4

Changes of Shoreline of Ghoramara Island in different years



Mapping Of Shoreline

Shoreline is a very dynamic feature of coastal area and situated between land and sea. Change of shoreline delineated by processing images of Landsat OLI and TM. In the figure below depicts shoreline positions in different year's viz. 1988 represented by Green, 1998 by Blue, 2008 by Black and 2015 by Red lines. By this we can say that the north-western portion of this island has affected the most by the strong currents of Hoogly River. And it can be also depicting that most of the erosion are taken place in Ghoramara Island are in the decade from 1988 to 2008.

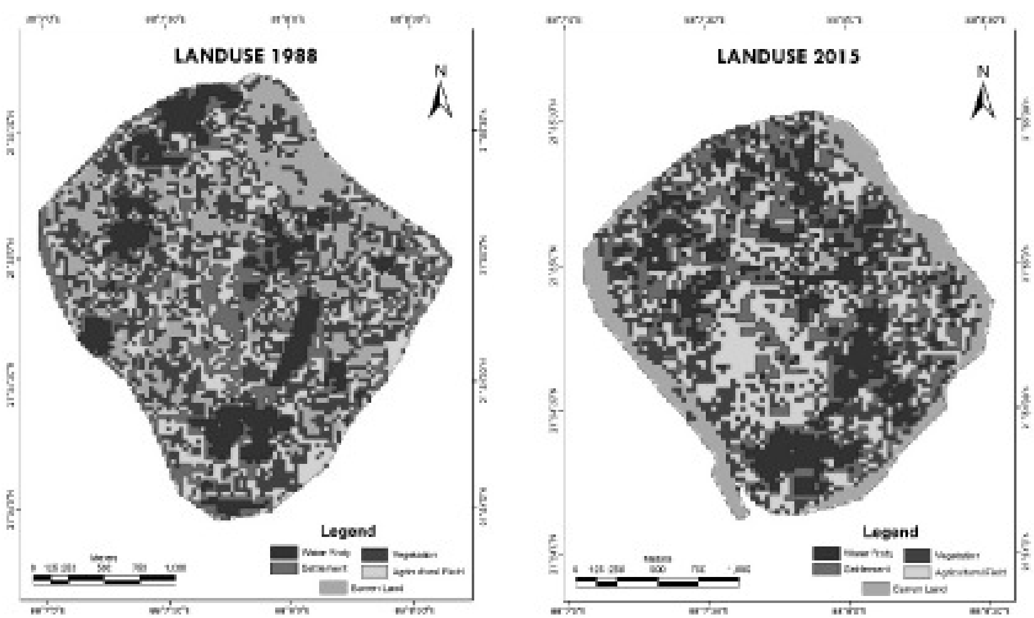
Land Use And Land Cover Change Analysis

To show the changing land use land cover we have taken multi-temporal satellite images that have been classified into five classes by ERDAS IMAGINE 9.3 software. The five classes include waterbody, barrenland, settlement, agricultural field and natural vegetation. The land use land cover of Ghoramara island has been changed through time (from 1988 to 2015) by various anthropogenic factors, cyclones, environmental factors. Table and the figure below show that change of land use land cover in percenrages from 1988 to 2015.

Landuse of Ghoramara Island is changed in different decades.

Fig:5

Changes of Land use of Ghoramara Island from 1988 to 2015



By the landuse map one can see the difference between the landduse of 1988 and 2015. Water body has been increase but all the other land decrease. Vegetation and Barren Land are decrease in very huge ammount. From the above figure it can be conclude that some of the barren land in 1988 become agricultural land in 2015. In the landuse of 2015 depict that barren land are available in the coastal region i.e. this area are now affected by salt of the sea and become barren.

Tab &Fig: 6

Changes of area in different landuse of Ghoramara Island from 1988 to 2015

Land use	Year 1988	Year 2015
Water Body	80.28	84.96
Settlement	121.59	110.61
Agricultural Land	123.93	109.7
Vegetation	148.14	62.46
Barren Land	109.71	55.89

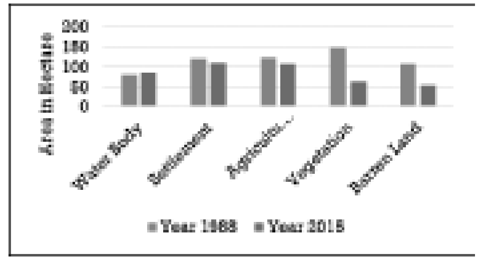
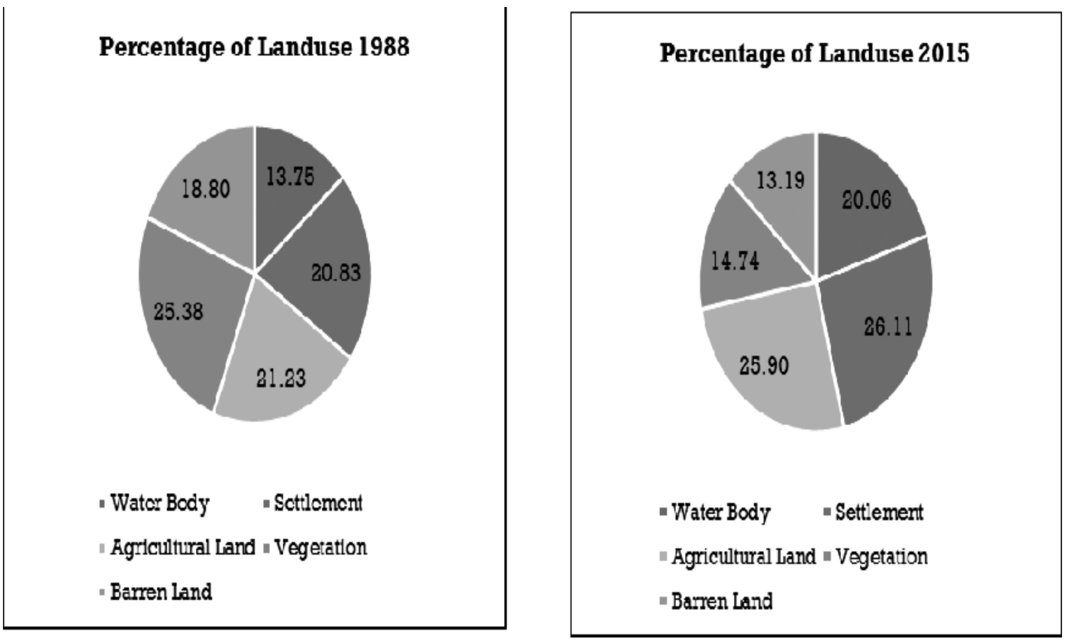


Fig: 7

Comparative Land use of Ghoramara 1988 and 2015



From the percentage landuse Vegetation and Barren Land are decrease but all the other land like Waterbody Settlement and Agricultural Land are increase in the period of 1988 to 2015. The causes behind that people try to lives in the Island for that they adjust with the availale land which are previouslly barren. They try to cultivate and settle their house in those lands.

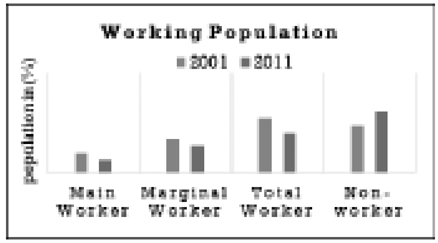
As the Ghoramara Island is disappearing very fastly, the existence of this island as well as the inhabitants put a question mark on their livelihood. They faces several challenges interms of agriculture is being affected because of the high levels of salinity of the soils due to high tides.

The erosion of Ghoramara island has affected the social life of the inhabitants in various ways. In this paper we consider the changes of occupation of the inhabitants from 2001 to 2011 with the help of available census data.

Tab & Fig: 8

Changes In Working Population In Last Decade Of Ghoramara Island

Census Year	2001	2011
Main Worker	19.82	12.56
Marginal Worker	33.86	26.69
Total Worker	53.69	39.25
Non-worker	46.31	60.75



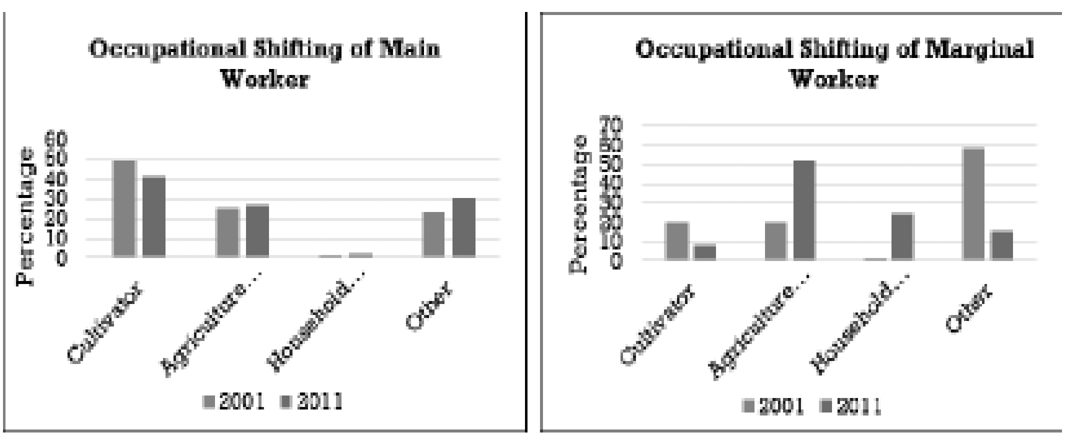
This diagram showing the changes of working population. In 2001 total working population was about 54%, but in 2011 it reduced to only 39%. This clearly indicates that 15% of the inhabitants of Ghoramara Island have lost their work in one decade.

This paper also try to establish the change of occupation of the workers. For this, we categorized the workers into two groups- main workers and marginal workers.

Occupational changes of main workers has been represented by the following diagram (Left). It depicts that percentage of cultivators has reduced and other type workers including fisherman, leave collection has increased in the decade. That means the inland water body are increase by decreasing the area of agricultural field. That's why people forced to transform their occupation from agriculture to other type of work like fishing.

Fig: 9

Occupational Shifting of the island dwellars of Ghoramara



When we consider the occupational shifting of the marginal workers it indicates that cultivator and other type workers including fisherman and leaves collection has been reduced and workers as agricultural labour and household industries has been increased. From the above figure and discussion we can conclude that cultivator become Agricultural labour and the fisherman become household industrial labour due to salinity in inland water body.

From the above understanding in clearly reveal that the cultivators has lose their homeland and become landless agricultural labour.

Conclusion

Multi-temporal satellite images were used to detect the shoreline changes of Ghoramara Island over a period of time. The maximum erosion occurs in the north-western portion of this island as the strong currents of Hoogly River rigorously hit this portion. The rate of erosion is higher than the accretion rate. The total area of this island has been reduced from 5.84 km2 in 1988 to 4.04 km2 in 2015. From 1988 till now Ghoramara island has facing massive soil erosion. As a result, the occupational structure of the inhabitants has been changed through time and they shifted their occupation from cultivator to agricultural labours and household industries due to loss of agricultural land.

REFERENCES

Hazra S, Ghosh T, Dasgupta R, Sen G (2002) Sea level and associated changes in the Sundarbans. *Sci Cult 68(9–12):*309–321

Chatterjee N, Mukhopadhyay R, Mitra D (2015) Decadal changes in shoreline patterns in Sundarbans, *India Journal of Coastal Sciences Volume 2* Pages 54-64.

Ghosh T, Bhandari G and Hazra S. (2001). Assesment of land use/land cover dynamics and shoreline changes of Sagar Island through remote sensing. *22nd Asian Conference on Remote sensing,* Singapore 2: 848-8522.

Mondal B (2015). Rehabilitation; A practical issue in the Sundarban deltaic area with special references to Ghoramara Island, South 24 Parganas, West Bengal, India. *International Journal of Humanities and Social Science Research. Volume 1.* Page No. 23-25.

Lillesand, T.M., and Keifer, R.W., (1994), *Remote Sensing and Image Interpretation*. (5th Edition), John Wiley and Sons Inc.

Rahman M M1 and Begum S June-December 2011. Land cover change analysis around the sundarbans mangrove forest of bangladesh using remote sensing and gis application. J. *Sci. Foundation, 9(1&2):* 95-107.

Gopinath G and Seralathan p (2005). Rapid erosion of the coast of Sagar Island, West Bengal-India. *Environ Geol (2005) 48*: 1058-1067.

Saha S and Ghosh T (March- April, 2015).The changing pattern of livelihood in Sagar Island, West Bengal, India. *Global Journal of Interdisciplinary Social Sciences. Volume.4 (2)* : 43-45.

Samanta K and Hazra S (2012). Landuse/ landcover change study of Jharkhali Islands Sundarbans, West Bengal using Remote Sensing and GIS. *International Journal of Geomatics and Geosciences. Volume 3, No 2*.

Das S, Roy Choudhury M, Das S, Khan S (2013). Monitoring shore line and inland changes by using multi-temporal satellite data and risk assessment: A case study of Ghoramara Island, West Bengal. Int. J. Earth. *Sci. And Tech. Vol.1 (1) 2013*. Pp. 1-20.

Maiti S AND Bhattacharya AK. (2009). Shoreline change analysis and its application to prediction: a remote sensing and statistics based approach. *Marine Geology 257*: 11-23.

Census of India, 2001: South 24 parganas.

Census of India, 2011: South 24 parganas.

10

Public Perception Regarding Pollution of The River Ganga : Case Study At Dakhineswar

Dipanwita De

Introduction

Pilgrimage sites around the world have a well known sacred recognition by their followers. The concern in most cases is many of these pilgrimage sites are known as places that put pressure on natural resources. Mount Fuji, Lumbini, Sri Pada, Bodh Gaya and especially Ganges are some sacred sites that are facing this pressure today. In all of the above cases people hold the resource in high regard as it has some relation to a god, goddess or spirit. However, people have been distracted and have forgotten to view the site as a natural resource that has a certain limit on how much pressure it could handle. This is the situation of the Ganges River. People regard the river as a holy site, but have failed to recognise the pollution that is affecting the river and the people (Wickramasekera, 2013). The Ganges, above all, is the river of India which has held India's heart captive and drawn uncounted millions to her banks since the dawn of history (Kishor, 2006). The Ganges River originates as a stream called "Bhagirathi" in the Gangotri glacier at 30 ° 55' N, 79 ° 7' E, 4100 meters above mean sea level. The Ganges River basin is the fourth largest river basin in the world and the largest among river basins in India. The river basin covers a catchment of 861,404 square km. Currently about half a billion people live within the river basin, at an average density of over 500 per square km, and this population is anticipated to rise to over one billion people by the year 2030 (Srivastava, 2010).

Millions of Hindu views the Ganges as a mother goddess. Therefore it is a river that is dearly loved. India's great civilisations and history began at this river. Between the early 2000 and 1500 B.C the Indo European immigrants who settled in north-western parts of India moved to the areas around the Ganges River (Shattuck 1999, 19). The great Indian civilisation began by the Ganges basin where all aspects of people's lives depended on this motherly river Ganga. The Ganges River has been at the core of sacred Hindu lore and tradition since ancient times. Ganga is known as the goddess Vindhyavasini in Hinduism (Hawley & Wulff, 1996). Ganga's water is said to be the "sustaining immortal fluid of mother's milk" (Hawley & Wulff, 1996). It is a commonly held belief that a dip in the river is believed to wash off sin, heal diseases and impurities, and a sip of the water is believed to cleanse your soul. Upon death, if one's ashes or body is floated in the river, Hindu's believe that the soul will rise to the heavens (Carpenter, 1986).

Yearly there are many festivals that take place along the Ganges River. All festivals celebrate a god or multiple gods in Hinduism and are visited by millions of pilgrims. The river is well respected and worshiped. However, the river is at the most extreme level of pollution. Despite the high levels of pollution, many pilgrims still bathe and drink the water to as a part of their traditions. During the pilgrimage season millions of litres of untreated sewage run directly into river. Even though people believe that that they are being purified when they bathe in the river, research carried out on bio monitoring and water quality monitoring proves that Ganges has the highest rate of pollution as well as the highest bacterial contamination when compared with the other major rivers that run through India (Bilgrami, 1998). The situation is hard to control because the people who use the river do not have to pay any cost for what they use or pollute. During the past three decades, industrialization and rapid urbanization have put unyielding pressure on the sacred river. Irrigation canals siphon off ever more of its water. Rivers like the Ganges can be life lines of a country's economy and its people, but with the toxic state of the river today it is unfit for human use. Today the concerning topic of pollution is arising inside and outside of India regarding the ecology of the river as well as the humans who are using it. The Ganga is known as the most polluted river in India as well as one of the ten most polluted river basins of the world (Daftuar, 2011).

In 1986 Rajiv Gandhi, Prime minister of India launched the Ganges Action Plan (GAP) to take measures to solve the Ganges River pollution problem with the objectives to "improve water quality, to conserve biodiversity and develop an integrated river basin management approach" (Srivastava, 2010) The plan lacked coordination. "Our limit is five milligrams. We cannot adopt WHO limits. They are for developed countries. India is a developing country. So we've set limits that work here" said a government official rejecting the WHO recommended maximum permissible limit in water of 1 milligram of pollution per thousand litres (Hollick, 2008). According to the GAP both point sources and non point sources were identified as polluters to the Ganges River (Srivastava, 2010). The plan suggested industrial pollution and municipal sewage as the point source pollution because the waste that is dumped in the Ganges River enters the river at specific sites. The industrial waste comes from tanneries, sugar and paper industries, textile industries, carpets, locomotives, coalmines, thermal power plants, fertilizer and chemical industries and more. The municipal sewage includes wastewater from fast growing urban areas, organic waste, sewage, trash, food and animal remains (Trivedi, 2010). The non point sources of pollution were also considered in GAP. Non point source pollution is waste that is does not enter the river from a specific source. According to GAP non point source waste includes disposal of dead bodies, animal, waste from religious events, runoff from medical waste, fertilizers from agricultural fields and cattle wallowing. During the festival season the temporary tents and toilets that are built and all the waste that comes out of those facilities are also sometimes dumped in the river. Aluminium and clay statues and millions of plastic bags that are taken by pilgrims to carry flowers for the rituals are also dumped in the river (Srivastava, 2010). These all fall under the category of non point source pollution. The ecology of the river as well as human health is at a major risk. According to research conducted compared to the 1960's plankton and 265 different fish species have sharply declined both qualitatively and quantitatively (Sinha & Khan, 2001). The water is used not only for religious practices but also for household purposes. Washing, drinking and cooking is all done using the unhygienic water of the Ganges River. The majority of the people who live along the Ganges River are very poor and uneducated. These people are unaware of the health risks they face now and that they will face in the future as well as the damage they are contributing to. Water borne diseases, diarrhea, helminthic infection, skin diseases and respiratory tract infection are increasing among the people along the river (Srivastava, 2010). Polluted river water can also affect the aquatic life and ecosystem (Dubey, 2012).

Methodology:

Since this research study involves public perception, the method to collect the data is based on a quantitative approach, namely a questionnaire. The questionnaire is divided into two parts, part A (demographic profile) and part B (public perception regarding pollution of the river Ganga). The study has conducted at Dakhineswar, a well known pilgrimage site of West Bengal. Total 250 respondents have randomly chosen and interviewed. Out of 250 respondents, 120 are local residents who live along and near the river Ganga and rest people visit Dakhineswar temple for religious purposes. To interview people, here I have applied 'close-ended' approach. However, respondents' own opinion regarding pollution problem have also emphasized.

Result and Discussion:

The entire study is divided into two parts, part A (demographic profile) and part B (public perception regarding pollution of the river Ganga).

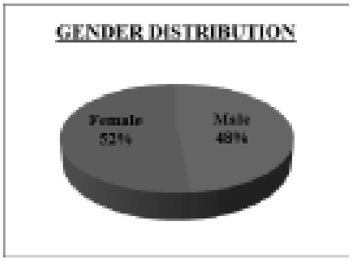
- **A. Demographic Profile of Respondents**:

Table 1

Age-Sex Structure

Age Group	Male	In %	Female	In %
<20	5	4.13	4	3.10
21-30	29	23.97	27	20.93
31-40	53	43.80	59	45.74
41-50	20	16.53	22	17.05
>50	14	11.57	17	13.18
Total	121	100.00	129	100.00

Figure: 1



Source: Primary survey

Figure: 2

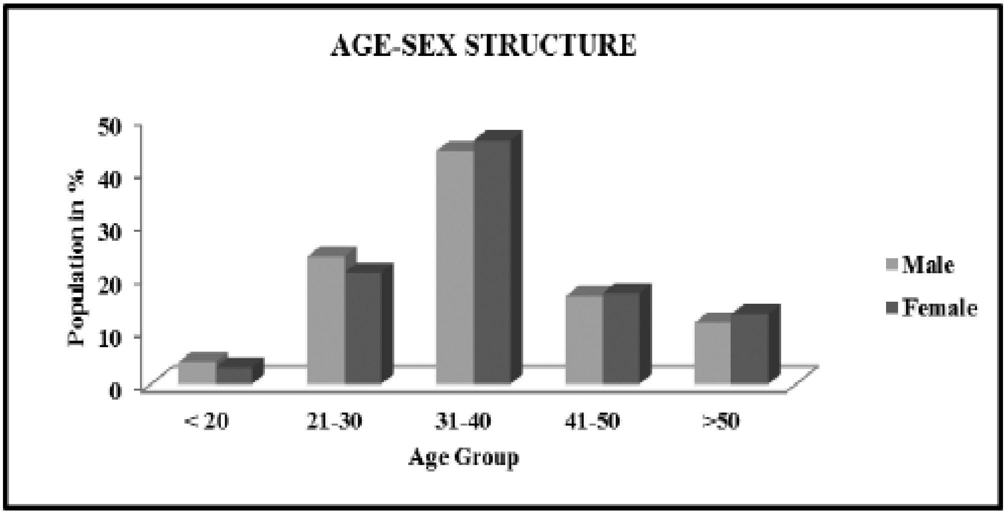


Table 2

Educational Level

Educational Level	Male	In %	Female	In %
Illiterate	13	10.74	20	15.50
Primary	29	23.97	27	20.93
Secondary	26	21.49	24	18.60
Higher Secondary	26	21.49	32	24.81
Graduate	18	14.88	15	11.63
Post Graduate	9	7.44	11	8.53
Total	121	100.00	129	100.00

Source: Primary survey

Figure: 3

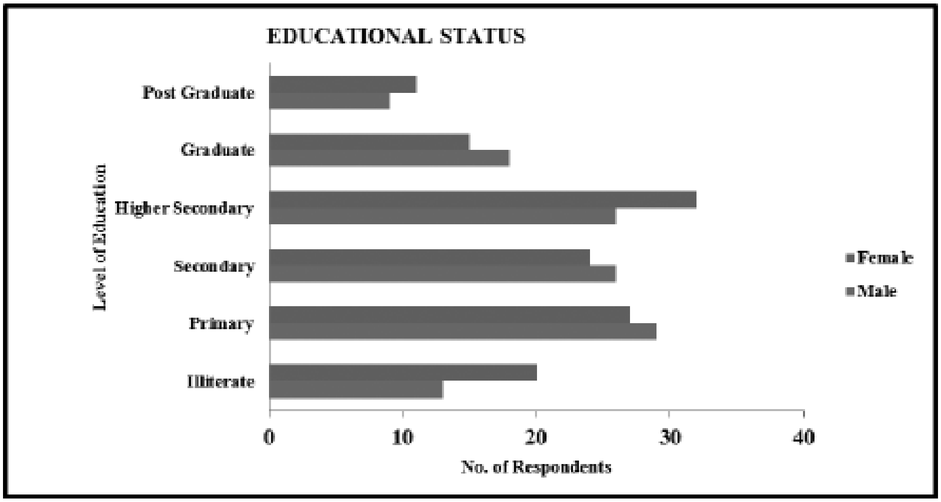
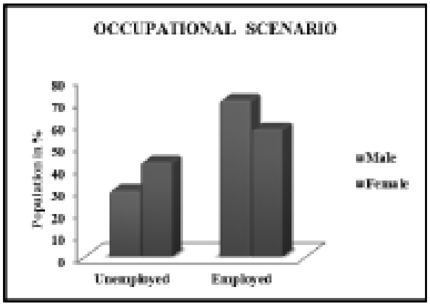


Table: 3

Occupational Scenario

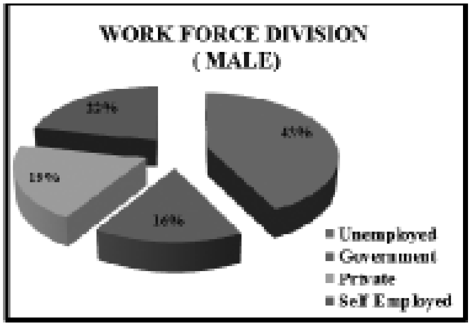
Occupation	Male	In %	Female	In %
Unemployed	36	29.7	55	42.6
Employed				
Government	17	14.0	21	16.3
Private	36	29.7	25	19.4
Self-Employed	32	26.5	28	21.7
Total	121	100.00	129	100.00

Figure: 4



Source: Primary survey

Figure: 5 **Figure: 6**



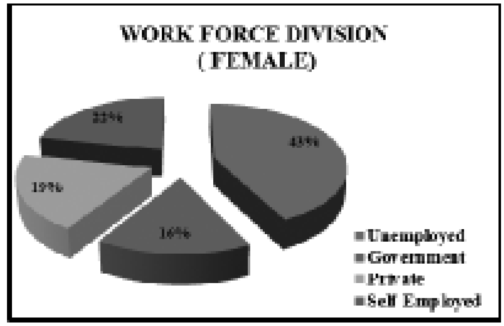


Figure-1 shows that among 250 respondents, 121 are male (48%) and rest of them are female (52%) and a majority of respondents are aged 31-40 years with the numbers of 112 (44.8 %). Table-1 and Figure-2 represent the detail information regarding the age-sex structure of respondents. 9.2% respondents are illiterate (Male-13 & Female-20).Most of respondents have only continued their study until higher secondary level (164 or 65.6%). Very few of them have able to complete graduation & post-graduation studies (4.7%). Table 2 and Figure 3 have clearly depicted the educational status of respondents. Lots of respondent are unemployed (36.4%) and most of the employed respondents are self employed or working in private sectors. Only 15.2% of them are engaged in government sector. Table 3 and Figure 4, 5 & 6 have thoroughly sketched out the occupational scenario of respondents.

B. Public Perception regarding pollution of the Ganga at Dakhineswar

Table 4

Basic Environmental Perception

S. No.	Category	Yes		No		Not Sure	
		F	%	F	%	F	%
1	Water is the habitat of aquatic life	239	95.6	6	2.4	5	2
2	Evaporation of polluted . water from river will cause air pollution (bad odour)	97	38.8	91	36.4	62	24.8
3	River water pollution weakens soil structure and causes erosion and sedimentation of river basin.	143	57.2	39	15.6	68	27.2
4	Polluted water in the river causes disease, cause aquatic animals to die.	109	43.6	98	39.2	43	17.2
5	Water pollution can cause the loss of soil nutrients and will affect the plant species.	125	50	37	14.8	88	35.2

6	Polluted water in river can affect the ecosystem.	120	48	81	32.4	49	19.6

Source: Primary survey

Figure: 7

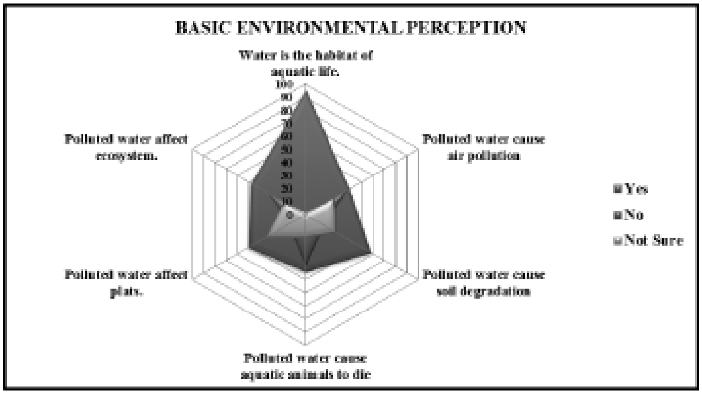


Table 4 and figure 7 depict the basic environmental perception of the respondents. In the opinion of respondents, they strongly agree that water is the habitat of aquatic life (95.6%). When a river is polluted, it can cause disease, poisoning, and death in aquatic animals, and become a habitat to dirty animals (43.6%). So, a majority of respondents strongly agreed that polluted water in river will affect the ecosystem (48%). At the same time, evaporation of polluted water from the river will cause air pollution (38.8%). On the other hands, polluted water can cause the loss of soil nutrients and weaken the soil structure, which can lead to erosion and sedimentation of river basin (57.2%) and affect the plants species (50%).

Table 5

Perception About The Water Quality Of The Ganga

Questions	All figures in %				
Do you think river Ganges is polluted?	YES – 90.2			No – 9.8	
How do you mainly know about the pollution of river Ganges?	Visual perception	Fisher men	Educational Institution	Friends & Family	Social Media
	63.7	34.3	16.1	17.5	41.2
What are the main sources of pollution?	Municipal Waste	Human Waste	Industrial Waste	Dumping site near river	Religious practices
	71.2	35.4	75.4	65.9	33.8
Water quality compared to 10 years ago	Better	Worse	Same	Don't know	
	8.8	39.4	29.7	22.1	
Since when the River Ganga has been contaminated?	No contamination	< 5 year	5-10 year	>10 year	No Idea
	9.4	23.2	28.4	30.4	7.6

Table 5 has depicted the public perception about the water quality of the river Ganga. Most of the people have agreed that the Ganga River is polluted (90.2%). Majority of respondents have come to know about the Ganges pollution from visual perception of river water and social media. They have identified municipal waste (71.2%), industrial waste (75.4%) and dumping site near the river (65.9%) are vulnerable for the water quality of this sacred river. There was no clear consensus among those who said the water quality has gotten better as to why it has improved. More than one third respondents have claimed, water quality of this river has worsened day by day and contamination of the Ganga has taken place more than ten years ago.

Most of those interviewed failed to realize that religious practices contribute to pollution. The idea is that there are other kinds of pollution that is contributing negatively to the water quality of the Ganges. Only, 35.4% respondents have agreed that religious practices are also responsible for Ganges pollution. Most of their answers were, Ganga is a goddess so no matter what kind of pollution she can purify herself and that is why we have faith in her.

Table 6

Use of the Ganges water

Do you use the Ganges water regularly?	Yes - 36.4		No – 63.6	
Do you face any problem due to use of the water?	Yes - 51.2		No - 48.8	
If yes, what are the types of problem?	Water born diseases	Diarrhoea	Skin diseases	Respirator y infection
	61.6	53.6	65.2	21.8

Source: Primary survey

Figure: 8

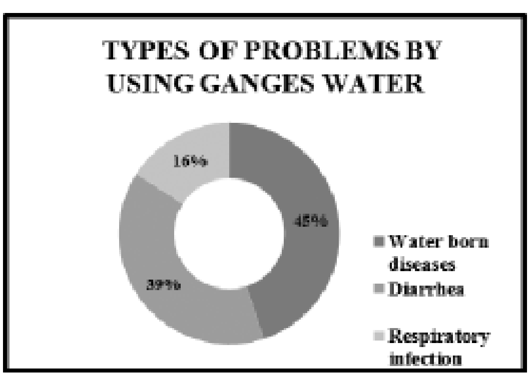


Figure: 9

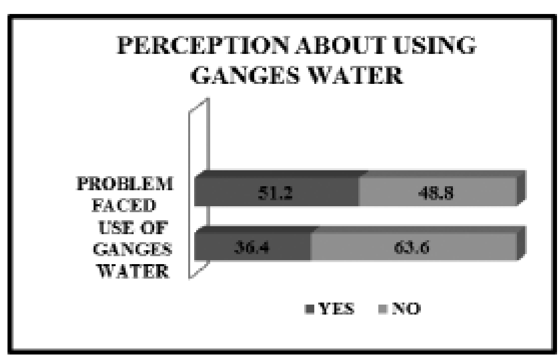
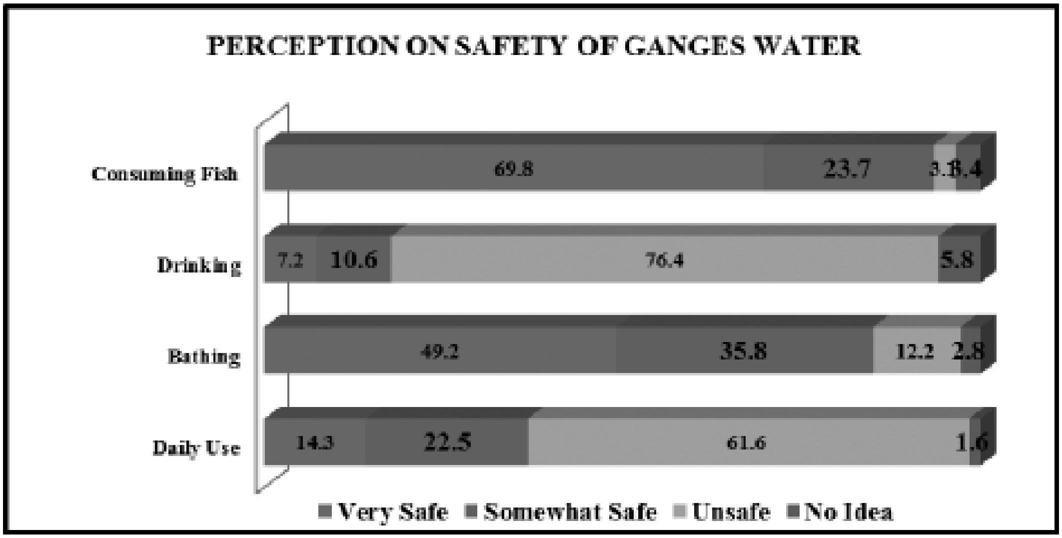


Table 7

Perceived Safety of River Ganges Water at Dakhineswar

Serial No.	Category	Figures in %			
		Very Safe	Some what Safe	Unsafe	No Idea
1	Domestic use/ Daily use	14.3	22.5	61.6	1.6
2	Bathing/ Swimming	49.2	35.8	12.2	2.8
3	Drinking	7.2	10.6	76.4	5.8
4	Consuming fish	69.8	23.7	3.1	3.4

Source: Primary Survey



More than one third respondents have used the Ganges water on a regular basis and 51.2% people have faced various problems like water born diseases (61.6%), Diarrhoea (53.6%), skin diseases (65.2%) and respiratory infection (21,8%) due to use of the water. Residents hold mixed views of the safety of the Ganges water at Dakhineswar. A majority of respondents (69.8%) felt it is safe to consume fish from the river. In contrast, over two- thirds of them have identified drinking from the Ganga is very injurious for health. Over half of respondents (61.6%) it is unsafe for daily use but near about half of them have found no risk in bathing or swimming in this river (Table 7 and figure). People are mainly focused on how the river provides them for rituals, washing, cooking and drinking. But few interviewees who were on pilgrimage from abroad and know more about environmental education were aware of the problem. This is where the focus of the pollution problem shifts. Progressive economic wealth causes human values to shift. When societies undergo a transition toward stability and modernity, individuals of society begin to be more aware of the needs and wants beyond their material needs. People begin to understand their surroundings better, the environment they live in and nature. Thus environmental concern can be found in wealthier nations while some developing countries like India that have significant levels of poverty don't have the luxury to care about the environment as much (Tilt 2010).

Table 8

Perception about How to mitigate the problem

Who should take initiative to solve or mitigate the problem?	State Govt.	Central Govt.	Local Authority	Local People	NGO	Joint co-operation
	51.2	67	59.3	48.2	23.2	93.4
How the problem will be decreased?	Awareness of people	Imposing heavy fines	Strict rules & regulation		No dumping at river	
	65.3	70.4	45.8		89.5	
Do you optimistic about the success of "*Swachh Bharat Abhiyan*"	Yes	No	Not Sure		Don't know	
	69.8	11.9	14.2		4.1	

Source: Primary survey

Approximately 90% of respondents have mentioned that not throwing or dumping any waste material to the river will be the most effective measurement to reduce the pollution of river Ganges. When respondents were asked about possible measurement to solve the problem, most of respondents identified imposition of strict fines on people throwing waste into the water to be the most favored solution to improve the condition of the river and they have also emphasized on the public awareness (65.3%) because majority of them have believed that individual citizens were responsible for the current condition of the river. More than 60% of respondents were optimistic about the success of "*Swachh Bharat Abhiyan*"in improving the water quality of the river.

Conclusion

The survey aimed to gauge the perception, awareness, opinion and behavior of people towards the Ganges pollution at Dakineawar. The present study has shown that local residents and pilgrims of Dakhineswar are well informed about the water quality of the Ganga. Most of respondents are agreed that Ganges River is polluted due to rapid development on landuse and uncontrolled human activities. When the Ganga is polluted, it affects aquatic animals such as poisoning, death and possible extinction. Pollution will also affect ecosystem, spread various dangerous diseases, affect the quality of human life through bad odour and acid rain, cause groundwater to be polluted and decrease quantity of freshwater for drinking, affect plant species and weaken the soil structure through causing the loss of soil nutrient, as well as lead to natural disasters for local residents. People begin to understand their surroundings better, the environment they live in and nature. Thus environmental concern can be found in wealthier nations while some developing countries like India that have significant levels of poverty don't have the luxury to care about the environment as much (Tilt 2010). Therefore, the government, private sector, non-governmental organizations (NGOs), and local residents should work together to protect the river and to mitigate the problem of water pollution.

References

Carpenter, Richard, A. (1986). The Ganges: An Example of Environmental Incongruity. *Environment: Science and Policy for Sustainable Development,* 28 (8): 32.

Bilgrami, K.S., Sanjib Kumar. (1998). Bacterial Contamination in Water of the River Ganga and Its Risk to Human Health. *International Journal of Environmental Health Research* 8 (1): 5–13.

Daftuar, H., Swati (2011). Polluted Flows the Ganga. *The Hindu*, Retrieved by June 26, 2016, from http://www.thehindu.com/todays-paper/tp-features/tp-youngworld/polluted- flows the- ganga/article2294996.ece

Dubey, Vineet Kumar, Uttam Kumar Sarkar, Wazir Singh Lakra,(2012).The Influence of Habitat on the Spatial Variation in Fish Assemblage Composition in an Unimpacted Tropical River of Ganga Basin, India." *Aquatic Ecology* 46 (2): 165–174.

Gandhi, Kishor. (2006). India's Date with Destiny: Ranbir Singh Chowdhary: Felicitation Volume. Allied Publishers.

Hollick, C., Julian (2008). Ganga: A Journey downs the Ganges River. Washington, DC: Island Press.

Sinha, Khan (2001). Impact of Environmental Aberrations on Fisheries of the Ganga (Ganges) River. *Aquatic Ecosystem Health & Management,* 4 (4): 493– 504.

Shattuck, Cybelle, T. (1999). Hinduism. Retrieved by August 16, 2016, from http://site.ebrary.com/id/10062768.

Srivastava, V. K. (2010). Indian Rivers Pollution-Critical Analysis: Ganga Action Plan. *Indian Chemical Engineer*, 52 (2).

Stratton, J., Wulff, D. M. (1996). Devi: Goddesses of India. Berkeley: University of California Press.

Tilt, Bryan. (2010). "The Struggle for Sustainability in Rural China Environmental Values and Civil Society." Retrieved on July 25, 2016, from www.worldcat.org/title/struggle-for-sustainability-in-rural-china.../682282719

Trivedi, R. C. (2010). Water Quality of the Ganga River: An Overview. Aquatic *Ecosystem Health & Management,* 13 (4): 347–351.

Wickramasekera, A. (2013). " Ganga can always survive and purify herself simply because she is a Goddess" Representation of Spiritual Practices in the Ganges Piver Pollution Problem. Retrieved by Sptember 7, 2016, from **http**s://ds.lclark.edu/sge/wp.../**sites**/.../Wickramasekera_Amanda_Final-Thesis-Draft.pd.

11

Greenhouse Effect and Changing Evironment

Baisakhi Sarkar

Climate in its various forms – variability, fluctuations, change, extremes – is appearing as a matter of serious concern about global environmental changes. There is great worry about what are the adverse effects of climatic phenomena on human being or on the resources on which societies depend: food production and security, water resources, energy, public health, public safety, economy and environment. Climate has become a highly charged (politically and economically) aspect of environmental change at local and global levels. Climate sensitive issues include a lot of items like agriculture, fisheries, health, economy, policy, disaster (flood, drought), etc.

Climate variability, change and extremes have positive and negative impacts on environment and society. Those impacts can vary over time even in the same location, depending on changes in the vulnerability of ecosystems and societies. Human activity began to affect the earth when early man began to use fire. However, the impact of humans began to accelerate when large-scale burning of fossil fuels began in Europe at the beginning of the industrial revolution (around 1750AD). Burning of carbon-based fossil fuels releases carbon dioxide (CO_2), and since 1750s the concentration of CO_2 has increased by 35 per cent. Similarly, methane, nitrous oxide and a suite of human-made chemicals - chlorofluorocarbons (CFC) and hydro-fluorocarbons (HFC) have increased in the atmosphere. Industrial activity releases sulfate aerosols into the atmosphere. It may be noted that while billions of tonnes of carbon dioxide are released annually, the amount of HFC and CFC released is far smaller. Thus, even 500 years into the future, carbon dioxide will remain far more important than the HFC or CFC for net impact.

Over the twentieth century and first quarter of twenty-first century, global average surface temperature has been increasing by 0.5ºC annually. A very rapid warming over the continental surface is happening since1976. Measurements of ocean heat content, measurements from weather balloons, observations of precipitation, atmospheric moisture, snow cover, land-ice, sea-ice, sea level, changes in terrestrial ecosystems and observed changes in some ocean circulation patterns and possibly climate variability and extreme weather and climate all point to a warming world. The impact is felt not only on sea level rise and coastal inundation, but a vast stretch of tropical and sub-tropical areas would face drought and desertification. Change in the density of vegetative cover is an important factor acknowledged as indicator of desertification. As density decreases, the risk of wind erosion, water erosion and the adverse effect of increased solar radiation on bare soils increase dramatically.

Climate Policy

Climate has become a highly charged (politically and economically) aspect of environmental change at local to global levels. Climate sensitive issues include a lot of items like agriculture, fisheries, health, war, economy, policy, disaster, etc. Warmer nights affect yield of barley, paddy and many other crops. Today, international community is negotiating on the development of "Law of Atmosphere", through the IPCC (Intergovernmental Panel on Climate Change). The Vienna Convention, Montreal Protocol, convention on Long-Range Trans-boundary Air Pollution, UN Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and Paris Protocol – all are aiming to control climatic degradation. Actions have been taken since the mid-1970s to reduce and eliminate ozone-depleting chemicals from industrial use. The Montreal Protocol in 1987 (and later amended several times) has sharply reduced CFC emissions. Since the late 1980s to the present, there have been several international conferences on global warming and for the effective control of greenhouse gas emissions. Since the late 1980s to the present, there have been several international conferences on global warming and for the effective control of greenhouse gas emissions. Acid rain, particularly trans-boundary acid rain concerns have generated a lot of discussion. This year since 7th November 2016, 12 day International Climate Summit is being held at Morocco.

Greenhouse Effect

Of the solar radiation reaching the top of the atmosphere, about 30 per cent is reflected back to the space by the atmosphere (primarily by clouds) and the surface (deserts); about 20 per cent is absorbed in the atmosphere; and about 50 percent is absorbed at the surface. For the planet as a whole, the radiation that is emitted away as infrared (or heat) radiation must balance the amount of solar energy absorbed. Were the earth's atmosphere transparent, the earth's average surface temperature would equilibrate at close to minus 18ºC, at the current reflectivity rate of earth-atmosphere system. Such a temperature would be too cold to sustain life in this planet. However, the earth's atmosphere is not transparent to infrared radiation; instead, a number of gases are able to absorb and emit infrared energy. As a result of this property of particular atmospheric gases, a warming influence on the climate is created. This warming effect occurs because a large fraction of the infrared radiation emitted by the surface and by the greenhouse gases and low clouds in the atmosphere is absorbed by these atmospheric gases before the energy is lost to the space. Less than 10 per cent of the infrared radiation emitted by the surface is at wavelengths that pass through the atmosphere directly to space without being absorbed. The energy that is absorbed in the atmosphere tends to warm it. A significant fraction of this energy is radiated back toward the surface, providing additional energy for more warming of the surface. This emission-absorption-re-emission process that recycles energy back to the surface is popularly called the greenhouse effect.

Greenhouse effect is a natural phenomenon that warms the earth by about 33ºC. It is caused by greenhouse gases in the atmosphere. The most important active greenhouse gas is water vapour. Also, under appropriate conditions, water vapour can condense and form clouds that absorb and emit infrared radiation as well as absorbs scattering solar radiation. Other active gases are CO_2 (carbon dioxide), CH_4 (a compound of carbon and hydrogen; Methane), N_2O (nitrous oxide), and a number of HCFCs (hydrogen, carbon, fluorine and chlorine chemicals) and CFCs (carbon, fluorine and chlorine chemicals). Because the concentrations of these gases are being directly affected by human activities, these greenhouse gases are referred to as the anthropogenic greenhouse gases. The natural greenhouse effect is currently being enhanced through human activity via the release of additional greenhouse gases into the atmosphere. The consensus of the scientific community, voiced through reports written by the Intergovernmental Panel on Climate Change (IPCC), is that this enhancement of the natural greenhouse effect has caused global warming over the last 150 years and that this warming is very likely to accelerate in near future. Human activities such as burning of fossil fuels, tropical deforestation, expansion of built-up area, emission of greenhouse gases are responsible for enhancing the naturally occurring greenhouse effect.

Global warming and its impact

Over the twentieth century the global average surface temperature has increased by 0.5ºC annually. A very rapid warming over the continental surfaces is happening since1976. Measurements of ocean heat content, measurements from weather balloons, observations of precipitation, atmospheric moisture, snow cover, land-ice, sea-ice, sea level, changes in terrestrial ecosystems and observed changes in some ocean circulation patterns and possibly climate variability and extreme weather and climate all point to a warming world. The impact is felt not only on sea level rise and coastal inundation, but a vast stretch of tropical and sub-tropical areas would face drought and desertification. Change in the density of the vegetative cover is an important factor acknowledged as indicator of desertification. As density decreases, the risks of wind erosion, water erosion and the adverse effect of increased solar radiation on bare soils increase dramatically. Recent observations show that for the past few years some north Indian states like Himachal Pradesh, Uttarakhand, Delhi, Jammu & Kashmir, Punjab, Haryana have been receiving plenty of rainfall during southwest monsoon. In east Rajasthan and Gujarat plains heavy rainfall caused sheet flood. These events could be explained by the hypothesis that summer low pressure trough over the subcontinent has a tendency to get shifted from Rajasthan to elsewhere (farther north northwest) and that the Arabian Sea branch of monsoon has become more powerful with respect to collection of moisture. In mid-June 2013 devastating flood in Uttarakhand was a combined impact of cloud burst in Uttarakhand, quick melting of glaciers at high altitude –all due to high temperature condition. In 2014 Srinagar (Jammu & Kashmir) and environs were deluged due to heavy downpour.

Global events

It may be mentioned that not only India but some other Asian countries like Philippines experienced flood during 19^{th}-20^{th} August 2013 due to heavy rainfall; south China was flooded due to heavy rainfall. This year also parts of China got flooded. This year (2016) Moscow was waterlogged during last week of August due to heavy rainfall. Local heavy clouds might have gained enough moisture due to accelerated evaporation rate from Himalayan snowfields. France experienced heavy rainfall and flood during summer 2013. A tornado devastated Oklahoma, USA on 21^{st} May 2013. A super cyclone damaged Great Britain in October 2013. In southeast Asia cyclone *Phailin* damaged Bay of Bengal coast during 8-14 October 2013. During same time typhoon *Nari* affected Philippines and Vietnam. Super typhoons devastated Philippines on 8^{th} November 2013 and again in 2014 and 2015.Hurricane *Hudhud* damaged Andhra coast (India) in 2014. In Africa, in April 2012, Kenya experienced flood. Eastern Australia received abnormally high amount of rainfall during summer. Hurricane *Mathew* damaged a vast part of Florida during summer 2016. Super typhoon *Haima* (wind speed 160miles/hour) developed in southwest Pacific Ocean, devastated

Philippines and southeast China during 19-22 October 2016. In last week of September 2016 South Korea experienced heavy rainfall due to typhoon. These indicate high sea surface temperature in local pockets promoting the development of cyclonic movement of air during early winter solstice.

For the past few years high and mid latitudinal countries of northern hemisphere are experiencing very hot summer as well as severely cold winter. This indicates rapid warming in summer and rapid cooling during winter; which might be due to a little more tilting of the earth's axis. It is interesting to note that on July 20th, 2013, southern Canada experienced 41º Celsius temperature; New Jersey (USA) recorded 38º Celsius temperature; and it is happening for past couple of years. In 2013, late July –early August temperature in Texas was around 48ºC. On the same day Kolkata, located in the Tropics, was not so hot; it had 37° Celsius temperature. In 2014 winter spell persisted in and around Toronto (Canada), around New Jersey (USA) up to mid- April 2014 (day temperature remained -5ºC when 10ºC is the expected average temperature).

A tilt in the earth's axis?

Not only human activities but there are some other causes leading to extreme climatic conditions. An inference is drawn from recent observations especially after the massive earthquake in Japan on 11th March 2011 and also the frequent earthquakes during the past couple of years, that axis of the earth (which had never been static) might have got tilted. According to Italian and US agencies the quake in Japan has shifted the earth's axis by 25 cm. Not only in Japan but frequent earthquakes occurred elsewhere. New Zealand experienced massive quake on 22nd February 2011. On 13th November 2016 an earthquake of magnitude 7.8 in Richter scale affected southern New Zealand. On 23rd August 2011 an earthquake occurred along the west coast of N. America. On 20th September 2011 Sikkim and Darjiling (India) experienced massive earthquake. In October 2013 an earthquake at a magnitude of 7.2 in Richter scale hit Philippines. In 2016 Myanmar suffered massive tremor. Earlier, on 26th December 2004 Indonesia and adjoining countries were severely affected by earthquake and tsunami. Earthquake could lead to change in earth's axis. Tilt in the earth's axis would lead to reception of more insulation by mid-latitude countries during summer. These countries have been experiencing extreme climatic conditions; hot summer and very cool winter.

Impact of polluted air on human health

Impact of heat stress on human metabolism is critical; people may suffer from allergies, high fever, dehydration, sunstroke etc in extreme cases. Atmospheric variables that may affect humans include heat, cold, wind, humidity, solar radiation, air pollution, air pressure, electro-magnetism and so on. Adverse weather condition and pollution would promote arthritis, respiratory ailments and allergies. Warm-blooded mammals have to keep their inner body temperature within a very narrow range (around 37ºC) or irreparable harm ensues. The body gains heat by its own metabolism; gains (or loses) heat from (or to) its surroundings by radiation, conduction and convection; and loses heat by evaporation (breathing and sweating). Heat stress is associated with various combinations of the following conditions: (1) high muscular activity; (2) high solar radiation, particularly in the tropics at high elevations; (3) high infrared radiation, e.g. near a blast furnace in a steel mill; (4) air temperature greater than body temperature (37ºC), producing a net gain in body heat from convection; (5) high humidity, reducing the rate of evaporation related cooling from the body; and (6) strong winds in combination with (4) and (5), increasing the convective heat gains of the body. The physiological mechanisms used to cope with heat stress are (1) dilating of blood vessels near the surface of the skin and increasing the heat exchange from the body to its surroundings; (2) increased sweating, resulting in evaporation related cooling; and (3) increased respiration. The voluntary mechanisms are (1) avoiding strenuous activity; (2) avoiding direct sunlight and strong infrared sources; (3) switching to lightweight clothing; (4) changing diet to reduce basal metabolic heat production; and (5) remaining in air-conditioned room (However, air conditioner would contribute to greenhouse gas emission). Humidex (humidity index) is derived from air temperature and humidity. For example, air temperature of 30ºC and above with relative humidity of 90 per cent and above, are extremely uncomfortable combination. Humidex graphs of different spot locations in different seasons are tools of interesting studies. Bioclimatology is an interesting research field that has many important practical applications for human comfort, agricultural yield, land use planning, forest management, building research, and so forth.

Conclusion

Financial loss or gain as a result of climate variability, change or extremes is aspect of climate economics. Economic researchers are concerned about risk analysis, discount rates, future generation welfare, and other climate related aspects of consideration. In 2013 convergence of upper air trough and low-pressure system pushed the monsoon line across northwest India well in advance of due date - the monsoon covered entire country about a month in advance of the normal date of July the 15th. Climate is changing gradually. The districts of Uttarakhand that experienced flood in 2013 were considered as areas of unpredictable/scanty rainfall 30 years ago. Kheri and adjoining districts of Uttar Pradesh are facing seasonal floods due to heavy rainfall in Nepal Himalaya; these districts are no more drought-prone, but flood prone. There is a need for revision of natural hazards map of India with respect to identification of flood prone and drought prone districts.

Cartography could serve the policy makers by creating maps and models showing potential areas to be affected by inundation due to sea level rise, flood-prone areas due to snow melt and catastrophic rain, drought prone areas due to excessive heating, cyclone prone areas, areas with unbearable sultry weather and so on. Land value revision and population migration trend could be projected with the help of maps and diagrams. Future planning would get some guideline for cognitive change in development pattern.

12

Morphomatric based Sub-watershed Prioritization using Spatial Information Technology: A case study of Upper part of Dwarakeswar

Jatisankar Bandyopadhyay, Lipika Khamaru, Kartic Bera and Nirupam Acharyya

Introduction:

A watershed is a hydrological unit which generates runoff by itself as a result of precipitation. Watershed degradation is the global problem, which is more serious in developing countries like India. West Bengal, India, being a part of the northern great Plains, a large number of watersheds can be delineated with different aerial coverage and most of them are in degraded condition that need to be managed properly. Watershed management implies prudent use of all the natural resources to ensure optimum and sustained productivity.

Geoinformatics technology has been successfully employed for identify scarcity and potential zone and also management (Bera et al. 2011).

The resource consideration for implementation of watershed management programs or various other reasons pertaining to administration or even political consideration may limit implementation to a few watersheds. Morphometric analysis of a watershed provides quantitative description of the drainage system which is an important aspect of the characterization of the watershed (Strahler, 1964). Even otherwise it is always better to start management measures from the highest priority watershed available. Watershed prioritization is the ranking of watershed according to the order in which they have to be taken up treatment. In this paper we have prioritized the watershed based on its morphometric parameter. Geo-morphological analysis of a watershed is usually used for evolving the regional hydrological models for resolving different hydrological difficulties of the ungauged watersheds in the absence of data accessibility conditions (Gajbhiye et. al.2014).

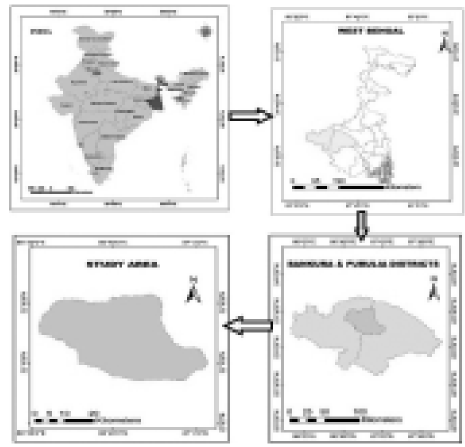
Objective:

In the purpose of better water resource management in the sub-watershed level the study aims to achieve the following objectives:

1. Identification of Dwarakeswar upper catchment area.
2. Delineation of sub watersheds of the area.
3. To study the physical parameter of the area like relief, drainage, climate, geology etc.
4. To classify the streams according to drainage order as suggested by Strahler.
5. To study the linear morphometric aspects.
6. To study the relief morphometric aspects of the study area
7. To study the areal morphometric aspects of the study area.

8. To analyse the land use land cover of the study area and analyse its relationship with the drainage pattern.
9. And finally to prepare sub-watershed prioritization map based on the above parameter.

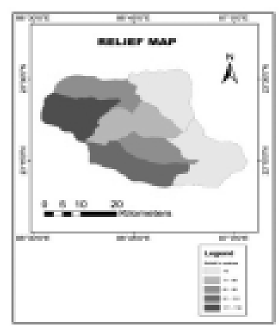
About the Study Area



Dwarakeswar River, also known as (dhalkisor) is a major river in the western part of West Bengal. The Dwarakeswar basin is one of the 26 river sub basins of the state and is under the Ganges-Bhagirathi system. The basin located between the latitudinal extension of 22º37’00"N and 23º33’0"N and longitudinal extension of 86º 31’0"E and 87º51’0"E. It occupies a total area of 4673sqkm. The river is about 220 km in length. It originates from Tilbani hill in Purulia district and

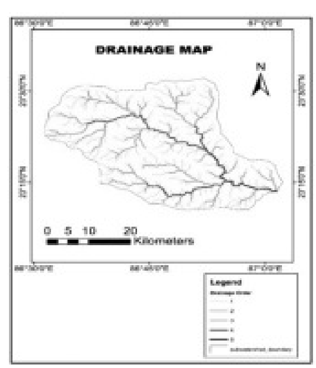
Passes through the three districts namely, Purulia, Bankura and Hoogly and releases ultimately into the Rupnarayan, a right bank tributary of the Bhagirathi- Hoogly in its lower reaches. The Gandheswari, Beko, Dudhbhariya, dangra ,futiyari, arkasa, Birai are some of the prominent tributaries of Dwarakeswar in the upper basin**.**

Relief



The relief map shows the relative relief of an area. It can be seen from the map below that sub watershed 1 and 7 that is the eastern part of the area shows a very low(below 70 m) relative relief while the western part shows mainly high elevated area where relative relief is very high(above 110 m). The middle area shows comparatively medium relative relief. However analysis of the map shows an undulated topography of the area.

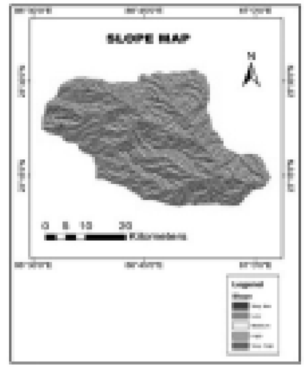
]**Drainage**



Dwarakeswar River is a major river in the western part of West Bengal. It originates from Tilbani hill in Purulia district and passes through the three districts namely, Purulia, Bankura and Hoogly and releases ultimately into the Rupnarayan. It flows from the northeast to southeast of the study area. In the study area it has formed a dendritic drainage pattern. We can see five stream orders prominently in the below drainage map below and 7 subwatersheds has been delineated based on these stream orders. The river in the study area is 80.250 km in length. Beko, Dudhbhariya, Dangra, Futiyari, Arkasa are some prominent tributaries of the river flowing through the study ar

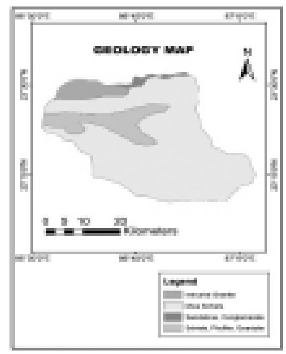
Slope

Slope is defined as the ratio between the difference between the elevation of two ground points and the distance between these two points. The slopes are varying in the area. Mainly the steep slopes are situated at the western part of the area and their direction is to the north and northwest. Mainly the medium slope covers the entire area. Very gentle slope or basically flat areas are very rare expressing that it is an undulated area.



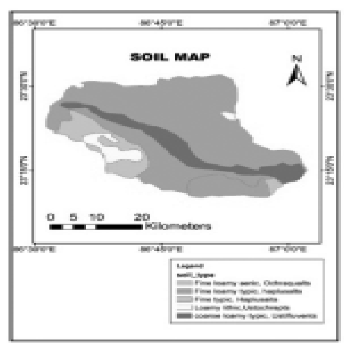
Geology

The geology of the study area is mainly comprises Archean and Dhawarian Rocks and is an extended portion of Chhotonagpur plateau. There are two shear zones; A – South Purulia shear zone that is WNW to ESE distributed tectonically. B – North Purulia shear zones. Apart from the whole districts, our study area mainly comprises of Granite, Gneiss, Migmatite, Mica schist, Amphibolites and Hornblende etc. And Intrusive Granites are also present.



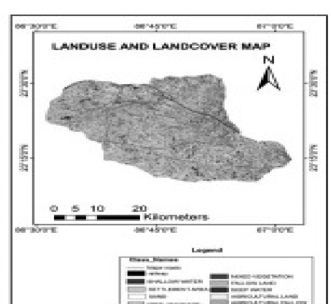
SOIL

Soil mapping helps to determine the rate of runoff, infiltration etc and thus helps in identifying the agricultural behavior of an area. The soil map of the study area reveals that the area is generally comprised of Sandy and loamy type of soil with very high to moderate draining capability. However cultivation is a prominent feature in this area depending on these soil types. After prolonged rainfall in the monsoon, when the soils have much moisture for cultivation “the shole” areas are cultivated once in the year. In the summer monsoon Gully erosion in these soil types are common.



Land use /Land cover

A land use land cover map has been prepared to show the relation between natural resources and anthropogenic activity of Dwarakeswar, upper catchment area using Remote sensing and GIS technology. The map shows that the land’s natural resources include the river, water bodies, mixed vegetation, open vegetation etc and depending upon this land cover a number of anthropogenic activities have been built up like the agricultural lands, settlement zone, roads, railway etc.



Climate

The climate of the district is tropical sub-humid with normal annual rainfall ranging from 110cm in the west to 140 cm in the east. The mean daily temperature ranges from minimum 12º c in the winter to 45º c in the summer. The variation in the number of rainydays and soil moisture limitations are common. Severe drought periods lasting for weeks affect the crop growth and yields during the Kharif season the main cropping season in the area.

Data and Methodology:

LANDSAT 5 TM satellite data and CARTOSAT DEM are collected from USGS, U.S.A and ISRO, INDIA official websites. The complete list of data and specification of the data are given below.

Table 1

Data Used

DATA	SOURCE	USED FOR
LANDSAT TM	USGS	Land use and land cover
CARTOSAT DEM	BHUBAN	DEM, Drainage, Contour, Slope
GEOLOGY MAP	GSI, KOLKATA	Geology
SOIL MAP	NBSS & LUP, KOLKATA	Soil

Morphometric Analysis

Watershed is a unit of particular runoff region; and runoff is the amount of total precipitation (Bera et al. 2013).The morphometric analysis is one of the significant geographical information system tools for prioritization of micro-watershed even without soil map and land use/land cover map. This is the most common approach which is used for basin analysis, morphometric associated with interpretation and analysis of ûuvially originated landforms. The drainage pattern refers to spatial relationship among streams or rivers, which may be influenced in their erosion by inequalities of slope; soils rock resistance, structure and geologic history of a region. The arrangement of the stream system of a drainage basin has been expressed quantitatively with some very crucial linear and aerial morphometric parameters such as Drainage density (Dd), Texture ratio(T), Stream frequency (Fu), Length of overland flow (Lo), Bifurcation ratio (Rb) ,Circularity Ratio (Rc) , Elongated ratio (Re), Form factor (Rf), Shape factor (Bs), Compactness coefficient (Cc). The relief parameters are relief ratio (Rh) and ruggedness number (Rn).

Table 2

Methods of Calculating Morphometric Parameter

	Morphometric parameter	Methods	Refferences
LINEAR	Stream order(u)	Hirerchial order Length	strahler,1964
	Stream length(Lu)	of the stream = Lu/	Horton, 1945
	Mean Stream length(Lsm)	Nu where, Lu= Stream length of order 'u' Nu= Total number of stream segments Of order 'u'	Horton, 1945

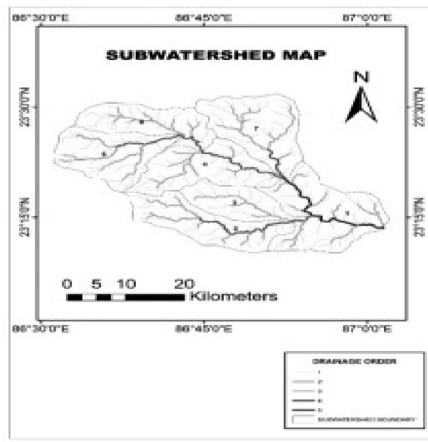
	Stream length ratio(RI)	RI=Lu/Lu-1; where Lu=Total stream length of order 'U', Lu1=Stream length of next lower order	Horton, 1945
	Bifurcation ratio(Rb)	Rb = Nu/ Nu+1; where, Nu=Total number of stream segment of order'u'; Nu+1= Number of segment of next higher order	Schumn, 1956
RELIEF	Basin relief(Bh)	Vertical distance between the lowest and highest points of watershed	Schumn, 1956
	Relief ratio(Rh)	Rh=Bh/Lb; Where, Bh= Basin relief;Lb=Basin length	Schumn, 1956
	Ruggedness no(Rn)	Rn = Bh × Dd Where, Bh =Basin relief; Dd= Drainage density	Schumn, 1956
AREAL	Drainage Density(Dd)	Dd = L/A where, L=Total length of streams;A=Area of watershed	Horton, 1945
	Stream frequency(N)	Df = N/A where, N=Total number of streams; A=Area of watershed	Horton, 1945
	Texture ratio(T)	T = N1/P where, N1= Total number of first order streams; P=Perimeter of watershed	Horton, 1945
	Form factor(Rf)	Rf=A/(Lb)2 ;where, A=Area of watershed, Lb=Basin length	Horton, 1932
	Circulatory ratio(Rc)	Rc=4ðA/P2 ;where, A= Area of watershed, ð=3.14, P=Perimeter of watershed	Miller,1953
	Elongation ratio(Re)	Re=2ˆ(A/ð)/Lb ;where, A= Area of watershed, ð=3.14, Lb=Basin length	Schumn, 1956
	Length of overland flow (Lof)	Lof = 1/2Dd where, Dd= Drainage density	Horton,1945
	Constant channel maintaenance©	C= 1/Dd, where Dd= Drainage density	Horton,1945

Prioritization Of Subwatershed

The drainage network of Dwarakeswar upper Beko watershed has been extracted from the CARTOSAT DEM. Then the drainage network has been divided upto subwatershed level. The various morphometric parameter namely linear, aerial and relief has been calculated in the Microsoft office excel based on the formulas in table 3. The prioritization was carried out by assigning ranks to the individual indicators and a compound value (Cp) was calculated.

Result And Discussion

Sub Water shed Delineation



Water sheds are those are as from which run off resulting from precipitation, flows past a single point into a large stream river, lake or an ocean. These are natural hydrologic entities that cover a specific a erialexten to fland from which rainwater flows to a defined gully, stream or river of a particular point. The drainage network helps in delineation of wate rshed for a particular river system. Water shed Atlas of India published All India Soil & Land Use Survey, Ministry of Agriculture and Co-operation, Govt. of India (1990) has been referred for delineation up to watershed level. Here the details of watershed have been measured up to sub watershed level over the drainage network as prepared from the CARTOSAT1 DEM measured. The sub watershed map and the table showing the area of each watershed are given.

Linear Morphometric Parameters

Linear parameters analysis includes:

Stream orders (Nu), stream length (Lu),

mean stream length (Lsm) and bifurcation ratio (Rb). The PARAMETERs have been discussed below in the table5.

Stream order (u): In any watershed study, the behavior of the ûow ûnding is very difficult; therefore, it is necessary to subdivide the watershed into sub-watersheds. It will be done according to stream order and area of the sub-watersheds. There are a number of methods of indicating stream orders for a stream network (Horton, 1945; Strahler, 1964).

Table 3: Area of sub watersheds

SUB-WATERSHED	AREA(sq km)
1	254.394
2	188.213
3	116.39
4	197.502
5	188.988
6	154.101
7	214.035

According to Strahler (1964), the smallest fingertip tributaries are designated as order 1. Where two first-order tributaries join, a tributary segment of order 2 is formed; where two of order 2 join, a segment of order 3 is formed; and so forth. The trunk stream through which all discharge of water and sediment passes is therefore the stream segment with highest order.

Stream number (Nu): Number of streams is also described as total counts of stream segments of different order separately and is inversely proportional to the stream order. Stream number is denoted by Nu. 330 stream segments were recognized in the upper Beko watershed, out of which 76.36% is a 1st order, 16.06% is a 2nd order, 4.85% is a 3rd order, 2.12% (6) is a 4th order, and 0.30% is a 5th order.

Total stream length (Lu): Total stream length is calculated as measuring the length of all ordered seasonal streams within the catchment area of the watershed and is denoted by Lu. According to Horton's second law (1945), the stream length characteristics of the sub-basins validate the ''laws of stream length'', which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio (Horton 1945). Generally, the total length of stream segments decreases with stream order.

Mean stream length (Lsm): Mean stream length is the ratio of total stream length of particular order to the total number of same ordered stream and is denoted by Lsm.

Bifurcation ratio (Rb): The term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order (Schumn, 1956). Bifurcation ratios characteristically range between 3.0 and 5.0 for basins in which the geologic structures do not distort the drainage pattern (Strahler, 1964). The lower bifurcation ratio values are characteristics of the watershed, which has suffered less structural disturbances and the drainage pattern has not been distorted by the structural disturbances. High value of Rb indicates the severe over land ûow and low recharge for the sub-watershed. In this study, the value of mean bifurcation ratio varies between 2.27 and 3.37 that indicate the area's drainage pattern is less affected by the structural disturbances. The bifurcation ratio is also indicative of shape of the basin also. An elongated basin is likely to have a high Rb, whereas a circular basin is likely to have low Rb.

Stream length ratio (RL): The stream length ratio (RL) is the ratio of the mean length of the stream of a given order (Lu) to the mean length of the streams of the next smaller order (Lu-1).

Table 4:
Linear Parameters

SWS	PARAMETRE	I Order	II Order	III order	IV Order	V order	Mean Rb
1	NUMBER OF SEGMENTS(Nu)	51	10	2	1	1	
	STREAM LENGTH(Lu)	88.704	45.92	9.389	1.669	27.577	
	BIFURCATION RATIO(Rb)		5.1	5	2	1	3.275
	MEAN STREAM LENGTH(Lsm)	1.739294	4.592	4.6945	1.669	27.577	
	STREAM LENGTH RATIO(RL)		0.517677	0.204464	0.177761	16.52307	
2	NUMBER OF SEGMENTS(Nu)	42	8	2	1	0	
	STREAM LENGTH(Lu)	61.569	14.598	25.915	21.843	0	
	BIFURCATION RATIO(Rb)		5.25	4	2	0	3.75
	MEAN STREAM LENGTH(Lsm)	1.465929	1.82475	12.9575	21.843	0	

	STREAM LENGTH RATIO(RL)		0.2371	1.775243	0.842871	0	
3	NUMBER OF SEGMENTS(Nu)	20	3	1	1	0	
	STREAM LENGTH(Lu)	40.677	18.226	11.125	3.693	0	
	BIFURCATION RATIO(Rb)		6.666667	3	1	0	3.555556
	MEAN STREAM LENGTH(Lsm)	2.03385	6.075333	11.125	3.693	0	
	STREAM LENGTH RATIO(RL)		0.448066	0.610392	0.331955	0	
4	NUMBER OF SEGMENTS(Nu)	40	8	2	1	0	
	STREAM LENGTH(Lu)	73.77	25.72	14.85	17.69	0	
	BIFURCATION RATIO(Rb)		5	4	2	0	3.666667
	MEAN STREAM LENGTH(Lsm)	1.84425	3.215	7.425	17.69	0	
	STREAM LENGTH RATIO(RL)		0.348651	0.577372	1.191246	0	
5	NUMBER OF SEGMENTS(Nu)	36	7	4	1	0	
	STREAM LENGTH(Lu)	63.551	28.538	20.988	12.979	0	
	BIFURCATION RATIO(Rb)		5.142857	1.75	4	0	3.630952
	MEAN STREAM LENGTH(Lsm)	1.765306	4.076857	5.247	12.979	0	
	STREAM LENGTH RATIO(RL)		0.449057	0.73544	0.618401	0	
6	NUMBER OF SEGMENTS(Nu)	28	9	3	1	0	
	STREAM LENGTH(Lu)	54.683	19.44	16.49	7.739	0	
	BIFURCATION RATIO(Rb)		3.111111	3	3	0	3.037037
	MEAN STREAM LENGTH(Lsm)	1.952964	2.16	5.496667	7.739	0	
	STREAM LENGTH RATIO(RL)		0.355504	0.848251	0.469315	0	
7	NUMBER OF SEGMENTS(Nu)	35	8	2	1	1	
	STREAM LENGTH(Lu)	73.15	32.03	17.49	10.17	0.09	
	BIFURCATION RATIO(Rb)		4.375	4	2	1	2.8438
	MEAN STREAM LENGTH(Lsm)	2.09	4.00375	8.745	10.17	0.09	
	STREAM LENGTH RATIO(RL)		0.437867	0.546051	0.581475	0.00885	

Relief Parameters

Relief parameters analysis includes the relief ratio and the ruggedness number. The following parameters have been discussed quantitatively for each sub watershed in the table no 6.

Drainage density (Dd): Drainage density is inûuenced by various factors, among which resistance to erosion of rocks, inûltration capacity of the land and climatic conditions rank high (Verstappen 1983). According to Langbein (1947), the signiûcance of drainage density is a low drainage density is more likely represent the regions with resistant like area with permeable subsoil under dense vegetative cover, and where relief is low. In contrast, high drainage density is favoured in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief. In the watershed, drainage density of seven sub-watersheds varies from 0.62 to 0.68 and is shown in Table 6.

Basin relief (Bh): The basin relief is nothing but the difference between highest and lowest elevation for a particular river basin. It is mainly representative of the underlying rock types and the slope present in the area. Here the relief ranges from 0.07 to 0.18, indicating a medium relief that is medium to gentle slope over the whole river basin.

Relief ratio (Rh): It is the basin relief divided by the length of the basin. The values of relief ratio are given in Table 4 which ranges from 0.0029 to 0.0084. It is noticed that the high values of Rh indicate steepness of the basin and is an indicator of intensity of erosion process operating on the slopes of the watershed.

Ruggedness number (Rn): It is the product of the basin relief and the drainage density where both the parameters are in same unit. An extreme high value of ruggedness number occurs when both variables are large and slope is steep (Strahler, 1956). The value of ruggedness number in the present basins varies from 0.04 to 0.12 indicating less run off in most of the sub watersheds.

Table 5

Relief aspects

SWS	SWS1	SWS2	SWS3	SWS4	SWS5	SWS6	SWS7
TOTAL STREAM OF ALL ORDER	65	53	25	51	48	41	47
TOTAL STREAM ALL LENGTH OF ORDER(Km)	173.259	123.925	73.721	132.03	126.056	98.352	132.93
AREA OF BASIN (SQ KM)	254.394	188.213	116.39	197.502	188.988	154.101	214.035
CONTOUR(M)	30	50	40	60	90	170	60
	100	200	130	140	270	90	140
DRAINAGE DENSITY(Dd)	0.6810656	0.65843	0.633396	0.6685	0.667005	0.638231	0.621067
BASIN LENGTH(Lb)	24	28.88	25.82	25.5	21.38	23.32	24.21
BASIN RELIEF(Bh)	0.07	0.15	0.09	0.08	0.18	0.08	0.08
RELIEF RATIO(Rh)	0.0029167	0.005194	0.003486	0.003137	0.008419	0.003431	0.003304
RUGGEDNESS NUMBER (Rn)	0.0476746	0.098764	0.057006	0.05348	0.120061	0.051058	0.049685

Aerial Aspects

In morphometric analysis of a river system, the maximum numbers of parameters are analysed for the areal parameters. The parameters include stream frequency (Fs), texture ratio (T), form factor (Rf), length of overland flow (Lof), constant channel maintenance(C) (aerial parameters). The result is discussed in the table 7.

***Stream frequency (Fs)**:* Stream frequency or channel frequency (Fs) is the total number of stream segments of all orders per unit area (Horton, 1932). Drainage frequency or channel frequency is directly related to stream population per unit area of the watershed (Horton 1932). It indicates the close correlation with drainage density value of the sub-watershed. The calculated value of stream frequency (Fs) ranges from 0.21 to 0.29 in upper Beko watershed, which can be attributed to moderate relief and high infiltration capacity.

Texture ratio (T): Horton (1945) defined drainage texture is the total number of stream segments of all order in a basin per perimeter of the basin. It is important to geomorphology which means that the relative spacing of drainage lines. Drainage texture is on the underlying lithology, infiltration capacity and relief aspect of the terrain. Smith (1950) has classified drainage texture into 5 different textures i.e., very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8).In the present basin texture ratio varies from 0.22 to 0.75 indicating an undulated topography throughout the basin.

Form factor (Rf): Horton (1932) outlined form factor as a dimensionless ratio of the area of the basin to the square of the length of the basin. Basin shape can be indexed by simple dimensionless ratios of the basic measurements of area, perimeter and length (Singh, 1998).The form factor calculated for all 7 sub watersheds are given in Table 7. Most of the researchers have suggested that the value of form factor is less than 0.7854 for perfectly circular basin (Rekha et al. 2011; Gajbhiye et al. 2014). In watershed, the smaller value of the form factor shows maximum elongation of the basin. The high value of form factor shows high peak in short duration and vice versa. In this study, it was found that the value of form factor varies 0.17(sw 3) to 0.44(sw 1), which indicates that the sub watersheds are basically elongated or nearly oval in the basin.

Circulatory ratio (Rc): Miller (1953) defined a dimensionless circulatory ratio (Rc) as the ratio between the area of the basin and the area of the circle having the same perimeter as that of the basin. The more the value of the Rc , the more the shape will be circular. The circulatory ratio calculated for the sub watersheds show that the value ranges from 0.38 to 0.61 indicating that the entire sub watershed is nearly elongated.

Elongation ratio (RE): Generally, the values of elongation ratio (Re) generally lie between 0.6 and 1.0 which is associated with a wide variety of climate and geological properties. The values close to 1.0 are typical of regions of very low relief, whereas that of 0.6 to 0.8 are followed with high relief and steep ground slope (Strahler, 1964). In this watershed, elongation ratio varies between 0.47 (SWS-3) and 0.75 (SWS-1), whereas the feature of watershed lies oval cum elongated in nature. However, sub-watersheds are elongated with moderate slope with relatively high to moderate relief

Length of overland ûow (LOF): The length of overland ûow (Lg) approximately equals half the reciprocal of the drainage density (Horton, 1945). This factor relates inversely to the average slope of the channel and is quite synonymous with the length of sheet ûow. The values of length of overland ûow in sub-watersheds vary from 0.73 (SWS-1) to 0.81 (SWS-7). More the value represents long time of flow in the basin.

Constant of channel maintenance (C): This parameter indicates the requirement of units of watershed surface to bear one unit of channel length. Schumn (1956) has used the inverse of the drainage density having the dimension of length as a property termed constant of channel maintenance. The drainage basins having higher values of this parameter, there will be lower value of drainage density. The constant(C) is expressed in km2/km and depends not only upon the rock type, climatic region, relief, vegetation cover but also upon duration of erosion and climatic history. Higher value of constant channel Maintenance reveals strong control of lithology with a surface of high permeability. Alluvial basin of plain and piedmont zone shows highest value, as the permeability in this zone is high. In the present basin the value ranges from 1.46 to 1.61.

Table 6

Areal aspects

SWS	SWS1	SWS2	SWS3	SWS4	SWS5	SWS6	SWS7
AREA OF WATERSHED (sqkm)	254.394	188.213	116.39	197.502	188.988	154.101	214.035
PERIMETRE OF WATERSHED(m)	84.76	73.4	52.68	70.59	62.56	70.97	66.53
BASIN LENGTH(Lb)	24	28.88	25.82	25.5	21.38	23.32	24.21
DRAINAGE DENSITY(Dd)	0.6810656	0.65843	0.633396	0.6685	0.667005	0.638231	0.621067
STREAM FREQUENCY(Fs)	0.2555	0.2815	0.2148	0.2582	0.254	0.2661	0.2195
TEXTURE RATIO(T)	0.6016989	0.223151	0.379651	0.566653	0.575448	0.394533	0.766571
FORM FACTOR(Rf)	0.4416563	0.22566	0.174583	0.303732	0.413446	0.283366	0.36517
CIRCULATORY RATIO(Rc)	0.4447486	0.43878	0.526761	0.497823	0.606499	0.384278	0.60735
ELONGATION RATIO(Re)	0.7500796	0.536158	0.471592	0.622029	0.725729	0.600813	0.682045
LENGTH OF OVERLAND FLOW(Lof)	0.7341437	0.759383	0.789395	0.747944	0.749619	0.783416	0.805067
CONSTANT CHANNEL MAINTAINANCE(c)	1.4682874	1.518765	1.57879	1.495887	1.499238	1.566831	1.610133

Prioritization Of Subwatershed

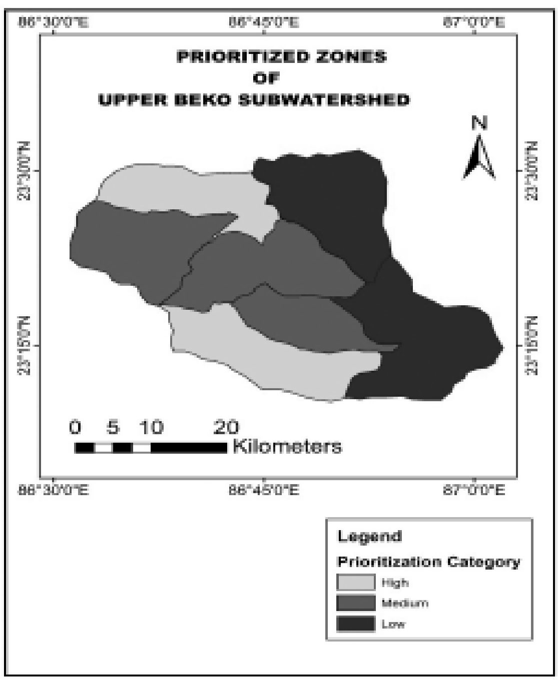
Drainage pattern of watershed refers to geospatial relationship among the streams or rivers and is associated with slope, soil type and rock resistance, structural and geological status of the basin. The study emphasizes the prioritization of the sub-watersheds on the basis of morphometric analysis. The parameters were calculated from area, perimeter, basin length, drainage density, and stream length but bifurcation ratio was calculated from the number of streams in particular micro-watershed. Bifurcation ratio being the one of the very important parameter plays significant role in prioritization of micro-watershed. All these parameters were computed using ARC/INFO and MS Excel Software. In this study, linear parameters are bifurcation ratio, drainage density, stream frequency, and the aerial parameters are circularity ratio, form factor, elongation ratio texture ratio, length of overland ûow, constant channel maintenance and the relief parameters are mainly the relief ratio and the ruggedness number. Hence, the linear and relief parameters have a direct relationship with erodibility and the aerial parameters have inverse relationship with erodibility, The highest value of the linear and relief parameters was ranked as 1 and next highest value was ranked 2 and so on, as well as the lowest value of aerial or shape factor was ranked 1 and next lowest value was ranked 2 and so on (Table: 8). Thus after ranking each parameter from rank 1 to 7, a compound value has been assigned to rank each of the sub watersheds by simply averaging the values of all the parameters for each watershed. . However, the ûnal priority has been assigned as the least rating value was assigned as highest priority; next higher value was assigned second priority and so on. The maximum and minimum prioritized score of sub-watersheds is 2.72 (sw2) and 5.18 (sw 7) respectively. The sub-watersheds have been categorized into three classes as high (2.72-3.18), medium (3.19-4.36) and low (4.37-5.18) priority on the basis of span of Cp value.

Table 7

Ranking of parameters

SWS	Rb	Dd	Fs	Rh	Rn	T	Rc	Rf	Re	Lof	C	Compound parametre	Final priority
1	3	1	4	7	7	2	3	7	7	7	6	4.909090909	VI
2	1	4	1	2	2	7	2	2	2	4	3	2.727272727	I
3	4	6	7	3	3	6	5	1	1	2	4	3.818181818	III
4	6	2	3	6	4	4	4	4	4	6	5	4.363636364	V
5	5	3	5	1	1	3	6	6	6	5	1	3.818181818	IV
6	2	5	2	4	5	5	1	3	3	3	2	3.181818182	II
7	7	7	6	5	6	1	7	5	5	1	7	5.181818182	VII

Figure 9: Prioritized zones map of the study area



Conclusion

Drainage morphometry of a sub-watershed reflects hydro-geologic maturity of that river. Satellite remote sensing has an ability of obtaining the synoptic view of a large area at one time, which is very useful in analyzing the drainage morphometry. GIS has proved to be an efficient tool in drainage delineation and this drainage has been used in the present study. The morphometric analysis of different sub-watersheds shows their relative characteristics with respect to hydrologic response of the catchment. The morphometric analysis of seven sub-watersheds exhibits the dendritic drainage pattern and the variation in stream ratio might be due to changes in slope as well as topographic features of the study region. Higher runoff may also affect the sediment yield. The variation in bifurcation ratio among the sub-watersheds is described to the difference in topography and geometric development. The stream frequencies for all sub-watersheds of the study exhibit positive correlation with the drainage density values indicating the increase in stream population with respect to increase in drainage density. Drainage density is very coarse to coarse texture. Elongation ratio shows that speciûc sub-watershed possesses nearly circular shape, while the remaining marks elongated pattern. Thus by analysing the morphometry of the drainage system the present study becomes valuable for erosion control, watershed management, land and water resources planning and future prospective related to runoff study. In our study the SWS 2 and 6 are of very high priority and 1 and 7 are of low priority. This priority class may be taken for conservation measures by engineers and the decision makers who planned for developments and management of natural resources.

GCP COLLECTION

SOIL DEGRADATION

GULLY EROSION AFTER RAINFALL

DWARAKESWAR RIVER

Referrences:

Bera K and Bandyopadhyay J, (2011). Management of Ground Water Using Geoinformatics in Dwarkeswar Watershed of Puruliya District, *Indian Cartographer, 31*, pp 265-270.

Bera K and Bandyopadhyay J, (2013) Prioritization of Watershed using Morphometric Analysis through Geoinformatics technology: A case study of Dungra subwatershed, West Bengal, India, Int. *Journal of Advances in Remote Sensing and GIS, Vol. 2, No. 1*.

Gajbhiye S, Mishra SK, Pandey A (2014) Prioritizing erosion-prone area through morphometric analysis: an RS and GIS perspective. *Appl Water Sci 4(1):*51–61.

Rekha, 2011. Morphometric Analysis and Micro-watershed Prioritization of Peruvanthanam Subwatershed, the Manimala River Basin, Kerala, South India *Environmental Research, Engineering and Management, 3(57),* pp 6–14. 12.

Strahler, A. N. 1964. Quantitative geomorphology of drainage basins and channel networks, section 4II, In: *Handbook of Applied Hydrology*, edited by V.T. Chow, McGraw Hill, p. 439.

13

Impact of Soil Erosion On Agricultural Land : A Case Study

C.P. Singh, Sangeeta Yadav and S .P.Singh

Introduction

Soil erosion in one of the most significant degradation processes which is not being widely perceived but gradually unfolding a serious threat to human well being. It has direct impact on the development of human society and is one of the important problems human being face. It has assumed dangerous dimensions in recent years with the fast striking land base and declining agricultural productivity on one hand and the increasing demand for food arising from the accelerated growth of population on the other. Thus posing a serious threat to the food security, although a problem of soil erosion is found all over the world, but India it is about where 53% of the geographical area is subjected to environmental degradation.

Deforestation, overgrazing, increased human activities, indiscriminate drainage practices and faulty method of agriculture on moderate and steep slope gradient have accelerated the rate of soil erosion in major parts of India. It becomes more serious where man has carelessly reshaped of deshaped topography for his benefits and more particularly for agricultural activities. Among the all factors influencing soil erosion slope gradient and relief are the prime geomorphic attributes which determine the uses of land for various purposes. Faulty agricultural practices lead to soil erosion causing loss of nutrients, thus affecting the crop productivity. Keeping this fact in view an attempt will be made to know the impact of soil erosion an agricultural land of Palamu Upland and its causative factors. In the present context, the techniques of applied geomorphology has been adopted to analyses the severity of the problem. Although a number of studies have been made, yet most of these are sketchy and spotty Rai etal 1981, Yadav 1984, Margan 1985, Valdiga 1987, and Yadav 1984 ,Singh 2002 ,Sheng Li et.al2010 , Wang Chunmei 2014, Eshghizadeh , M et.al 2016 .Accelereted soil eroision is a problem of serious magnitude with a multitude of determental impact in various tropical & sub - tropical countries .lately, attempts have been made to qantify the extend of soil erosion by running water on various categories of land uses such as agricultural land ,forest ,Posture and baren land.El –Swaify and Dangler (1982) have crtically examine the impact of rain for all eroision in tropics They have stressed on qantitative understanding of causative parameter in order to ensure conservation effective land use planning and utilization in the tropics recentely , remote sensing is considered one of the best tool for measuring the extend and magnitutde of soil erosion. Rai et al, (1981)Has studied six selected slope of profile of hills around Sillong to obtain the relationship between slope land use and intensity of erosion . Yadav(1984),using ariel photographs, has demarcated some patches of Vindhyan uplands into severe, moderate and low intensity soil erosion categories .Morgan (1985) has made very interesting filed study, selecting seven sights in United Kingdom covering different soil type in land use condition of cerials, woodlands, grasslands, and bare ground to examine the effects of storms on soil losses . Valdiya (1987) has measured the volume of sedmients carried by streams and run- off water in an experimental patches of 50m x 50m in land use conditions of forest ,grass , milet and there fellow land and observe a successive increase .Singh(2002) has studied the severity of soil erosion problems in the Vindhyan Plateau. In the present paper, in order to analysis the severity of soil erosion, impact of geomorphic attributes on agricultural land has been evaluated.

About the study Area

The study area (Garhwa and its Adjacent Area) lies between latitude 24^0 03' 15" N to 24^0 35' 05" N and longitudes 83^0 23' 08" E to 83^0 58' 10" E and covering an area of about 1414.50 km^2. It's situated mostly in Palamu Upland and western margin of Jharkhand State. The area is surrounded by river Son in the north, North Koyal River in the east, and Kanhar River in the south west.The elevation of the area, in general decreases from south to north and varies from 127 m to 535 m. Geologically the area is characterized by four major group of rocks i.e. Archeaons or Basement super group, Bijawar, Vindhyan, Gondvana (Lower Gondvana semri group). The soil are red sandy, red yellow and sandy clay loam in texture. Its enjoys tropical monsoon type climate and has a mean annual rainfall of 123 cm and mean annual temperatures of 29.68^0c.

Methodology and Materials

In the present context the techniques of applied geomorphology have been adapted to evaluates the severity of soil erosion. Soil erosion is not the result of one but several factors such as slope gradient, relief, surface run-off, rugged terrien's specific gravity of soil particles, vegetation cover, land use pattern , climate etc which in combination accelerate the soil erosion process, Among these, slope gradient, relative relief, vegetation cover and land use pattern have been taken into account to assess the severity of soil erosion in the present study. Land use including vegetation cover has been mapped at village level taking secondary information. To get a comprehensive picture of land degradation in terms of soil erosion, the superimposition of maps depicting slope relative relief, arable land and forest area has been made (Fig. 3, 4, 5). Further 13 sample villages from different physiographic units have been studied with the help of field observations to assess the rate of soil erosion (Fig.5). The above variable has been analyzed in sequel.

OBJECTIVES

The main objectives of the present study is to examine the impact of soil erosion on agricultural land of Garhwa and its Adjacent Area and also its causative factors.

Finding & Discussion

Slope

The average slope of the area varies from below 1^0 to over 14^0. The general inclination of slope increases from north to south in the study area. About 76.55 percent of the total area lies between the slope categories of 2^0 - 10^0 (gentle to moderate). Moderately steep slope (over 10^0) covers rather a small area of 9.98 percent. Level slope (below 2^0) has 24.41 percent areal coverage and mostly found in south west part of the area (Namatola, Kururitola etc) of the nature of tending in these parts is generally flat .Slope categories ie. Gentle slope (2^0-6^0) has 50.42 percent areal coverage. Moderate slope (6^0-10^0) having 16.15 percent areal coverage is maximum found in the dissected land, water divide and upper margin of the area (Table 1) Moderately slope (over 10^0) embraces about 9.98 percent of the study-area. It covers the area located near the scarps and dissected uplands where the altitude is quite high.

Table 1

Arial Distribution of slope

Slope Category (In Degree)	Area (km^2)	Cumulative Area (km^2)	Area (Percent)	Cumulative Area (Percent)	Major Slope Type
Less than 2^0	589	2412	24.41	100.00	Level
2^0 To 4^0	784	1823	35.51	76.65	Level
4^0 To 6^0	408	1039	16.91	43.04	Gentle
6^0 To 8^0	205	631	8.49	26.13	Gentle
8^0 To 10^0	185	426	7.66	17.64	Moderate
10^0 To 12^0	119	241	4.93	9.98	Moderate
12^0 To 14^0	67	122	2.77	5.05	Moderate Steep
More than 14^0	55	55	2.28	2.28	Moderate Steep
Total			100.00		

Relative Relief

Relative relief of the area has been found to vary from 11m to 245 m, which is arbitrarily grouped in five classes(Fig.3). Extremely low relative (below 25m) is found over 978 km^2 or 40.54 percent of the study region. Low (25m-50m) and moderate (50m-100m) relief are embraces 627 km^2 (23.99%), and 565 km^2 (23.42%) respectively, Moderately high (100m-200m) and high (over 200m) relative relief account for 9.43 percent and 0.49 percent of the study-area. Table-2 Moderate, moderately high and high relative are the found upper part of the pleatues, dissected upland, scarp, gorges steep slope of valleys and generally found in north and middle part of the region.

TABLE 2

Spatial Distribution Of Relative Relief

Relative Relief	Area (km^2)	Area (Percent)	Grid Frequency	Grid Frequency (Percent)	Symbol
Less than 25	978	40.54	1030	38.70	Rel
25-50	627	25.99	694	26.08	Rl
50-100	565	23.42	606	22.77	Rm
100-200	230	9.53	288	10.82	Rmh
More than 200	12	0.49	43	1.61	Rh
Total	2412	100.00	2661	100.00	

Present Land Use and Status Of Forest Cover

Evidences show that land use pattern influences the rate of soil erosion to great extent .By and large the study area is a plateau area in places clad with forest. After the urban-industrial development, there has been a greater use of land for construction such as roads, power plants and industries, besides settlements and cultivation, thereby producing significant changes in the land use pattern of the study area. Table 3 depicts land use of the study area for the period (1995-06). According to the statistics of revenue department 46.83 percent of the area was covered with forest in 2005-06 which is quite low from the standard land down for hilly and plateau area. According to the National Forest Policy of 1952, there has been a increase of about 1.13 percent in the forested area during 1995-2005 (Table 3). At block level, Nagar Uttari, chiniga has registered a maximum decline of 13447.17 ha and 11715.73 ha during this period. It may be attributed here that it is the most industrialized and urbanized block.

Table 3

Land use changes during 1995 -2006

Land Use	1995-96(ha.)	(%)	2005-06(ha.)	(%)	Growth (1995-2006
Arable Land	129715.48	28.11	131185.27	23.22	+1.13
Forest	159899.36	34.66	264539.03	46.83	+65.25
Cultivable Waste Land	40514.69	8.78	40787.96	7.24	+0.67
Area not Available for Cultivation	131186.19	28.45	128266.94	22.71	-2.22
Total	461315.72	100.00	564779.20	100.00	+20.50

Source: Land records , Garhwa

Table 4

Block wise Land Use Pattern (1995 – 06)

S.N.	Blocks	Arable Land			Forest Area			Cultivable Waste Land			Area not Available for Cultivation		
		1995-96	2005-06	Growth	1995-96	2005-06	Growth	1995-96	2005-06	Growth	1995-96	2005-06	Growth
1	Bhavanathpur	24254.5	23535.47	-2.96	28144.73	27188.43	-3.39	943.45	877.52	-6.98	4219.8	3949.2	-6.41
2	Machhiyav	2015.46	2314	14.81	10431.25	9341.11	-10.44	17417.5	16122.35	-7.43	10963.25	9845	-10.19
3	Ramana	3415.75	3617.43	5.9	3944.15	3756.11	-4.76	3523	3733.53	5.97	54473.1	52451	-3.71
4	Garhwa	21786.45	23576.41	8.21	4854	4254.75	-12.34	763.49	817.45	7.06	3311.26	3117.11	-5.86
5	Meral	24151	27531.45	13.99	1515	1487.45	-1.81	758.95	887.5	16.93	13795.43	12845.79	-6.88
6	Nagar Utari	19243.45	17231.33	-10.45	13447.17	12384.12	-7.9	1457.15	1575.16	8.09	2316.51	2417.73	4.36
7	Dhurki	13157	12757	-3.04	13411.51	13211.89	-1.48	3457.85	3125.75	-9.6	7609.41	8115.11	6.64
8	Kharaula	12157.75	12357.54	1.64	12995.17	11751.45	-9.57	2578.97	2875.45	11.49	7622.11	7877.45	3.34
9	Dnadi	12451.45	12115	-2.7	13511.75	12545.75	-7.14	2451.75	2445.75	-0.13	17159.05	16851.05	-1.79
10	Chiniya	12751.55	118551.8	-7.05	12345	11715.73	-6.61	1751	1785.75	19.84	6402.6	6645.75	3.79
11	Bhandariya	11515	10951.65	-4.89	15115.75	14975.85	-0.92	5411.58	6541.75	20.88	3313.67	4151.75	25.29
	Total	159899	264539	68.09	129715	122613	-5.47	40514.7	40788	0.67	131186	128267	-2.22

Source: Record of the block , Garhwa

The share of cultivated land accounted for 23.22 percent in the 2005-06. The spatial distribution of maximum cultivated land is mainly concentrated in three parts of the study area, i.e. north eastern part, parallel belt of north Koyel River and southeastern part. At block level cultivated area has increases and decreases i.e. maximum area increased in garhawa block (8.21 %) which are responsible factor population growth and better irrigational facilities. In Nagar Uttari block has maximum registered decreased area (10.45%). It may be attributed that cultivated land occupied in residential , poultry, fisheries, and Piggery small industries (Table 4).

Further, Table 5 depicts the land use pattern of selected villages for 1995 to 2005 and the changes over the same period. In the process of development, the forests in the some areas starting depleting. It has been observed that the area under forest in sample villages, i.e. Kandava, Kusumahi, Chamakali has declined by 3.51 percent, 8.36 percent and 6.41 percent respectively. But in Navadih, Shivpur, Benkatwa , Pratapur, Kalyanpur, and Arangi, the area under forest has been increase by 4.49% 6.14%, 14.26% 8.40%, and 2.67 percent respectively. The Maximum decreased forested area has been recorded in village Kandava (8.36%) as there has been a significant increase in area cultivation (31.01%). The acreage under arable land has declined in the most of the villages (particularly in Nawadih, Hariharpur, Shivpur and Arangi) during 1995-2005. The maximum declined in agricultural land has been recorded in Nawadih (19.06%) Hariharpur (13.29%) and Shivpur (9.08%) during 1995-2005. The villages of Vishunpur, Ranitola, Kandava, Kusumahi and Benkatwa have experienced increase in agricultural land . Maximum percentage increase of in the agricultural land has been marked in Vishunpur (31.22%) Kandava (31.01%) Kusuhmahi (32.43%) and Benkatwa (38.62%) villages during 1995-05.

Table 5

Distribution of Arable Land and Forest Area in Selected Villages of Study Area (1995-06)

S.N.	Selected Village	Area of Village (ha.)	Slope (Degree)	Relative Relief (M)	Drainage Density (km/km^2)	Agricultural Land (%)		Growth(%)	Forest Area (%)		Growth (%)	Soil Erosion Intensity
						95-96	05-06		95-96	05-06		
1	2	3	4	5	6	7	8	9	10	11	12	13
1	Navadih	483.35	8-9	40-60	4-5	8.34	6.75	-19.06	77.79	81.29	4.49	Low
2	Hariharpur	1533.5	10	60-80	3-4	15.43	17.48	-13.29	64.23	65.0	1.19	Low
3	Shivpur	335.45	8-9	40-60	3-4	45.64	49.79	-9.09	31.45	33.15	6.14	High
4	Vishunpur	455	8-9	120-140	4-5	52.43	68.80	31.22	27.45	28.15	2.55	Moderate
5	Ranitoli	228.64	11	140-160	3-4	11.33	14.37	26.83	58.15	59.14	1.70	Low
6	Bana	93	7	60	3-4	54.13	59.37	9.70	12.45	14.23	14.29	High
7	Pratappur	118.05	8-9	120	4-5	42.13	47.32	12.31	18.45	20.0	8.40	High
8	Klyanpur	138	9-10	70	4-5	39.48	45.48	15.19	28.45	27.15	-3.51	Moderate High
9	Kndava	224	5-6	80	4-5	35.47	46.47	31.01	39.45	36.15	-8.36	Moderate
10	Kusumahi	534	10	80	4-5	43.41	57.49	32.43	35.41	33.14	-6.41	Moderate
11	Chamakali	546	10	120	4-5	48.49	57.49	18.56	21.45	22.0	2.56	High
12	Benkatava	277	10	100-120	2-3	28.48	39.48	38.62	32.45	33.0	1.69	Moderate
13	Arangi	280	8-9	120	2-3	27.58	26.27	-4.02	37.45	38.45	2.67	Moderate

Source : Land records of the sample villages (2006)

Dimension of Erosion On Agricultural Land

After the independence the region exhaled a well adjusted balance between its people and the environment. But with the construction rail and road net ruthless cutting of forests along with re-shaping-and di-shaping topography have taken place in the name of development. It ultimately led to gradual increase in the volume of run-off which, in combination with moderate to moderately steep slopes and moderate to high relative relief, have accelerated e rate of soil erosion in various parts of the study area. Many of the deforested areas have been converted into arable land. But due to unscientific agricultural practices on sloping land, the soil is eroded by wind (pre-monsoon period) and rain water (monsoon period).

In general, the topography of the region is undulating and dissected and so is the spatial distribution of arable land (Fig.5). Consequently, with the onset of monsoon the process of soil erosion starts. Even at the micro level agricultural land is subjected to soil erosion owing to undulation of terrain and on adjustability with it. Although soil erosion is experienced in the entire area, its extent and severity is felt move on the agricultural land of the region.

Valdiya (1987) has also arrived at a similar conclusion on the basis of his study of a 50m x 50m patch .In plots with millet crop ,the water loss by run – off has been 26% while soil loss is measured as 31.6 tonnes /acre . The intensity of run-off and soil loss has been even more on bare fellow land and quit low in the case off forested and grass covered area . Similar findings have been reported by Yadav(1984) in the case of South Mirzapur ,on the basis of an interpretation of aerial photographs . Severity of soil erosion increases significantly with high relative relief , low vegetation cover and frequent drainage channels .

To assess the magnitude of soil erosion thirteen sample villages have been selected (Fig. 5). A composite qualitative picture of the agricultural land has been obtained on the basis of slope, relative relief , drainage texture and forest cover. Accordingly, these villages have been placed into four categories of Low, moderate ,moderately high and severe soil erosion intensities zones (Table 5). Low intensity of soil erosion is marked in the villages of Nawadih, Hariharpur, and Ranitola. It is because of gentle slope, low relative relief and course to moderately fine drainage texture. In these villages, the area under forest varies from 65 percent to 78 percent. The soil erosion of moderate intensity includes villages such as Vishunpur, Kandwa, Kusumahi, Benkatwa, and Arugee. These villages have moderate to moderately sleep slopes, moderately relief and frequent tributaries and distributaries. The area under forest in these villages from 28 percent to 40 percent whiles the areas under agricultural land accounts for 50 percent. It reflects that a considerable proportion of the area in these villages is barren which soil erosion is more proen sol erosion. Moderately high intensity of soil erosion has been well marked in only one village, namely Kalyanpur , This village has moderately steep slopes (Over 10^0) and moderately fine drainage texture (4-5 km/km^2). The higher rate of soil erosion has been assessed due to unscientific agricultural practices as this village possesses 49 to 57 percent of the areas under cultivation. It has been also confirmed during the course of field study.

Severe soil erosion intensity has been observed in the villages of Shivpur; Bana, Pratapur, and Chamkalle. These villages possess small properties of area under forests, varying 14 percent to 33 percent. Further, these are characterized by moderately steep slope (over 10 degree) and moderately fire drainage texture (4-5 km/km^2). It has been observed that owing to moderate drainage texture on the one land and how vegetation covers on the other. These villages suffer from severe soil erosion. All these villages have more than 50 percent of their total area under cultivation, which demonstrates that agriculture is the main-stay of their economy. However , due to irrational agricultural practices on steep slopes, the intensity of soil erosion is high. Simultaneously large scale grazing takes place in these villages as the number of cattle is quite high. The field investigation has revealed that the yield per ha has decreased due to loss of soil productively, caused by soil erosion.

The poor formers of these backward areas realize the magnitude of the problem including impact on their agricultural land, but their poor economy in no way permits either to check to soil erosion or to supplement soil fertility. The soil loss can be compensated by adding requisite doses of fertilizers . With the passes of time, awareness amoung the farmers towards saving their valuable land resources is increasing . The knowledge of causative parameters of soil erosion will provide base to the soil conservationist for estimating losses under a particular set of conditions. It will also help in reducing loss by imposing necessary modifications in agricultural Practices Or By Resorting To Other Management Measure.

Remedial Measures

- Formers are aware of soil loss but unless and until they fully understand the problem, efforts soil conservation con not succeed. Therefore, qualified soil conservation staff should arrange field exhibition to demonstrate soil loss by soil erosion.
- Audio-Visual aids may prove more effective in population where the literacy rate is very low.
- The severity of erosion by surface run-off on agricultural land may reduce by constructing terraces or benches parallel to or conformable to contour lines and providing reinforcement through walling with trees and scrubs, plant at 3m-7m interval.
- Encouragement and incentives should be given for constructing field bunds and bundhis this as well as forestation, wherever necessary.
- There should by restrictions on forest cuttings and as for as possible land under forest should not be brought under cultivation.
- In the rainy season, the field should not be kept fallow and to overcome nutrient deficiency
- An appropriate rotation of crops (especially by cultivation of leguminous crops) should be adopted. The legumes increase the soil holding capacity.
- Grazing on the fields should not be allowed.
- A comprehensive and integrated approach should be adopted for utilization, maintenance and conservation of soil, water and vegetation as these are inter dependent.
- The adoption of various soil conservation measures reduces by geomorphic attributes . Tillage and cropping practices , as will as land management practices , directly affect the overall soil erosion problems and solutions on a form . when crop roations are changing tillage practices are not enough to control erosion on a filed , a combination of approaches are more extreme measures might be necessary.

Conclusion

Thus, it has concluded that the severity of soil erosion has been assessed qualitatively which in turn reflects that the region is suffering from this problem badly and needs proper care. So, in author's view quantitative understanding of the problem is equally important for making the conservation programmed a success. Detail information could help be decision makers to better target of soil erosion in different scales and to design the best management practices for a given region.

References

Dani , D.D., V. D. Arya and S . Pande (1982), Landuse and erosion intensity in a Himalayan Watershed : An illustration from Ramganga catchment , *Himalayan Research and Development , Vol .1(2nd),*pp.184-88.

El – Swaify and E.W.Dangler(1982) , SoilErosion and Conservation in the Tropics , *American Society of Agronomy and Soil Science of America ,Madison* , pp .1-25.

Jha ,C.S.(1990) , Landuse and vegetation analysis of dry tropical forest region , Unpublished Ph.D Thesis ,in Boatany ,Submitted to Banaras Hindu University.

Morgan, R.P.C.(1985),Soil erosion measurement and soil conservation research in cultivated areas of the U K .,*Geographical Journal, Vol.151(1*),pp 11-20.

Prasad ,R (1981),Soil Erosion in the lower catchment of Chambal River *, Geographical Review of India ,Vol .43*,pp. 365-71.

Rai ,R . K et al (1981), Hilly Slope, landuse and soil erosion around Shillong (Meghalaya), *Geographical Review of India, Vol.43* , pp, 359-64.

Singh , C.P.(2002),*Applied Geomorphology : A Study* , B R P C New Delhi , pp 200-212

Valdiya ,K.S.(1987), *Environmental Geology : IndianContext* ,Tata McGrawHill Publishing Company Limited ,New Delhi , pp .186-89 .

Yadav, R.S.(1984), Environmental problems and eco-development sub-regions in South Mirzapur, *The National Geographical Journal of India ,Vol.30(4),* pp.259-68.

Sheng Li et.al(2010) *The impact of land useon the risk of soil erosion on agricultural land Canada* ,Published on DVD Brisben Australia page 114-117 pp

Wang Chunmei (2014) ,Study on the factors affecting the benifts of agricultural research programme, *Jourenal of Economics and Management , Vol 2, No.1* pp 38-42

Eshghizadeh , M et.al(2016), Effect of natural land covers on runoff and soil loss at the hill – slope , *Global J.Environ.Sci.Manage.2(2)* pp125 -134

Fig. 1

Fig . 2

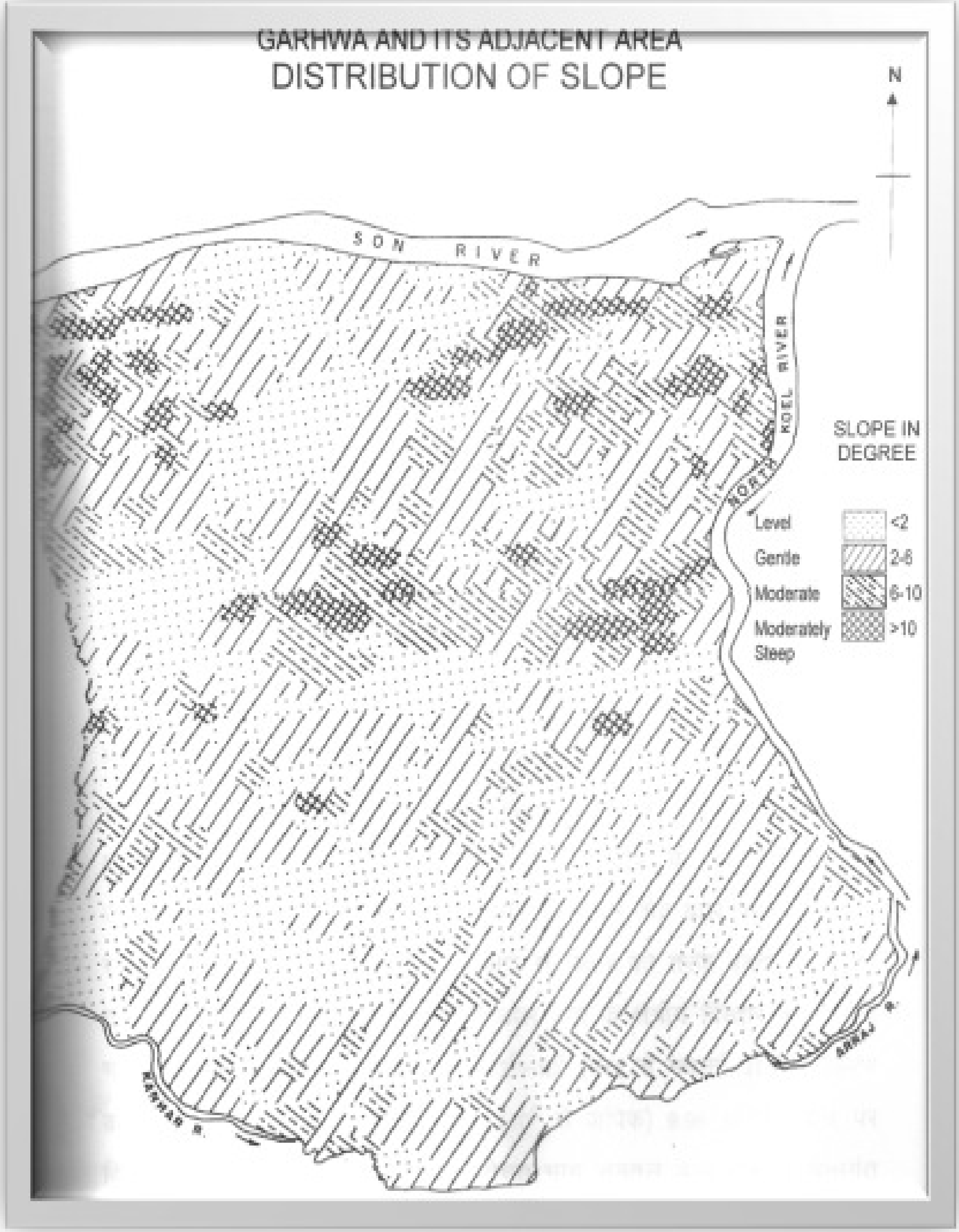

GARHWA AND ITS ADJACENT AREA
DISTRIBUTION OF SLOPE
N
SON RIVER
NORTH KOEL RIVER
SLOPE IN DEGREE
Level <2
Gentle 2-6
Moderate 6-10
Moderately Steep >10

Fig .3

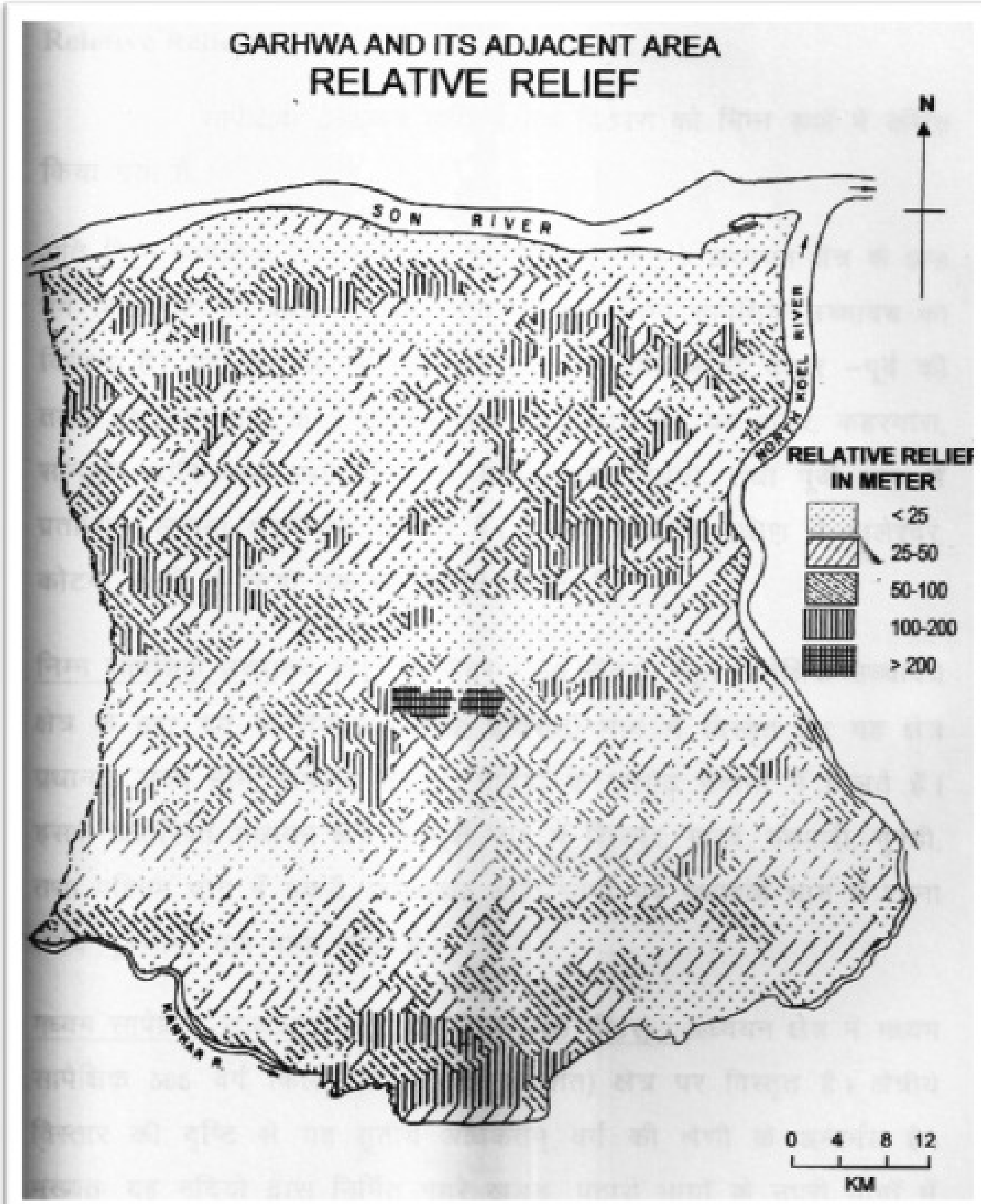

GARHWA AND ITS ADJACENT AREA
RELATIVE RELIEF
N
SON RIVER
NORTH KOEL RIVER
KANHAR R.
RELATIVE RELIEF IN METER
< 25
25-50
50-100
100-200
> 200
0 4 8 12
KM

Fig .4

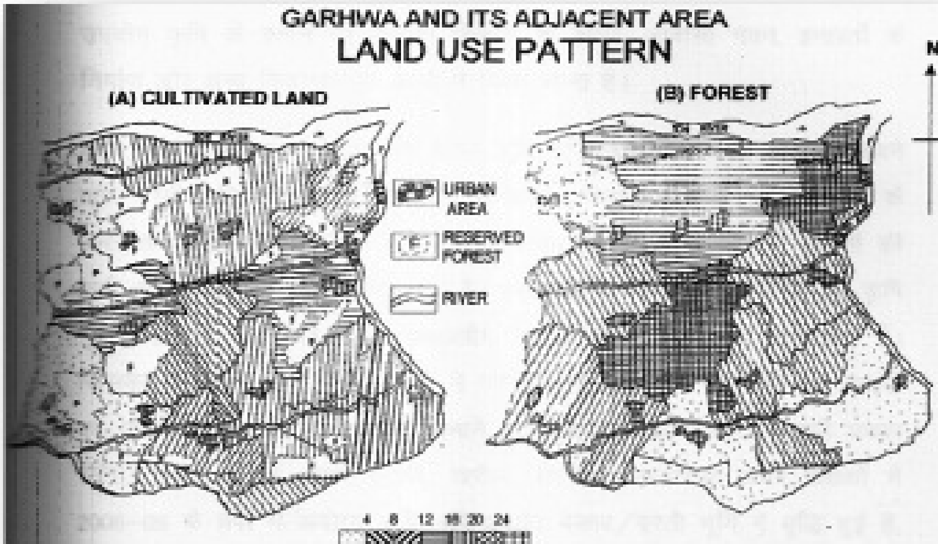
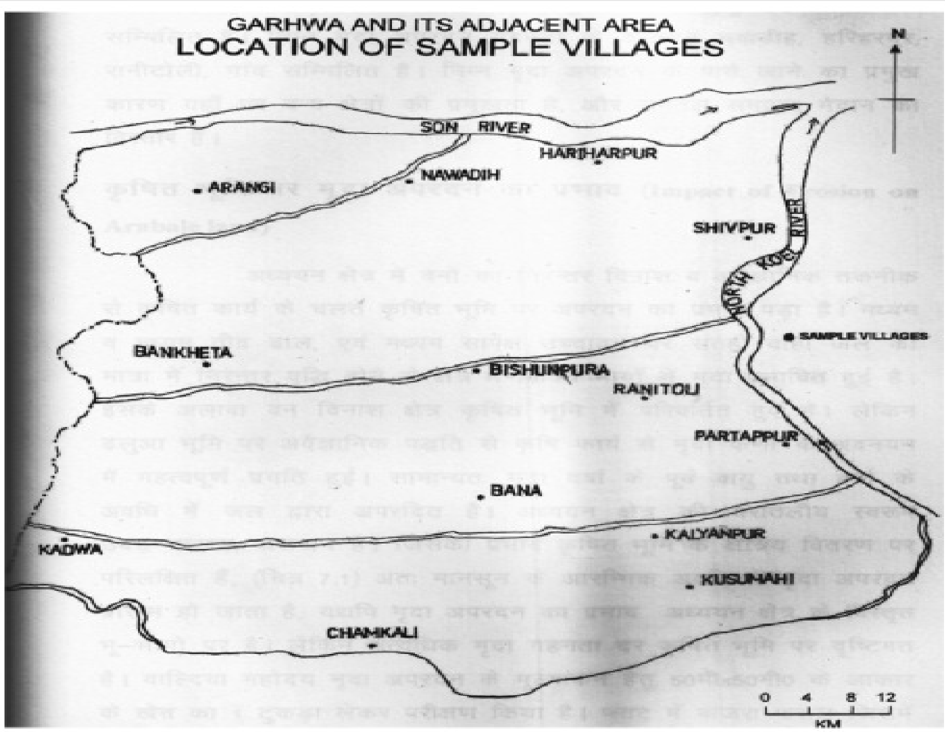

GARHWA AND ITS ADJACENT AREA
LAND USE PATTERN
(A) CULTIVATED LAND
(B) FOREST
N
URBAN AREA
RESERVED FOREST
RIVER
4 8 12 16 20 24

Fig. 5


GARHWA AND ITS ADJACENT AREA
LOCATION OF SAMPLE VILLAGES
N
SON RIVER
HARIHARPUR
NAWADIH
ARANGI
SHIVPUR
NORTH KOEL RIVER
SAMPLE VILLAGES
BANKHETA
BISHUNPURA
RANITOLI
PARTAPPUR
BANA
KALYANPUR
KADWA
KUSUMAHI
CHAMKALI
0 4 8 12
KM

14

Urban Expansion Leadds to Geomorphic Change : A Case Study on Identified Zone of Kulick River

Prolay Mondal

Introduction:

Urban expansion is the uncontrolled and uneven expansion of an urban area into the surrounding landscape, poorly planned patterns of development. After Bengal partition Raiganj developed as an urban area rapidly through people coming from east Bengal. Although population pressure also rises at this city from Jharkhand and Bihar state due to its transitional zone in nature.

Geomorphic Process deals with the endogenic and exogenic forces causing physical stresses and chemical actions on earth materials and bringing about changes in the configuration of the surface of the earth are known as geomorphic processes. It is hampered by human activities at identified zone of Kulik river bank. For this study image analysis is help to identify what amount of change in Kulik River as well as land use / land cover change in 43 years span.

Simon J. Price et al., 2011 mentioned in their paper that "Landscape is a complex concept that can include topography, landform, an object, a way of seeing the world and an inhabited space." and "Rapid population growth and the exploitation of the Earth's resources through urbanization, industrial and agricultural activity have led to humans becoming one of the most significant factors in the evolution of the Earth's landscape. As such, humans are a geological and geomorphological agent."

According to S. N. Mohapatra et al., (2014), "The construction activities have affected important geomorphic features such pediplain, buried pediplain, residual hills, and denudational hills. It was concluded that, instead of shortsighted urban development, proper measures should be taken in accordance with scientific planning for the urban expansion of the city in the future."

The changes that occur as a result of urban expansion are also influenced by their interaction with the disturbed geomorphological process response systems, such as weathering on building stone resulting from air pollution (Viles 1993).

In the year of 1976 D. Coates told that "In urban geomorphology man acts as physical process to change the natural terrain to cityscape. Urban geomorphology is the surface component of urban geology and forms the important subfield of environmental geology.

Wolman, M. G. and Schick, A. P. (1967) also mentioned in their research article that "There is a need to understand the dynamic interaction between the different aspects of urban expansion as expansion of built-up area, construction activities over natural features which cause diversion and destruction of aquifers, and the specific geomorphic features of the urban area. The streams become overloaded with sediments and thus change the courses."

Geographic Profile of Study Area:

The study area mainly concentrated with Raiganj town surroundings area. Raiganj (District Headquarter of Uttar Dinajpur) located on the bank of the River Kulik is where "Raiganj Wildlife Sanctuary", the largest bird sanctuary in Asia situated. Kulik basin lying between Rajmahal hills and North bengal plain. The alluvium is estimated to be Pleistocene age.

Significance of The Study:

The present study is focus on effect of urbanization on geomorphic process. Raiganj city is growing rapidly. It is also famous for Kulik Bird Sanctuary in the Asia as well as World. This sanctuary depends on Kulik River & its surroundings stock Bill. The urbanization of Raiganj has brought about significant changes in landscape and land cover. It has adverse effects in terms of physical environment. To knowing the recent situation the study carried out some facts. These are follows:

- Geomorphic process interrupted
- Kulik River Course change
- Vegetation cover loss
- Open stock bill area exhausted
- Biodiversity is loss

Objectives:

The primary objective of this study was to effect of urbanization on geomorphic process and compares the extent of channel shifting of Kulik River. It may be categorized as follows –

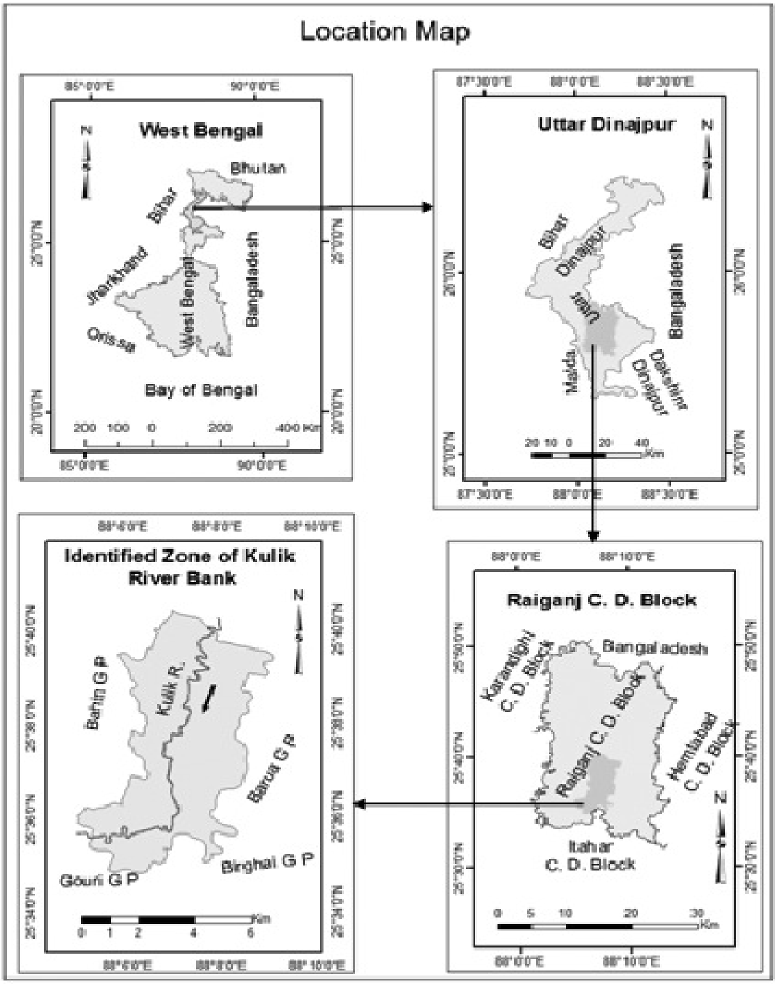
- To understand how urbanization affect landscape of Raiganj.
- To know the reason of Kulik river course change.
- To assess how we reduce adverse effect of urbanization on landscape
- To know how geomorphological impact of these changes in the deposition of made ground, removal of material through excavation & waste garbage deposition on Kulik river.

Study Area:

This study is concentrated on Raiganj city and adjacent area (identified zone of Kulik river bank) of Raiganj C.D. Block, Uttar Dinajpur, West Bengal(Fig. 1), located at 25^0 34' 45'' N. to 25^0 40' 22'' N. and 88^0 04' 57'' E. to 88^0 09'09''E. with a total are of 35.77 km^2.

Figure-1

Location Map of Study Area



Methodology (Sources of Data):

Satellite Image processing based this study involves a series of procedures that includes image rectification and restoration, digitization, classification (LU/LC), data collection and analysis, ground truth verification, data analyses & morphometric analysis and data interpretation (Fig. 2). Here two major type map i.e. Land Use/ Land Cover map and Channel Shifting Map of identified river bank of Kulik prepared through ERDAS 2014 and ArcGIS 10.2 software which have allowed to analysis and extract the information. For getting this information from LANDSAT 3 MSS & Google image, here applying different filters of image for digital improvement. The digital analysis of these data was carried out through following technique (Fig. 2).

I have applied multi-temporal and remote sensing (RS) data to monitoring the environment of **identified zone of Kulik river bank** and GIS techniques. In this study I used different types of data like: Texas topographic map (scale 1:250000), land use map (CLC – Corine Land Cover), orthophoto and multi-temporal Satellite (Table-1).

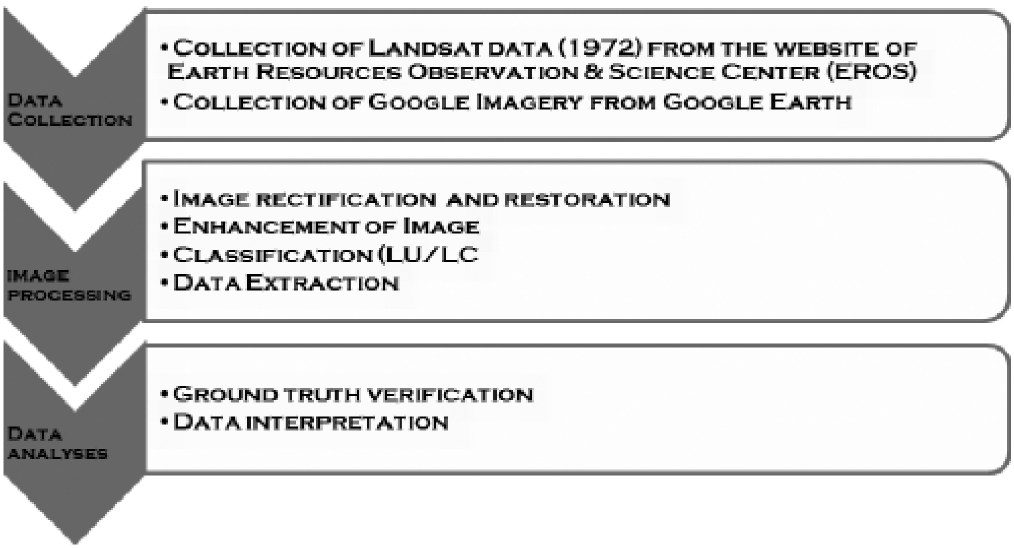
Table-1

Details of the Romort Sensing data that are used in the study

Image	Data	Spatial	Number of bands Resolution (M)	Radiometric resolution
LANDSAT 1MSS	1972	30	5,6,7	6 bit
Google Image	2015	15	-	-

Figure-2

Methodology



Result and Discussion:

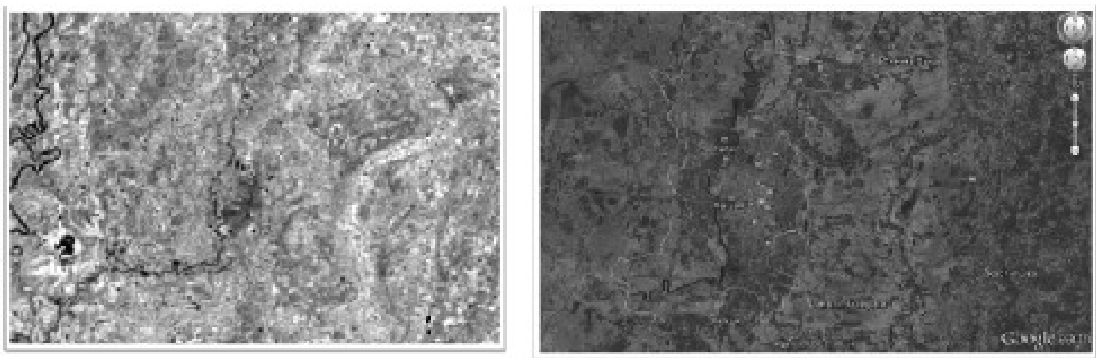
Geomorphic behaviour of Kulik River is basic to three processes: sediment transport, sediment supply and sediment storage, with the intensity of each process respectively. As per agricultural practice demand and grow up as a Raiganj township these three type process hamper in Kulik river bank. Natural geomorphic processes obstruct by river water loss, vegetation loss, settlement grow up in river bank area, rapidly change land use pattern. All these happen due to uneven pressure on indentified zone of Kulik river bank.

As a result river is shifted in western side. From the identified zone of Kulik River Bank, here a physiographic common feature is Ox-bow Lake. Two stream line draw in a map (Fig. -3), which represent 1972 and 2015 Kulik river flow on the study area. The map clearly indicates that Kulik shifted on the western side. During 43 years pans of Kulik River (1972 to 2015), a question arise i.e. why this river one side shifted. Although Ox-bow Lake says that after some time river will be again straight flow. Then why only shifting take place on western side. That means except above stated three processes, there will be some force or process is there which act over the cause of geomorphic change for Kulik channel shifting. This is happened due to built up area pressure on eastern side. From the Figure–4, it clear that settlement area is much more expansion on eastern side of the study area. In eastern side of river bank, Marshy, vegetation cover converted into built up area much more than western side. In other hand, Marshy, vegetation cover converted into agricultural field in western side. The people of this area use river bed as agricultural field due to their economically requirement as well as river water is reducing day by day.

The data on associated building built up on river bed, all respondent think that due to uneven pressure of growing population in Raiganj Municipality and its surroundings they are force to use this area. They are not able to buy the land in high price which is far from river bank. But the maximum poor people easily built up their house in river bed without purchasing land. This area is political tension zone from Indian independent time, as a result migratory people also built up their house on this river bed.

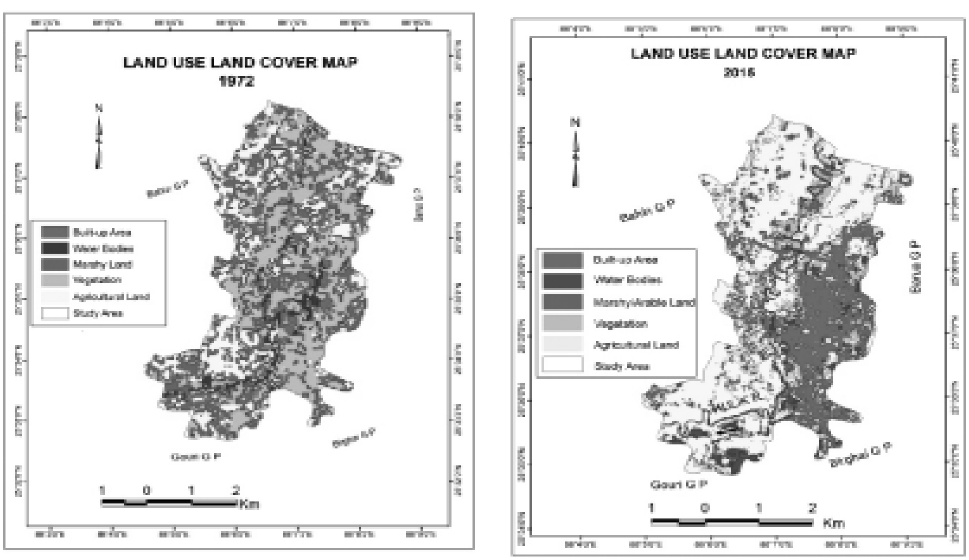
Figure–3

Satellite image,1972 (Left) and Google Image,2015 (Right)



Figure–4

Land use Land Cover Map of Study Area (1972 and 2015)



Source: Computed from Landsat-1 (1972) and Google Earth (2015)

Table – 2

Land use/ land cover data

Land classification data from satellite image

LC/LU types	1972		2015	
	%	sq. Km	%	sq. Km
Agricultural Land	16.6	5.93782	62.7	22.42779
Built-up area	9.68	3.462536	22.94	8.205638
Vegetation	37.72	13.49244	6.67	2.385859
Water Bodies	7.27	2.600479	5.82	2.081814
Marshy/Arable Land	28.73	10.27672	1.87	0.668899
Total =	100	35.77	100	35.77

The study area is characterized by the following LC/LU units' Agricultural Land, Built-up area, Vegetation, Water Bodies, Marshy/Arable Land, with area coverage of 16.6, 9.68, 37.72, 7.27, and 28.73 per cent respectively as per 1972 image data. Whereas in 2015 image data is represent same LC/LU units' with area coverage of 62.7, 22.94, 6.67, 5.82, and 1.87 per cent respectively.

All these LC/LU units are noted to be changed (Figure-4. & Table-2). Vegetation, Water Bodies, Marshy/Arable Land are more affected than other LC/LU units. These three are affected by inherent and anthropogenic factor as evidenced by the plates and also decrease their area cover. While built up area and agricultural land increase remarkably. In addition to these natural differences, land development and urbanization also strongly influence streams. Aggradations and degradation are often the symptoms of a problem (Urbanization) within the watershed, such as changes in land use within the watershed that occur over the study area and affect the Kulik's hydrology as well as geomorphic process. Here, Kulik may also aggrades or degrade very quickly if the problem is caused by a very large storm event or a localized disturbance, such as flush flood without proper sediment controls. Kulik naturally move and change their shape due to erosion and redistribution of bed and bank materials. Dynamic equilibrium is a term that is used to explain how a Kulik can be described as "stable" despite the fact that it actually changes shape which is very much associated with Rills and gullies erosion. From the image analysis it is the clear evident that geomorphic process hampered by human activities.

Table –3

Population Characteristics of Study Area (2011)

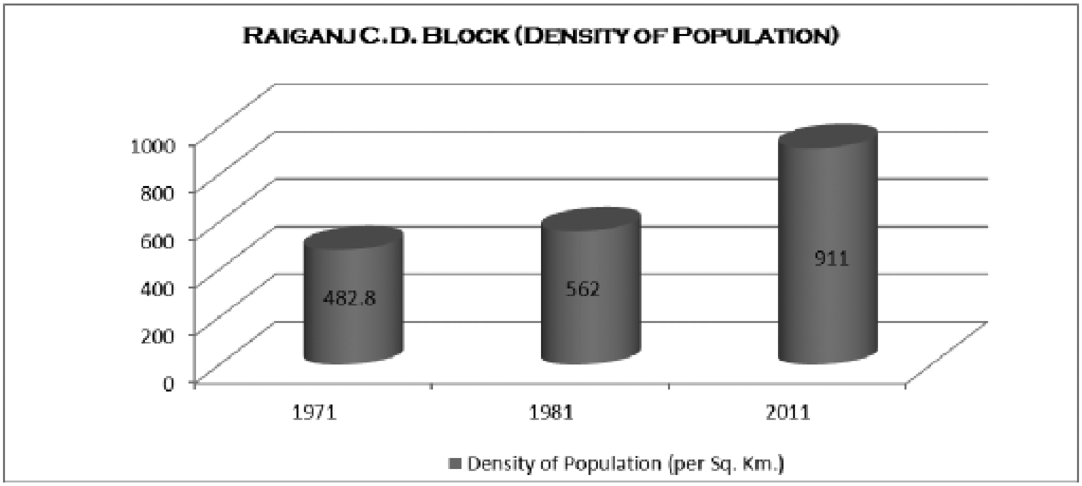
Name	T/RU	Total Population	Area (Sq. Km., Approx.)	Total Population (2011)	Population Density (per sq. km), 2011	Total Population of Raiganj C.D. Block from 1971 - 2011
Bhattagidighi	Rural	2188	3.91	2188	560	➢ 1971 population density 482.8 / sq km ➢ 1981 population density 562 / sq km ➢ 2011 population density 911 / sq km ➢ Percentage of Raiganj population to district population is 14.31
Soharai	Rural	4449	3.52	4449	1264	
Kotgram	Rural	3112	0.9	3112	3458	
Bhatghara	Rural	2766	1.72	2766	1608	
Abhor	Rural	1460	1.83	1460	798	
Tenahari	Rural	3512	3.49	3512	1006	
Abdulghata	Rural	568	0.53	568	1072	
Chandar	Rural	2835	0.59	2835	4805	
Udaypur	Rural	3690	0.9	3690	4100	
Bogram	Rural	3983	1.67	3983	2385	
Nachhratpur Katabari (CT)	Urban	6011	1.87	6011	3214	
Kasba (CT)	Urban	10067	3.75	10067	2685	
Raiganj Municipelty-	Urban	183612	10.64	183,612	17257	
Total		228253	35.32		6462	

Source: Census 2011

The population data revels that Raiganj population is highest among the other area. If you consider the density of population then result is same i.e. highest population density from others area. If we see the previous Population density of Raiganj C.D. Block then data shows that density of population is doubled within 40 years (Table - 2, Figure - 4).

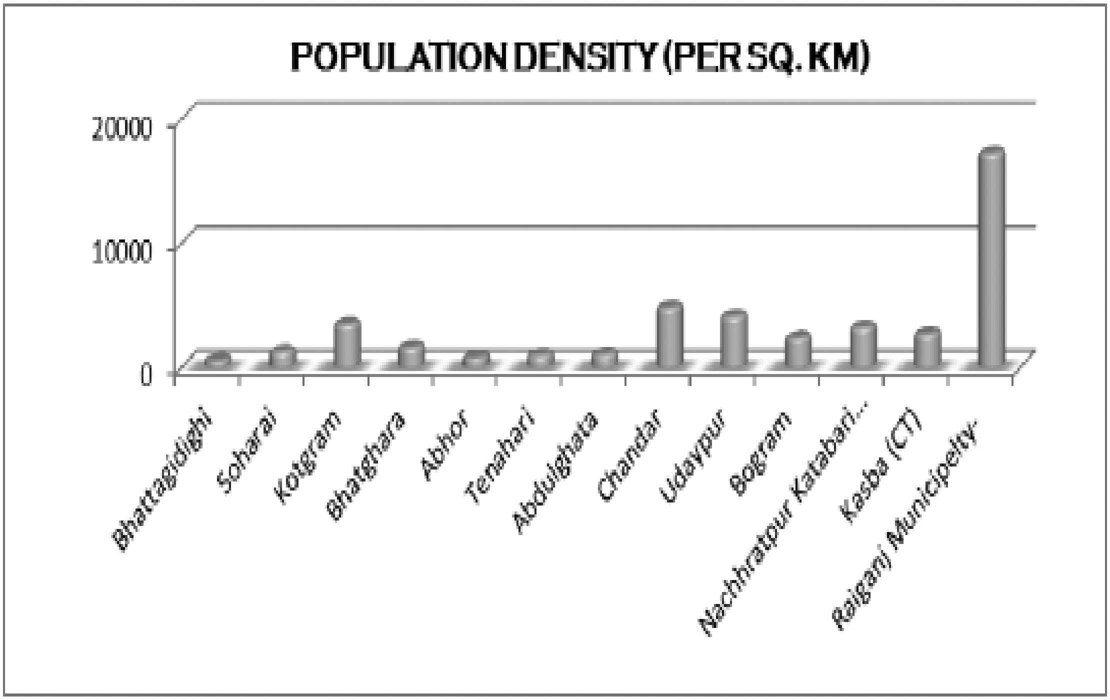
Figure–5

Population Density of Raiganj CD Block (1972 – 2011)



Figure–6

Population Density of Different Villages in Study Area



Source: Census,2011

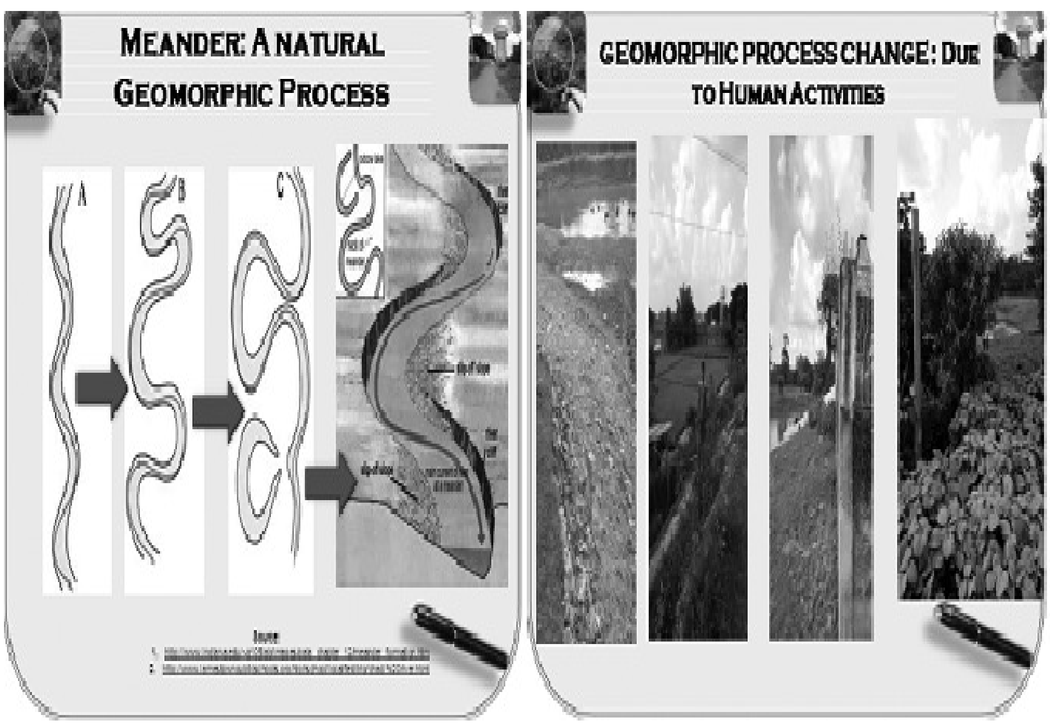
Comparison between A Natural Fluvial Geomorphic Process And Interrupted Fluvial Geomorphic Process Due To Human Intervention:

The Picture (**Plate-1)** shows that the natural geographic process interrupted by human activities. As a result channel shifting towards west side where more human interference over the river bank dwellers. These human activities are as follows which leads to channel shifting (Kulik River)**:**

- Pressure of human habitation
- Agricultural field grow up in river bed
- Forest degradation
- Settlement built up in river bed
- Waste garbage management plant built up in river bed
- River water flow decrease

Plate-1

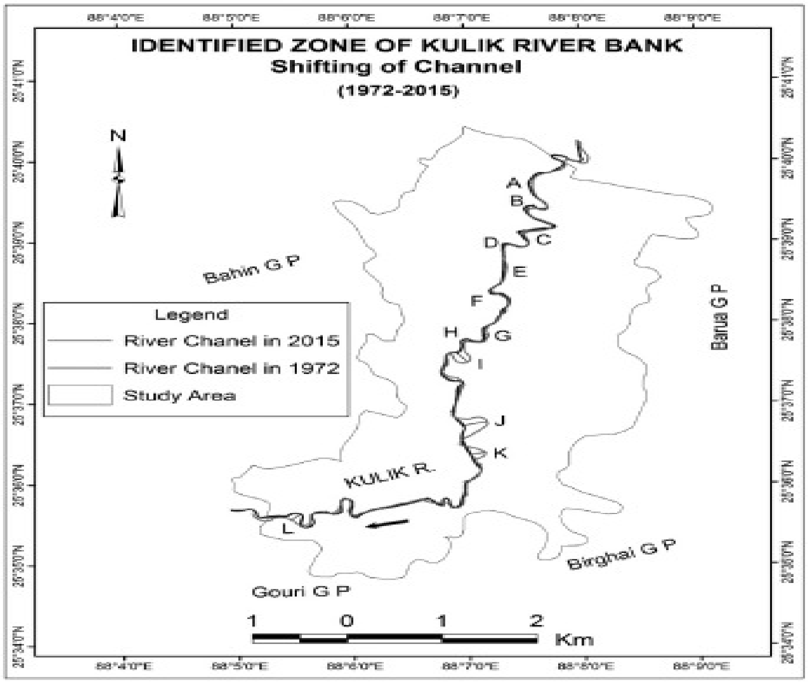
Natural fluvial geomorphic process (Left) and interrupted fluvial geomorphic process due to human intervention (Right)



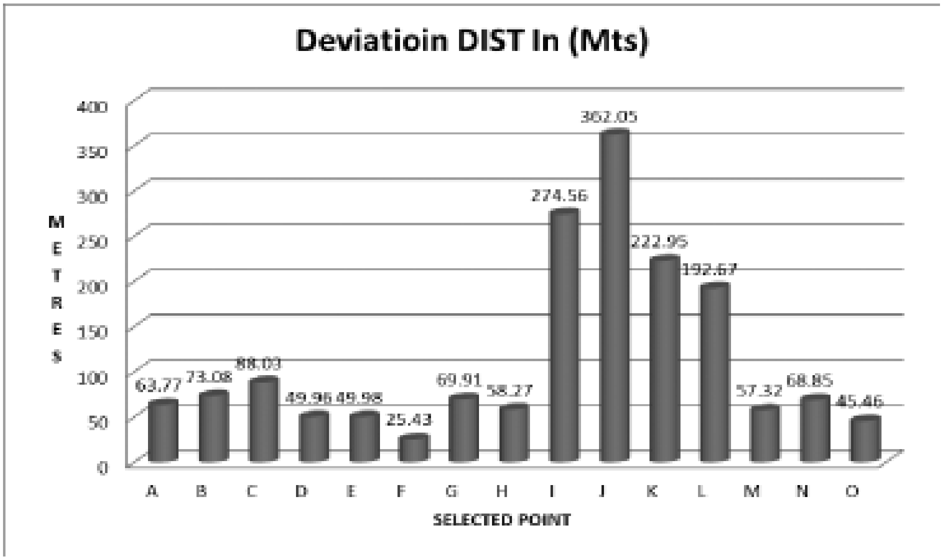
Channel Shifting During 43 Years Pan

From the figure -7 and figure-8 we can get a clear idea about the shifting characteristics of river chanel, Most channel shift at the point of 'J' at 362.05 mts and lowest in the 25.43 mts at the 'F' point.

Figure–7
Shift of River Chanel



Figure–8
Shifting of Channel in the Identified Zone of Kulik River



Concluding Remarks

From investigation, it is revealed that habitation along the bank of Kulik River continuously changing geo-environmental characters there. Most important is human activities on the Kulik is being forced to change it natural course and consequence of its effect on topography of the areas through which the Kulik follow. Most interesting is the people deciding both side bank of the Kulik are dependent on agriculture economy of the rural people are being seriously affected. Waste depositions in the Kulik by the people are dangerously affecting aqua species and birds.

Outcome of the research is mostly interesting. Here environmental degradation takes place due to human activities. I am sure though outcomes are not important only for academic exercise but also awareness programme. If these outcomes are being consider by the administration it will help sustainable development of the area which Kulik river follows. No education is proper education which does not aware people for sustainable development.

Acknowledgment

The author is grateful to Amborish Das for extending GIS based work assistance to carry out this work. I would like to express my sincere thanks to Prof. (Dr.) Vibhas Chandra Jha, Principal, Vidya Bhavana, Visva Bharati, Santiniketan, Professor N.C. Ghosh, S.N. Bose Institute of Mathematics & Mathematical Sciences, Kolkata, and Dr. Gopal Chandra Debnath Associate professor, Dept. of Geography, Visva Bharati, Santiniketan West Bengal for their help and encouragement.

References

Coates, D. (1976):*Urban Geomorphology*, Geological Society of America, Boulder, Colo, USA.

Douglas I., Lawson N. (2001) The human dimensions of geomorphological work in Britain. J. Ind. *Ecol.* ***4***:9–33, (doi:10.1162/108819800569771) cited in Simon J. Price et al. Humans as major geological and geomorphological agents in the Anthropocene: the significance of artificial ground in Great Britain.

Hooke R. L. (2000) On the history of humans as geomorphic agents.Geology28:843–846,

(doi:10.1130/0091-7613(2000)28<843:OTHOHA>2.0.CO;2) cited in Simon J. Price et al. *Humans as major geological and geomorphological agents in the Anthropocene: the significance of artificial ground in Great Britain*

Mohapatra, S. N. Pani, P. and Sharma, M. (2014): Rapid Urban Expansion and Its Implications on Geomorphology: A Remote Sensing and GIS Based Study, *Hindawi Publishing Corporation Geography Journal, Volume 2014.*

Strong, F.W. (1912): *Eastern Bengal District Gazetteers Dinajpur*, N. L. Publishers: Sitiguri, West Bengal.

Thomas J. (2001) The archaeology of place and landscape *Archaeological theory today* Hodder I. 165–186Cambridge, UK Polity Press

Viles, H.A. (1993): The Environmental Sensitivity of Blistering of Limestone Walls in Oxford, England: a Preliminary Study. In D.S.G. Thomas and R.1. Allison (edt.), *Landscape Sensitivity*, Chichester. John Wiley & Sons. pp. 309-326

Wolman, M. G. and Schick, A. P. (1967): Effects of construction on fluvial sediment: urban and suburban areas of Maryland, *Water Resources Research*, *vol. 3*, pp. 451–464.

Wilkinson B. H. (2005) Humans as geologic agents: a deep-time perspective. Geology 33:161–164, (doi:10.1130/G21108.1) cited in Simon J. Price et al. *Humans as major geological and geomorphological agents in the Anthropocene: the significance of artificial ground in Great Britain*

http://www.ecologyandsociety.org/vol10/isss2/art2
http://rsta.royalsocietypublishing.org/content/369/1938/1056
http://dx.doi.org/10.1155/2014/36145
http://www.unicef.org/sowc2012/pdfs/SOWC-2012-DEFINITIONS.pdf

http://www.geosocindia.org/public/journals/256/pdf/GeomorphicProcessesandEvolutionofLandforms.pdf

15

Impact of Climate Change on Major Drainage Basins of India : A Review

Hemanta Kumar Ghosh

Introduction

In India, river basins having catchment areas exceeding 20,000 sq. km are classified as major basins. The country has 12 such basins whose total catchment area is 2.528 million sq. km. Among the major rivers, the Ganga–Brahmaputra–Meghna (Barak) system is the largest with catchment area of about 11.0 lakh km^2 (more than 43% of the catchment area of all the major rivers in the country). Three major basins, viz. Indus, Ganga and Brahmaputra are snow-fed. Mahanadi, Godavari and Krishna river basins have catchment area more than one lakh km^2. Seven other medium-sized basins are the Sabarmati, Mahi, Narmada and Tapi rivers flowing west and the Subarnarekha, Brahmani, Baitarani and Cauvery rivers flowing east together cover 15% of the total drainage area of India.

Analysis of instrumental climate data has revealed that the mean surface temperature over India has increased at a rate of about 0.4°C per century (Rao, 1995) which is statistically significant. Maximum temperature showed significant rising trend of 0.008°C/yr during monsoon season; 0.014°C/yr during post-monsoon season and 0.008°C/yr in the annual maximum temperature during the period 1914–2003 for Central Northeast (Subash et al., 2010). Minimum temperature showed significant rising trend of 0.012°C/yr during post-monsoon season and significant falling trend of 0.002°C/yr during monsoon season revealed in studies of the long-term trends and variations of the monthly maximum and minimum temperatures in various climatological regions in India. Pal and Al-Tabbaa (2010) showed increasing monthly maximum temperature, though unevenly, over the last century. Minimum temperature changes were found more variable than maximum temperature changes, both temporally and spatially, with results of lesser significance. Though the monsoon rainfall in India exhibited no significant trend over a long period of time, particularly in the all-India scale, pockets of significant long-term rainfall changes were identified in some studies (Kumar. et.al. 2012).

Trends in monsoon rainfall in different sub-divisions and the whole of India were examined for the period 1871–1988 by Subbaramayya and Naidu (1992). Decreasing trends found in the central and western Indian sub-divisions during the late 19th century. Kothyari and Singh (1996) found decreasing trend in monsoon rainfall and rainy days in the Ganga basin, and annual rainfall over India starting around the second half of the 1960s. Singh and Sontakke (2002) analysed rainfall data for the period 1829–1999 over the Indo-Gangetic Plains (IGP) and found significant increasing trend (170 mm/100 yrs) from 1900 in the summer monsoon rainfall over western IGP; non-significant decreasing trend (5 mm/100 yrs) from 1939 over central IGP and non-significant decreasing trend (50 mm/100 yrs) during 1900–1984 and non-significant increasing trend (480 mm/ 100 yrs) during 1984–1999 over eastern IGP. According to 'Intergovernmental Panel on Climate Change' (IPCC) climate projections over India indicate that rainfall increase is expected by 10–20 % over Central India by the end of this century (IPCC, 2007 c).

In recent years, there has been increasing concern that the water resources of these river systems may be vulnerable in the context of global climate change (IPCC, 2007; Kundzewicz et al., 2007), which could have considerable implications for the livelihoods and well-being of the people in the region (Eriksson et al., 2009). Rising temperatures and changes in precipitation could affect the hydrological regime through factors such as changes in seasonal extremes, increased evapotranspiration, changes in glacier volume (Bolch et al., 2012), and changes in snow and glacier melt (Lutz, Immerzeel, Shrestha, & Bierkens, 2014). A number of authors have suggested that shrinking of glaciers in response to rising temperatures might result in a marked reduction in water availability in some rivers in the medium-to-long term (Bolch et al., 2012; Immerzeel, Beek, Konz, Shrestha, & Bierkens, 2012; Kaab, Berthier, Nuth, Gardelle, & Arnaud, 2012).

Objectives of the Study

The following were the specific objectives of this study:

- To generate better information and understanding on climate change impact assessment on drainage basins.
- To focus on the spatio-temporal changes in temperature, seasonality, and intensity, on the drainage basins.
- To focus on the spatio-temporal changes in rainfall amount, seasonality and intensity on the drainage basins.
- To explain the future projections on temperature and rainfall variability.
- To identify the basins those are mostly vulnerable to climate change.
- To raise awareness for effective coping and adaptations measures to droughts and floods.
- To improve climate resilience in selected areas of India; and stakeholders.

Material and Methods

The researcher has reviewed previously published academic literature, including journal articles, conference proceedings, NGO publication, policy and government documents, best practice manuals and handbooks, press/popular media report on climate change impact on drainage basins of the country. To collect information, and opinion related to this study the researcher was adopted the analytical descriptive approach.

The Indus Basin

The Indus originates in the high Himalayan mountains of China, India and Pakistan in the north and extends to the dry alluvial plains of Sindh Province in Pakistan in the south, finally draining into the Arabian Sea (Ali & De Boer, 2007; FAO, Aquastat, 2011a).

The Indus has the largest irrigation network in the world. The water is regulated by two major storage dams in the upper Indus Basin (the Tarbela Dam on the Indus and the Mangla Dam on the Jhelum) that are fed predominantly by melt water (Immerzeel et al., 2010; Laghari, Vanham, & Rauch, 2012).

Archer and Fowler (2004) analyzed precipitation in the upper Indus Basin from 1895 to recent times; they did not identify any significant long-term trends although they suggested a statistically significant increase in annual precipitation at several stations over the period 1961–1999. But study of Khattak, Babel, and Sharif (2011) found no clear trends in precipitation at 20 stations in the upper Indus Basin (Pakistan) between 1967 and 2005. The difference between these results may be due to the different periods covered, different methods of analysis. Precipitation in the upper Indus Basin is projected to increase by 25% compared to the baseline by 2046–2065, (Immerzeel et al., 2010), while Akhtar, Ahmad, and Booij (2008) projected an increase of up to 21%.

Fowler and Archer (2006) reported a consistent lowering of mean and minimum summer temperatures, but no consistent trend in maximum summer temperatures, between 1961 and 2000. Khattak et al. (2011) also reported an increase in winter maximum temperatures between 1976 and 2005 in the upper, middle and lower parts of the Indus Basin of 1.79, 1.66 and 1.20 8C, respectively. Chaudhry and Rasul (2007) identified a significant increase in annual mean temperature in Balochistan, Punjab and Sindh Provinces in Pakistan between 1960 and 2007 of 1.15, 0.56 and 0.44 8C, respectively. Bhutiyani et al. (2007) also concluded that the north-western Himalayan region has warmed significantly during the last century, at a rate higher than the global average. Kazmi et al. (2014) generated future temperature scenarios

Lutz et al. (2014) investigated the impact of climate change on the hydrological regime in the Indus basin suggested that annual runoff will increase by 7–12% by 2050, primarily due to accelerated melt in the upper Indus Basin together with an increase in precipitation. Laghari et al. (2012) also suggested that water availability might increase in the short term, but will decrease in the long term.

The Ganges Basin

Most of the basin is strongly influenced by the summer monsoon with the eastern part receiving the highest rainfall. The effect of the monsoon weakens from east to west; the Koshi catchment in the east receives 72–81% of rainfall during the monsoon season (June to September) (Nepal, 2012), while the Bhagirathi and Mandakini sub-basins to the west receive only 55–65% (Molden et al., 2014; Shrestha, 2008).

Shrestha, Wake, Dibb, & Mayewski, (2000) found no distinct trends in precipitation in the Nepal Himalayas between 1959 and 1994. Singh, Kumar, Thomas, and Arora (2008) reported that historically annual precipitation in the Ganges Basin has remained stable. But Nepal (2012), in an analysis of precipitation trends in the Koshi catchment, found an increasing trend in annual precipitation at 22 of 36 stations and a decreasing trend at 14 stations, but the results were significant at only three stations (two increasing and one decreasing). Sharma, Vorosmarty, and Moore (2000) also found localized trends in precipitation in the Koshi basin, but they lacked basin-wide significance. Pervez and Henebry (2014), in their study projected an overall increase in monsoon precipitation of 12.5% and 10% with a decrease during the pre-monsoon and increase during the post-monsoon seasons over the Ganges Basin. Immerzeel et al. (2010) projected an 8% increase in upstream precipitation in the Ganges Basin.

Shrestha, Wake, Mayewski, and Dibb (1999) reported that the maximum temperature in Nepal increased at a rate of 0.06 ^{0}C/yr between 1978 and 1994, with higher rates at stations located at higher altitude. The maximum temperature in the Koshi catchment (a sub-basin of the Ganges) increased by 0.058 ^{0}C/yr over the last four decades (Nepal , 2012). Immerzeel et al.

(2012) projected an annual increase in temperature of 0.06 ^{0}C/yr between 2000 and 2100 in the Langtang catchment in Central Nepal.

Wiltshire (2014) suggested that under a warming climate, the volume of glaciers in the eastern Himalayas (Nepal and Bhutan) will decline over the twenty-first century, despite increasing precipitation, as a result of less precipitation falling as snow as well as increased ablation. Nepal et al. (2014b) estimated that the contribution of snow melt to river flow in the Dudh Koshi catchment would decrease by 31% with a 2 8C rise in temperature, and by 60% with a 4 8C rise, changing the river from 'snow dominated' to 'rain-dominated'. study by Immerzeel et al. (2010) for 2046–2065 projected a decrease of 17.6% in mean upstream water supply in the Ganges Basin, with the reduction in melt runoff partly compensated for by increased upstream rainfall (+8%).

The Brahmaputra River Basin

The Brahmaputra River drains an area of around 580,000km2, covering four countries (% of total catchment area in brackets): China (50.5%), India (33.6%), Bangladesh (8.1%) and Bhutan (7.8%). Its basin in India is shared by Arunachal Pradesh (41.88%), Assam (36.33%), Nagaland (5.57%), Meghalaya (6.10%), Sikkim (3.75%) and West Bengal (6.47%) (Singh et al 2004).

Immerzeel (2008) analyzed historic trends using global 100-year monthly high-resolution data (1900–2002) and concluded that the precipitation did not show any clear trend and was mainly determined by the monsoon, his prediction indicated about accelerated increase in precipitation with a greater increase over the Tibetan Plateau than over the plains areas; the increase in precipitation in summer could indicate a potential increase in extreme events. Flugel et al. (2008) studied the variation in annual mean and seasonal precipitation in the upper Brahmaputra River basin from 1961 to 2005 and found a slight increase in mean annual precipitation as well as in autumn, spring and summer. Pervez and Henebry (2014) concluded that the peak of monsoon precipitation is likely to shift from July to August and an overall 12% and 16% increase in monsoon precipitation over the Brahmaputra Basin.

Immerzeel (2008) found a temperature increase of 0.6 8C per 100 Years and projected an accelerated seasonal increase in both maximum and minimum temperatures in the Brahmaputra Basin from 2000 to 2100. The changes were more prominent on the Tibetan Plateau than on the flood plain. Dobler, Yaoming, Sharma, Kienberger, and Ahrens (2011), concluded similar as Immerzeel (2008) . Flu¨gel et al. (2008) identified an increase in average annual temperature in the upper Brahmaputra River basin of 0.28 8C per decade from 1961 to 2005, and of average winter, autumn, spring and summer temperatures of 0.37, 0.35, 0.24, and 0.17 8C per decade.

Study of Immerzeel et al., (2010) Mirza, (2002) indicated that climate change is expected to have a significant effect on the hydrology and water resources of this basin. Prasch (2010) in his research concluded that water availability will decrease on average, due t the the increase in evapotranspiration. He also predicted that the percentage of snowfall in precipitation will continue to decrease. Prasch, Marke, Strasser, and Mauser (2011) inferred that glacier ice melt will accelerate from 2011 to 2040 due to the increase in air temperature and longer melting periods, and that as the amount of glacier ice is reduced, ice melt will decrease.

The Godavari River basin

Godavari rises in the Sahyadris near Triambakeswar, about 80 km from the shore of Arabian Sea, at an elevation of 1,067 m in the Nasik district of Maharashtra. After flowing for about 1,465 km in a general south-easterly direction through Maharashtra and Andhra Pradesh, Godavari falls into the Bay of Bengal north of Rajahmundry. The basin extends over an area of 312,813 km^2, which is nearly 10% of the total geographical area of the country. It is bounded on the north by the Satmala Hills, the Ajanta Range and the Mahadeo Hills, on the east and south by the Eastern Ghats and on the west by the Western Ghats. The study area of the research is the upper Godavari basin in Maharashtra state in India The mean monthly *T* max in the upper Godavari basin varies from 29.64 to 38.60 and mean annual *T* max is 32.45. The mean monthly *T* min ranges from 14.38 to 25.12 based on decadal (1961–2000) observed values. (Saraf & Regulwar, 2015).

he study conducted by Saraf & Regulwar, (2015) shows increase in mean annual precipitation in Upper Godavari basin. The higher rate of increase is observed in the month of June, July and August. In projection of wet spel length, two of his study model showed different result. One shows decrease in wet spel length in 2020s and 2050s but increase in 2080s, another model shows increase in projected wet spel length during all three time period.

Climate change scenario for the Godavari river basin shown to have extreme weather conditions are likely to appear more frequent, leading to an increased risk of flood and drought. Rainfall is projected to increase by 186 mm (14%) by the mid century and 243 mm (18%) by the end of the century. The annual amount of rainfall is expected to increase, majority in wet season leading to a high risk of flood whereas decreasing or marginal increase in other season can lead to drought due to higher temperature (Gosain et.al., 2011).

The Krishna River basin

The Krishna is one of the longest rivers in the Peninsular India covers an area of nearly 8% of India (about 1,300 km in length). It originates at Mahabaleshwar in Maharashtra, passes through Maharashtra, Karnataka and Andhra Pradesh before meeting Bay of Bengal. The drainage area of the entire basin is about 2,58,948 km^2 of which 26.8% lies in Maharashtra state, 43.8% in Karnataka state and 29.4% in Andhra Pradesh state. Its important tributaries are the Tungabhadra River which itself is formed by the rivers Tunga and Bhadra, the Koyna, Bhima, Malprabha etc. In the present study the Krishna basin is divided in to 23 sub-basins. (Kulkarni et.al., 2014).

Gossain et al. (2006) suggests that in the Krishna basin a decline in precipitation by 20% can be expected. A corresponding decrease in runoff is predicted to vary from 30 % to 50%. An increase in the annual precipitation, surface runoff, water yield and actual evapotranspiration has projected for the period 2041-2070 in the study of Kulkarni et.al. (2014).

Research of Bouwer et. al., (2006) indicates that the average annual temperature increased by about 0.7^{0}C, from 26 ^{0}C over the period 1901–1915 to 26.7^{0}C over the period 1986–2000. Average total annual precipitation increased slightly, by 9% between the same periods, from 765 to 835mm. Their analysis has shown that observed downstream river runoff in the Krishna river basin exhibited a strong decline after 1960. At the same time, peak discharges decreased substantially.

Praveen Kumar et. al. (2014) studied for assessing vulnerability of Krishna river basin and suggested that early sowing at farm ponds, soil moisture conservation by in-situ green manure crops etc can be very useful to conserve water.

The Mahanadi River Basin

Mahanadi river has catchment area of about 1, 41,134 km^2 that lies in Chhattisgarh (75136 km^2), Orissa (65628 km^2), Maharashtra (238 km^2) and Jharkhand (132 km^2) states. The river originates in Chhattisgarh and traverses a length of about 357 km before entering Orissa state, where it further traverses about 494 km before it confluences with Bay of Bengal. It covers nearly 4.3% of total geographical area of the country, with a sediment load to the basin of the order of 7.10 x 109 kg/yr (Subramanian, 1978).

Rao and Kumar (1992) examined the inter-annual variability and the long term trends in the monsoon rainfall and in two derived climatic parameters, aridity index and moisture index for the Mahanadi basin using precipitation and temperature data for the period from1901-1980.The study revealed that the basin has experienced a good number of deficit years during the last two decades of the study period. Study conducted by Rao (1995) indicated a decrease in monsoon stream flow for the historic period. One possible reason for such decreasing trend is the significance increase in temperature due to climate warming.

The increasing trend of temperature in Mahanadi river basin due to climate change is even more severe. The surface air temperature over the basin is increasing at a rate of 1.1^{0}C per century which is more than double the rate of increase for entire India. Increase of temperature at such a high rate may increase the evaporation and thus reduce the effective rainfall which is which is reflected in the stream flow prediction. An increasing trend of extreme draught is also observed by Ghosh and Mujumdar (2007) due to high surface warming which is consistent with the prediction of Mahanadi stream flow obtained by Mujumdar and Ghosh (2008).

Climate change can affect significantly on monthly power generation that depends on four performance criteria (reliability, resiliency, vulnerability and deficit ratio) in Hirakud dam. The annual hydropower generation and reliability will decrease and vulnerability will increase as a result of climate change (Ghosh et.al. 2010., Loucks et.al. 1981)

Future trends in maximum and minimum temperature for annual and seasonal period indicate that there is an increase in the pattern for the maximum and minimum temperature for the time periods 2020s, 2050s and 2080s (Pandey et.al., 2015)

The Cauvery River basin

The Cauvery river is the fourth largest river in peninsular southern India, after Godavari, Krishna, and the Mahanadi. The Cauvery river rises at an elevation of 1,341m above mean sea-level. In its course of 802 km from the Western Ghats to the Bay of Bengal, the main river flows for 381 km in Karnataka, 357 km in Tamil Nadu, and provides the boundary between the two states for the rest. One of its important tributaries in Karnataka, the Kabini, originates in Kerala; and drainage from Kerala contributes to the Bhavani and the Amaravathy, two of the river's tributaries in Tamil Nadu. (Singh & Gosain, 2013).

The rainfall during January, February–May, July, August and November shows negative trend whereas October shows positive trend in Cauvery river basin. With reference to the long-term average (1901 -2002), a decrease in the pre-monsoon rainfall is observed from 1910 to 1929 followed by an increase up to 1965 with negligible fluctuation, and a declining trend from 1982 to 1999. There is an insignificant decrease of 21 mm rainfall over the 102 years period compared to the normal rainfall of 190.45 mm (Sawant et al., 2015).

Geethalakshmi et.al. (2011). studied on 129 years climatic data (1971 to 2099) to observed that the increase in maximum temperature was 3.7°C-3.1°C. The increase in minimum temperature was 4.2°C-3.7°C during the same period. The increase in minimum temperatures is higher than that in maximum temperatures in their both models.

The Cauvery Delta is vulnerable to the effect of rising seas levels as a result of climate change, rate of sea level rise of about 0.3 mm/year. (TA 7417- IND, 2011).

Conclusion

The design of hydro-infrastructure is generally based on the assumption that climate is stationary. Changes in rainfall due to global warming will influence the hydrological cycle and the pattern of stream-flows and demands (particularly agricultural), requiring a review of hydrologic design and management practices. Changes in run-off and its distribution will depend on likely future climate scenarios.

Modelling the climate system is a theoretical approach only which may not precisely happen as projected. Also variables related to the future actions of human beings (e.g. Green House Gas Emissions) are subjected to unpredictable policy decisions and human activities. Climate models itself carry the uncertainty but they are the best tools for projecting the future climate change.

The Indian sub-continent contains the second largest population of the world, but has low per capita income, so the impact of climate change will be severe for this continent. Indian climate is dominated by the southwest monsoon, which brings most of the precipitation over the country. It is critical for availability of freshwater for drinking and irrigation for agriculture. Changes in climate at different spatial and temporal scales, and particularly the southwest monsoon, have significant impacts on agricultural production, water resources management and hence on the economy of India. An understanding of the hydrological response of a river basin under changed climatic conditions would help in modifying the present practices of planning, designing and management of the water resources.

References:

Ali, K. F., & De Boer, D. H. (2007). Spatial patterns and variation of suspended sediment yield in the Upper Indus River basin, *Northern Pakistan. Journal of Hydrology*, 334, 368–387.

Archer, D., & Fowler, H. (2004). Spatial and temporal variations in precipitation in the Upper Indus Basin, global teleconnections and hydrological implications. *Hydrology and Earth System Sciences,* 8, 47–61. doi:10.5194/hess-8-47-2004.

Bhutiyani, M. R., Kale, V. S., & Pawar, N. J. (2007). Long-term trends in maximum, minimum and mean annual air temperatures across the Northwestern Himalaya during the twentieth century. Climatic Change, 85, 159–177.

Bolch, T., Kulkarni, A., Ka¨a¨b, A., Huggel, C., Paul, F. Cogley, J. G., . . . Stoffel, M. (2012). The state and fate of Himalayan glaciers. *Science*, 336(6079), 310–314.

Bouwer, L. M., Aerts, J. H. J. C., Droogers, P. & Dolman, A. J. (2006). Detecting the long-term impacts from climate variability and increasing water consumption on runoff in the Krishna river basin (India). *Hydrol. Earth Syst. Sci.,* 10, 703–713.

Chaudhry, Q. Z., & Rasul, G. (2007). Development of a mesoscale convective system over the foothills of Himalaya into a severe storm. Mountains witnesses of Global Changes. Volume 10.*Development*, 30, 60–77. doi:10.1080/07900627.2013.859044

Dobler, A., Yaoming, M., Sharma, N., Kienberger, S., & Ahrens, B. (2011). Regional climate projections in two alpine river basins: Upper Danube and Upper Brahmaputra. *Advances in Science and Research*, 7, 11–20. doi:10.5194/asr-7-11-2011

Eriksson, M., Jianchu, X., Shrestha, A. B., Vaidya, R. A., Nepal, S., & Sandstro¨m, K. (2009). The changing Himalayas impact of climate change on water resources and livelihoods in the greater Himalaya. Kathmandu: International Centre for Integrated Mountain Development (ICIMOD).

FAO, Aquastat. (2011a). Indus River basin. Retrieved from http:// www.fao.org/ nr/water/aquastat/ basins/ indus/ index. stm

Flugel, W.-A., Pechstedt, J., Bongartz, K., Bartosch, A., Eriksson, M., & Clark, M. (2008). Analysis of climate change trend and possible impacts in the Upper Brahmaputra River Basin – the BRAHMATWINN Project. 13th IWRA World Water Congress 2008, Montpelier, France.

Fowler, H. J., & Archer, D. R. (2006). Conflicting signals of climatic change in the Upper Indus Basin. *Journal of Climate*, 19, 4276–4293. doi:10.1175/JCLI3860.1

Geethalakshmi, V., Lakshmanan, A., Rajalakshmi, D., Jagannathan, R.,Sridhar, G., Ramaraj, A. P., Bhuvaneswari, K., Gurusamy, L. & Anbhazhagan, R. (2011). Climate change impact assessment and adaptation strategies to sustain rice production in Cauvery basin of Tamil Nadu. *Current Science*, Vol. 101, No. 3.

Ghosh, S. & Mujumdar, P.P. (2007). Nonparametric method for GCM and scenario uncertainty in drought assessment. *Water Resour Res.* 43.W07405.

Ghosh, S., Raje, D.& Majumdar, P.P. (2010). Mahanadi stream flow: climate change impact assessment and adaptive strategies. *Current science*, Vol. 98, No.08, 25 April 2010. Retrieved from https://www.researchgate.net/publication/44029508

Gosain, A. K., Rao, S. & Arora, A. (2011). Climate change impact assessment of Water Resources of India. *Current Science,* Vol. 101, No. 3, 356-371.

Gosain, A. K., Rao, S. & Basuray, D. (2006). Climate change impact assessment on Hydrology of India River Basins. *Current Science*, Vol. 90, No. 3, 346-353.

Immerzeel, W. (2008). Historical trends and future predictions of climate variability in the Brahmaputra basin. International Journal of Climatology, 28, 243–254. doi:10.1002/joc.1528

Immerzeel, W. W., Beek, L. P. H., Konz, M., Shrestha, A. B., & Bierkens, M. F. P. (2012). Hydrological response to climate change in a glacierized catchment in the Himalayas. Climatic Change, 110, 721–736.

Immerzeel, W. W., van Beek, L. P. H., & Bierkens, M. F. P. (2010). Climate change will affect the Asian water towers. Science, 328, 1382–1385. doi:10.1126/science.1183188

IPCC (2007c) Climate Change (2007) : Climate change impacts, adaptation and vulnerability– Summary for Policymakers. Contribution of the Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 22

IPCC. (2007). Climate change 2007: Impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC intergovernmental panel on climate change. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), Assessment (p. 976). Cambridge, UK: Cambridge University Press.

Kaab, A., Berthier, E., Nuth, C., Gardelle, J., & Arnaud, Y. (2012). Contrasting patterns of early twenty-first-century glacier mass change in the Himalayas. *Nature*, 488, 495–498.

Khattak, M. S., Babel, M. S., & Sharif, M. (2011). Hydro-meteorological trends in the Upper Indus River basin in Pakistan. *Climate Research*, 46, 103–119. doi:10.3354/cr00957

Khattak, M. S., Babel, M. S., & Sharif, M. (2011). Hydro-meteorological trends in the Upper Indus River basin in Pakistan. *Climate Research*, 46, 103–119. doi:10.3354/cr00957

Kothyari, U. C. and Singh, V. P. (1996). Rainfall and temperature trends in India. *Hydrol. Process*, 10, 357–372.

Kulkarni, B.D., Deshpande, N.R., Patwardhan, S.K., Bansod, S.D. (2014). Assessing Hydrological Response to Changing Climate in the Krishna Basin of India. *J Earth Sci Clim Change* 5: 211. doi:10.4172/2157-7617.1000211

Kumar, V., Jain, S. K. and Singh, Y. (2010). Analysis of long-term rainfall trends in India. *Hydrol. Sci. J.*, 2010, 55, 484–496.

Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Do¨ ll, P., Kabat, P., Jime´nez, B., & Scott, M. J. (2007). Climate change 2007 – the physical science basis, S*cience*. Cambridge: Cambridge University Press.

Laghari, A. N., Vanham, D., & Rauch, W. (2012). The Indus basin in the framework of current and future water resources management. *Hydrology and Earth System Sciences*, 16, 1063–1083. doi:10.5194/hess-16-1063-2012

Laghari, A. N., Vanham, D., & Rauch, W. (2012). The Indus basin in the framework of current and future water resources management. *Hydrology and Earth System Sciences*, 16, 1063–1083. doi:10.5194/hess-16-1063-2012

Loucks, D.P., Stedinger, J.R., Haith. (1981). Water Resource System Planning, Eaglewood Cliffs, NJ, Prentice Hall.

Lutz, A. F., Immerzeel, W. W., Shrestha, A. B., & Bierkens, M. F. P. (2014). Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. Nature Climate Change, 4, 587–592. doi:10.1038/nclimate2237

Mirza, M.M.Q. (2002). Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. *Global Environmental Change*, 12, 127–138. doi:10.1016/S0959-3780(02)00002-X

Molden, D. J., Vaidya, R. A., Shrestha, A. B., Rasul, G., & Shrestha, M. S. (2014). Water infrastructure for the Hindu Kush Himalayas. *International Journal of Water Resources*

Mujumdar, P.P. & Ghosh, S. (2008). Modeling GCM and scenario uncertainty using a possibilistic approach: application to Mahanadi River India. *Water Resour. Res.*, 44, W06407.

Nepal, S. (2012). Evaluating Upstream-downstream Linkages of Hydrological Dynamics in the Himalayan Region. PhD. Thesis. Friedrich Schiller University of Jena, Jena.

Nepal, S., Krause, P., Flu¨gel, W.-A., Fink, M., & Fischer, C. (2014b). Understanding the hydrological system dynamics of a glaciated alpine catchment in the Himalayan region using the J2000 hydrological model. *Hydrological Processes*, 28, 1329–1344. doi:10.1002/hyp.9627

Pal, I. & Al-Tabbaa, A. (2010). Long-term changes and variability of monthly extreme temperatures in India. *Theor. Appl. Climatol.*, 100, 45–56.

Pandey, P. (2015). Impact of Climate Change on The Hydrology of Mahanadi River Basin. M. Tech. Dissertation. Deparment Of Civil Engineering, National Institute Of Technology: Rourkela.

Pervez, M. S., & Henebry, G. M. (2014). Projections of the Ganges–Brahmaputra precipitation Downscaled from GCM predictors. *Journal of Hydrology*, 517, 120–134. doi:10.1016/j.jhydrol. 2014.05.016

Prasch, M., (2010). Distributed process oriented modelling of the future impact of glacier melt water on runoff in the Lhasa River Basin in Tibet. Ph. D thesis. Faculty of Geosciences, University of Munich (LMU).

Prasch, M., Marke, T., Strasser, U., & Mauser, W. (2011). Large scale integrated hydrological modelling of the impact of climate change on the water balance with Danubia. Advances in Science and Research, 7, 61–70. doi:10.5194/asr-7-61-2011

Praveen Kumar, N. S., Paul, K.S.R. & Rao, D. V. S. (2014). Assess the vulnerability of climate change in Krishna river basin of Andhra Pradesh. *International Journal of Development Research*, Vol. 4, Issue, 5, pp. 1059-1061.

Rao, P. G. (1995). Effect of climate change on stream flows in the Mahanadi river basin, India. *Water Inter.* 20, 205–212.

Rao, P. G., and K. K. Kumar (1992), Climatic shifts over Mahanadi river basin, Curr. Sci., 63, 192– 196.

Saraf, V. R. & Regulwar, D.G. (2015). Evaluating Potential Impact Of Climate Change On Hydrological Variables In Upper Godavari River Sub Basin, India Using Swat. *E-Proceedings of The 36th IAHR World Congress, The Hague, The Netherlands.*

Sawant, S., Balasubramani, K. & Kumaraswamy, K. (2015). Spatio-temporal Analysis of Rainfall Distribution and Variability in the Twentieth Century, Over the Cauvery Basin, South India. In Mu. Ramkumar et al. (eds.), Environmental Management of River Basin Ecosystems, *Springer Earth System Sciences*, Springer International Publishing Switzerland. DOI 10.1007/978-3-319-13425-3_2

Sharma, K. P., Vorosmarty, C. J., & Moore, III, B. (2000). Sensitivity of the Himalayan hydrology to land-use and climatic changes. *Climatic Change*, 47, 117–139. doi:10.1023/A:1005668724203

Shrestha, A. B. (2008). Resource Manual on Flash Flood Risk Management. Module 2: Nonstructural Measures. Vol. (includes CD insert), ICIMOD, 91 pp.

Shrestha, A. B., Wake, C. P., Dibb, J. E., Mayewski, P. A, (2000). Precipitation fluctuations in the Nepal Himalaya and its vicinity and relationship with some large-scale climatology parameters. International Journal of Climatology, 20, 317–327.

Shrestha, A. B., Wake, C. P., Mayewski, P. A., & Dibb, J. E. (1999). Maximum temperature trends in the Himalaya and its vicinity: An analysis based on temperature records from Nepal for the period 1971–94. *Journal of Climate*, 12, 2775–2786. doi:10.1175/1520-0442(1999)012,2775: MTTITH.2.0.CO;2

Singh V.P., Sharma B., Shekhar C, Ojha, P. (2004). The Brahmaputra Basin Water Resources, Kluwer Academic Publishers, ISBN 1-4020-1737-5.

Singh, A. & Gosain, A. K. (2013). GIS Based Hydrological Modelling for Climate Change Impact Assessment. *Greener Journal of Science, Engineering and Technology Research*. Vol. 3 (7), pp. 210-219.

Singh, N. and Sontakke, N. A. (2002). On climatic fluctuations and environmental changes of the Indo-Gangetic Plains, India. *Climatic Change*, 52(3), 287–313.

Singh, P., Kumar, V., Thomas, T., & Arora, M. (2008). Changes in rainfall and relative humidity in river basins in northwest and central India. *Hydrological Processes*, 22, 2982–2992. doi:10. 1002/hyp.6871

Subash, N., Sikka, A. K. and Ram Mohan, H. S. (2010). An investigation into observational characteristics of rainfall and temperature in Central Northeast India – a historical perspective 1889–2008. *Theor. Appl. Climatol.*, DOI: 10.1007/s00704-010-0299-2.

Subbaramayya, I. and Naidu, C. V. (1992). Spatial variations and trends in the Indian monsoon rainfall. *Int. J. Climatol.*, 1992, 12, 597–609.

Subramanian, V. (1978). Input by Indian rivers into the world oceans. Proc. Indian Acad. Sci., 87 A (E & P Sciences-2), No. 7, 77-88.

TA 7417- IND: Support for the National Action Plan on Climate Change. (2011). Appendix 4 Cauvery Delta Sub Basin Support to the National Water Mission Government of India. Governments of Punjab, Madhya Pradesh and Tamil Nadu. Asian Development Bank.

Wiltshire, A. J. (2014). Climate change implications for the glaciers of the Hindu Kush, Karakoram and Himalayan region. The Cryosphere, 8, 941–958. doi:10.5194/tc-8-941-2014

16

Climate Change: Cause And Challenges For Hydrological Status In Plateau Region Of Jharkhand

Jitendra Shukla

Introduction

Climate change is one of the biggest manmade global environmental challenges in front of the world. Climate change is a change is the statistical properties of the climate system when considered over a long period of time regardless of cause. The United Nations frame work convention as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate Variability observed over comparable time periods.

Climate change is one of the most serious challenges and problems infront of the hydrological status which supports the global economy. It refers to any significant change in measures of climate (Such as temperature, precipitation or wind) lasting for an extended period (decades or longer). There have been cooling and worming of the earth over the last billions of years but the changes have not so been extremes as it witnessed in the present. This change affects people, plants and animals.

Effect of climate change on the hydrological status includes:

(i) Surface temperature increase and everything else affected by increase in green house gases.
(ii) Changes in the range of distribution of precipitation
(iii) Drying of river beds, lakes, aquifers shrinkage in the water sources.
(iv) Lengthening of growing seasons
(v) Occurrences of extreme weather events
(vi) Regional depletion in the level of ground water
(vii) Short growth of vegetation
(viii) Drying and shrinkage in the source heads of streams
(ix) Decline in the growth of forest
(x) Decline in the regional formation of clouds.

Objectives:

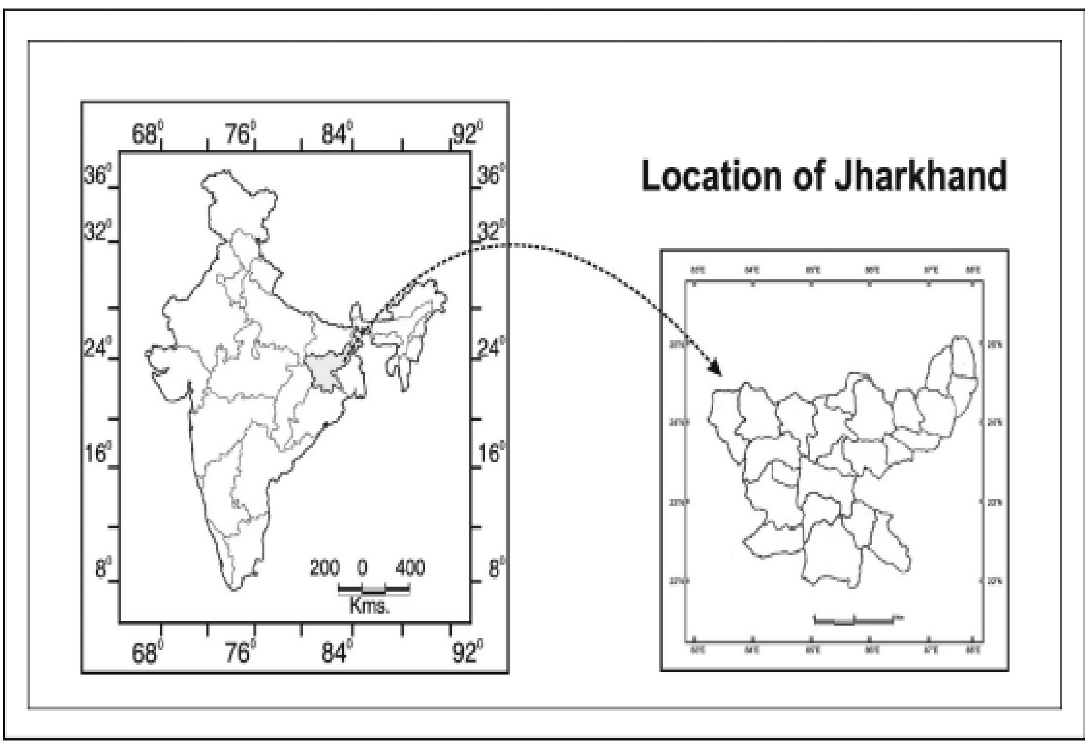
(i) To study the cause of climatic change at the regional scale.
(ii) To lime light the challenges of the climate change specially on the hydrological status in the plateau region of Jharkhand.
(iii) To suggest suitable policy measures to control over this problem in the Jharkhand.

Methodology:

The present study is based on secondary data. Annual time series data is used for the entire period from 1950-2015. The data collected to post and pre-reforms and also sub-period which are made use for comparison. The factors as variation in the precipitation occurrences, extreme weather events' regional depletion in the ground water level, drying stream's source heads, depleting vegetation and ever increasing surface temperature are stared. The secondary data is obtained from published as well as documented sources, pertinent literature. The reports, summary of ISID, IPCC reports have been used.

Study Area

Geographically, the state of Jharkhand covers an area of 79,714 KM^2 and lies between the latitudes $21^0$58'N to $25^0$18'N and longitudes $83^0$22'E and $87^0$57'E. The state is characterized with plateaus of different elevations, valleys, scarps, ridges, hillocks etc. Tropical moist deciduous and tropical dry deciduous forests comprises the natural vegetation and are found over hilly landscape, rough terrain, narrow valleys, steep scarps and poorly accessible areas Jharkhand state constituted by 05 division, 24 districts, 259 C.D. blocks, 4423 Gram Panchayats and 32,615 villages.



Results and Discussion

Factors that can shape climate are climate forcing. These include such process as variations in solar radiation, deviations in Earth's orbits, mountain building and continental draft and changes in Green house gas concentrations. There are a variety of climate change feed backs that cam amplify or diminish the initial forcing. Some parts of the climate system, such as the oceans and ice caps and responds slowly in reaction to climate forcing because of their large mass. Therefore, the climate system can take centuries or longer to fully respond to new external forcing.

The most important factor of climatic change over the globe in general and the plateau area of Jharkhand in particular are : (i) Anthropogenic warming, water vapour and several other gases (GHGS) such as carbon dioxides (CO_2), Nitrous oxides (N_2O), Methene (CH_4) and Chlorofluorocarbon (CFC_s) warms earth's atmosphere because absorb and remit radiation.

Table – 1

Relative contribution of trace gases in the Atmospheric Global warming (Botkin and Keller, 2000)

Sl. No.	Gases	Relative Contribution (in %)	Growth rate per year (in %)
1.	CFC	15 – 25	5
2.	CH_4	12 – 20	1
3.	O_3	8	0.5
4.	N_2O	2	0.2
5.	Total	40 – 50	-
6.	CO_2	50 – 60	0.3 – 0.5

Radio active forcing which are used to measure of influence that a factor has in altering the balance of incoming and outgoing energy in the earth atmosphere system is an index of the importance of the factor as a potential climate change mechanism combing radio active forcing due to increase in CO_2 , CH_4 and N_2O +2.30 w/m^2 and the rate of increase time is very likely to have been unprecedented more than 10,000 years. The CO_2 radioactive forcing increased by 20 percent from 1995-2005, the longest change is any decade. Changes in Solar irridance since 1750 are estimated to cause a radioactive forcing of 0.12 w/m^2.

Impact of climate change has direct bearing upon hydrological status in the plateau region of Jharkhand. It has been identified as :

(a) Erratic monsoon with serious effects on rain-fed rivers, water and power supply, and the underground water level.

(b) Crisis of fresh water in the urban area and increase in fluride in the drinking water.

(c) Increased frequency and intensity of drought and floods.

(d) Studies indicate that over 50 percent of Jharkhand are likely to shift in forest types, adversely impacting association biodiversity, regional climatic dynanamics as well as livelihood based upon forest products.

Jharkhand states marked by plateau region with highly undulating surface. Surface and ground water resources have been badly affected by the topographic nature. A very less amount of rain water are preserved on such a terrain.

Climate change has influenced moisture content of the atmosphere. A warmer climate has accelerated the hydrologic cycle, altering rainfall magnitude and timing of run-off, warm air holds more moisture and increase evaporation surplus moisture. With more moisture in the atmosphere rainfall events tend to be more intense increasing the potential for floods. However, if there is little or no moisture in the soil to evaporate the incident solar radiation goes into raising the temperature. Which could contribute to longer and more severe oronghts (Mall, C. C. Gupta, A. K. 2008) It has can be observed from the table that the continuous depletion of groundwater at the regional scale is due to the decrease in soil moisture. It has accelerated the drought episodes and finally ground water level in different areas. Study reveals that increasing temperature and decline in rainfall have reduced be recharge and ground water level.

Table – 2

Trends of rainfall in Jharkhand

Year	Annual Rainfall (in millimeter)
1991	1074.38
1995	939.05
1996	935.02
1997	1048.07
1998	852.35
1999	735.42
2000	842.32
2001	878.39
2002	942.15
2003	921.16
2004	832.25
2005	739.39
2006	724.78
2007	812.35
2008	798.35
2009	942.35
2010	901.52
2011	917.32
2012	842.31

Source : India Meteorological Dept (IMD), Govt. of India

It is apparent from the table that the annual rainfall is not found in definite trend. The is frequent change in rainfall over the year. The minimum rainfall observed in 2006. Jharkhand is heavily dependant on the monsoon to meet its water needs.

Subtle changes have been noted in the monsoon rain patterns by scientist IIT Delhi. They warn that there will be decline in Summer rainfall by 2050s. Relatives small Climate Changes causing large water resources problems. However little work has been done on hydrological impacts of possible climatic change for Indian regions / basins.

Status of water scarcity in Jharkhand

Out of total 32,615 villages, 52% villages 16,969) facing acute shortage of drinking water in the Jharkhand states. Out of 3.23 lakhs of drinking water wells of this state will stop providing water for drinking purpose. The total no. of handpumps in the state is 3,41,860. Out of it 2,96,000 hand pumps are functional and rest 45,860 are defunct. It is due to continuously decline of ground water. Most of the district of the state facing acute shortage of water supply.

Table – 3

Status of Major water shortage oams / reservoirs of Jharkhand

Name of Dams/ Reservoirs	Water level in 2015	Water level in 2014	Status of Shortage of Water level	Observation
Hatia Dam	9.26'	28'	19 feet below than previous year	Capacity in declaiming
Rukka Dam, Ranchi	1917'	1978	61' less than previous yearslowering	Water capacity
Gonda Dam	2110.8'	2118.0	Seven feet below than previous year	Capacity declaiming to supply water
Charaba Dam Hazaribagh	10'	22'	12' less than previous year	Unable to Supply Water
Adityapur, Jamshedpur	15'	35'	20 feet less than previous year	Sever water crisis
Tenughat Dam Bokaro	—	—	As compared to previous year hardly 33% water is available	Situation is alarming
Maithan Dam, Dhanbad	140^0 meter	145^0 meter	5 meter mess	Situation is alarming
Hira Dam Chatra	—	—	—	Situation is alarming
Kalaghagh Dam Chatra	—	—	—	Situation is alarming
Konara Chatra	—	—	—	Situation is alarming
Panchayat Hill Dam	—	—	—	Situation is alarming
Tilaiya Dam	—	—	—	Situation is alarming
Masanjore Dam	—	—	—	Situation is alarming

Source: Department of water resource, Govt. of Jharkhand.

The volume of water supply has been decreased in Hazaribagh, Koderma, Tilaiya, Ranchi, Latehar, Dumka, Jharia, Deoghar etc. too.

Origin Sources of major rivers of Jharkhand are in Danger:

Most of the important rivers sources are in danger. The Damodar river originates at a place chullapani. Gradually the availability of water bodies at this places is decreasing and thus the Damodar River is in danger. The Swarnarekha river is being treated the life line of Jharkhand states. It orginates at Ranchua, Piska Nagri. At its origin point water flow is decreasing fastly. Likewise the source region of South Roel, Karo, North Koel are also depleting rapidly. Most of the water falls dried away in most of the month.

Jharkhand is known for a number of aquifers. Most of the aquifers have been oried due to lowering of water table and insufficient recharge of Ground water in Jharkhand state mainly stored in secondary porosity features or void spaces developed as result of weathering, fracturing, joining shearing or faulting phenomena. The gneisses and granites rocks with associated schists and quartzite's constitutes the main consolidated rock terrain. Major portion of the state occupied by hard rock which are devoid of primary porosity and occurrence and movement of ground water is controlled by the joints fractures, and fissures. The water table in the consolidated formations is continuously lowering. In most of the urban centre water table has gone to 1000'. Sources of ground recharge in Jharkhand is the vertical perolations of rainwater. Vertical percolation is hindered by the presence of highly weathered and metamorphosed rocks. Depression in ground water circulation. Restricted ground water circulation favours concentration of fluoride. Fluoride concentration in ground water is serious problem in Jharkhand.

Table – 4

Yearwise status of fall of underground water in Jharkhand

Year	Fall in water table (m)
2004	07
2005	09
2006	11
2007	13
2008	17
2009	17
2010	20
2011	24
2012	25
2013	28

Source : Central Ground water Board, Ranchi according to reports of GSI, continuous depletion of ground water of Jharia is 106%, Godda 122%, Jamshedpur 132% and Kanke 135%, Ramgarh 93% and Dhanbad 145%. It all these area have been declared as ranger zone.

Table – 5

Fall of underground watertable in different places in Jharkhand

Name of the District	Fall of underground water
Ranchi	52 Feet
Jamshedpur	56 Feet
Godda	61 Feet
Chas	50 Feet
Giridih	51 Feet
Palamau	49 Feet
Chatra	47 Feet
Pakur	48 Feet
Simdega	10.6 Feet
Gumla	13.8 Feet
Lohardaga	14.9 Feet
Hazaribagh	12.7 Feet
Singhbhum	13.8 Feet
Bokaro	13.4 Feet
Dumka	12.1 Feet
Jamtara	11.8 Feet

Source : Deptt. Of Irrigation and water resources, Govt. of Jharkhand.

Increasing extreme weather events

Climate change is reflected in the increasing fluctuating weather cycle with unpredictable cold waves, heat waves, flesh flood and drought. The most noticeable of such event in terms of drought causing mass level damage of fauna and flora statewide drought in 2009, 2011, 20014, 2015 extremely increasing cold waves heat waves and prolonged dry spell, abnormal temperature in January and February and Rainfall deficiency in monsoon season. The entire events took a heavy toll on hydrological status and often causing loss of human life.

Conclusion

From the above discussion following conclusion may been drawn :

1) Regional climatic models suggest 2.5-5 degrees Celsius of mean surface temperature in Jharkhand.
2) Hydrological cycle is likely to be altering that drought and flood intensity is increasing.
3) Ground water potentially is decreasing due to less recharge and rainfall.
4) Severity of floods and droughts are becoming more severe.
5) Shrinking riparian, source head of river, aquifers, watersheds and drying of pond, lakes etc. in Jharkhand state is major challenges and add considerable stress to our societies and to the environment. From shifting weather patterns that threaten food production and increase the risk of catastrophic flood droughts.

References

Ahlawat, Sharmila (2008).G lobal warming : causes and solutions, *Kurushetra, vol. 56, No. 9,* P.P. 31-33, July.

IPCC (Intr Governmental Panel on climatic change (2007) : Climate Change : The Physical Science basis, extracts from the IV assessment Report, Survey of Environment, 2007, The Hindu, P.P. 147-55.

Nayan, Rajiv (2006). Changing Climate: Just do something Right now, *Chronicle, Nov*, P 20.

Narain, Sunital (2008). The mean world climate change, *Down to Earth*, July 16-31, P. 7.

Reddy, D. R. Sreenivas, G. N. R. G. Verma (2010). Climate change and its impact on agriculture. In *Climate Change And Agriculture Over India,* 320.

http://www.ipcc.ch/ipcc reports

http:moef.nic.in

http:/news.bbc.co.4k/2/hi/science/nature/722087 stem: “Climate ‘could devastate Crops’” BBC News.

17

Imprints Of Climate Change: A Study Of Gandeshwari Rivulet Zone, Bankura, West Bengal

Malavika Sinha

The river links geographical space and geographical attributes with geological time scale. The river Gandeshwari lies in edge of Purulia Bankura ductile shear zone. This study covers the empirical identification of the geographical imprints on land and to make a liaison between geographical imprints and climatic changes. The climatic system provides water (matter) in forms of precipitation to river system. The earth system (geology, geography) provides slope (path) and surface runoff gets energy (momentum) by flowing on it. Now this region lies in Am type of climate. This area has experienced sequential climatic diversities since Azoic to Quaternary (Gutierrez 1990).

Objective

The objective of this study is to accesses the sequential changes in climatic conditions through the geological era with help of animal fossil, rock strata and landform configuration of the Gandeshwari basin area.

Study Area

Gandheswari river is 49 kilometers (31.36 miles) long, flows in Bankura district, West Bengal (Fig.1& Table 1). It originates near the border zone of District Purulia and Bankura. It flows side by the Shushunia Hill (height 440 m, 23° 22' 30'' N and 86° 58' 200'' E) and occupies an area of 389 square km (approx) and north of Bankura, it meets the river Dwarakeswar (Fig.2). It is subject to sudden flooding during rains (flash flood). The river is flowing since Silurian era (Paleozoic era) when warm and green house era has started (Mandal & Ray, 2009). The site and situation of the water course was full of fallacies. The evolution of that surface runoff has started during late Carboniferous to early Permian era (Mandal & Ray, 2009). During Mesozoic fissure eruption (Triassic, Jurassic and Cretaceous) the flow was interrupted but the location has not shifted. During Cenozoic (Eocene to Miocene) the flow direction had changed (Pal 2014) by the tectonic activities.

Table: 1

Attributes Of Gandeshwari Rivulet

Name of River	Gandeshwari (Fig 1 & 2)
River System	Tributary of Dwarekeshwar River (upto 5th order of stream) (A.N.Strahler, 1964)
Length of River	49 km
Basin Area	339km² (approx) (It covers Chhatna Block, Bankura I and II Blocks)
Originating Point	Near Purulia and Bankura District Boundary at extreme north
Remarkable point	Shushunia Hill (Bankura District, Chhatna Block)
End Point	Meets Dwarekeshwar River Near Bhujsahar Village
Predominant Fact about River	Lineament guided rivulet (mainly the lower confluence)

Methedology

Here, the basic concept of Hotton's uniformitarianism; 'present is the key to the past' (uniformitarianism, 2016) has taken as a focal point of study to assess the palaeo-geomorphic history of Gandeshwari rivulet zone. On the basis of palaeontological and geological information, the palaeo geomorphic situations as well as identification of past climatic situation have been identified. The study is purely imperial. The basic rock types and mineral composition have been studied in references with its origin and their recent changes have been identified in reference to weather condition.

Study of Climate Change and Time Scale

The single unit (in terms of time) of climate is approximately 35 to 40 years. Therefore the discussion of climatic change covers in cyclic scale and only the variation of weather phenomenon governs by the graded and steady time scale. The evolution, in terms of climate phenomenon, landforms configurations, tectonic as well as evolution of flora and fauna all are goes in hand in hand with cyclic time scale. The cyclic changes of climatic conditions are very common facts; it includes tens to millennia. The discussion of climate changes is only possible in cyclic scale and variation of weather phenomenon includes steady state scale only. Here the discussion of climatic variation covers with the perspective of rock strata and their age of occurrences. Here to identify the sequential changes of climatic phenomenon of *Rurh* Bengal, the Gandeshwari river basin is selected which may acts as a sample unit to depict the climatic sequences of whole area.

Climatic Change and Evidences From Rock Stratas

This river Gandeshwari began to flow during Silurian on the ancient craton which reflects the azoic formation (Mandal & Ray, 2009). Since Silurian this surface runoff has modified by the various sequential formations and climatic conditions. The composition of rock strata are the assimilation of both as well as geology and climatic conditions too. The present land configurations and lithology are the relicts of past climatic events which are described by cyclic scale. Here the Chhotonagpur Gneiss and Gneiss complex and Granite are the most common rocks which are the result of Proterozoic formation and the occurrences of anorthosite is the reflection of Proterozoic orogeny with dry climatic condition (Ahmad, 2007). Then Gondwana formation evolved with warm and humid condition (Talukdar, Chottopadhyay, & Saynal, 2012). During Tertiary (Pleistocene), the sediment deposition on river bed as well as the land mass was the dominant fact and also formation of quartzite, sandstone, shale and limestone are the most common facts (Valdiya, 2016).The anorthosite and the existence of amphibolites are the evidences of retrogressive metamorphism which has covered the northern patches of the basin area. Here no tertiary orogeny has taken place but instead of absent of tertiary orogeny, the proterozoic orogeny has taken place. The dolerite, pegmatite, aplit, vein quartz, granite, gneiss, are most common rocks of the study are and all these are the pre coal seam formation of Carboniferous era. The formation of sedimentary rock is the reflection of Permian warm phases and the conglomerate, sand stone composes with quartz and feldspar, with gneiss which composed with sillimanite and kyanite bearing quartzite are observed in Shushunia hill zone is the reflection of Permo Carboniferous glaciations and warm climatic phases during the late Permian era (Ghosh, 2010). The mature sedimentary rocks of arenites are observed near the Bhujsahar village. This is the evidence of Gondwana Super group with a unique sequence of fluviatile rock deposit in Permo Carboniferous (late Carboniferous and early Permian) time. The evidence of Plio Pleistocene formation such as shale is very common in lower catchment area with combination of humid climatic condition. Here, the Quaternary glaciation was not the dominant fact. The Gandeshwari river basin area has crossed a long path of climatic variations since Azoic, Proterozoic, Palaeozoic (carboniferous) and Tertiary (lateritic terrain) with the phases of cold to warm situation, warm to cold, cold and warm-humid phases simultaneously.

Table 2
Evidences Of Climate Changes Of Gandeshwari River Basin

Sl No.	Climatic Type	Geological Era	Time Rivulet Zone	Rock Composition of
	Desert or semi Cold desert climate	Proterozoic (Silurian)	*443.7* to 416.0 million years ago	granites, Chotonagpur gneisses and few ultra basic rock (Fig.2)
	Cold Snow ball	Carboniferous (cooler and drier)	358.9 million years ago	The dolerite, pegmatite, aplit, granite, gneiss, are most common rocks of the study area. It contains mostly sediments formed during Carboniferous (Fig.2)
	Warm Phases of Climate	Permian (Ice Age) mid-Permian period as the climate gradually warmed and dry climate, In the late Permian period, the drying continued although the temperature cycled between warm and cool cycles	298.9 million years ago	Lacustrine alluvial deposit. The mature sedimentary rock of arenites is observed near the Bhujsahar village. This is the evidence of Gondwana Super group with a unique sequence of fluviatile rock deposit in Permo Carboniferous (late Carboniferous and early Permian) time.
		Mesozoic	252.17 - *66* million years ago	No imprint has observed

Arid- Semi Arid	Cenozoic Pliocene The global average temperature in the mid-Pliocene (3.3–3 mya) was 2–3 °C higher than today, and carbon dioxide levels were the same as today	(Cenozoic Era 66 - 0 million years ago) 5.333 to 2.58 million years	quartz and feldsparThe Shushunia hill zone covers with gneiss which composed with sillimanite and kyanite bearing quartzite. It is metamorphosed form of peri-alluminaus sedimentary rock of Pliocene formation
Sub Humid	Quaternary (Pleistocene) Era of dazzling white ice and snow, and thereby Earth's	2,588,000 to 11,700 years ago	Formation of Lateritic nodules
Sub humid	Quaternary Climate Holocene (Warm Phases)	11,700 years back	Shale and Mud Stone QuartzFossil of Several plants and mammals
Sub Humid	1000 AD	1000 years	Humid climate(Shushunia as bornhardt and monodonack)
Do	1916-2016AD	100 years	Static Humid climate (evidences from fossils)

Sources: (Pal, 2014)

Climatic Change and Palaeontology

Palaeontological analysis gives the idea about climatic changes of Gandeshwari rivulet zone (Dutta, 1976). The evidences of humid climate observed in faunal fossils (Table 3) who had been surviving in that zone with wet climatic conditions (Neogi, 2011). Presence of *Bas namadicus (recent caw),* the fossilized remains of *Palaeaxadan namadicus* (extinct elephant species) found from this region as belonging to a period before 40000 BC (beyond the limit of the sensitivity of the instrument, Jadavpur University). The fossils of Giraffe and Zebra (Table 3) are the evidences of semi arid to arid climatic condition (Pal, 2014) during late Permian. A large collection of animal fossils have found in this area (Table 3). Those fossils (animal) depict the stratigrafic sequence of the alluvial deposits and those were placed in the late Pleistocene-Holocene era. Directorate of Archaeology, West Bengal collected more than two thousand artifacts ranging from Chello-Acheulian to Neolithic era (Sankhyan, Dewangum, & Chakraborty, 2014, Aug.) from this basin area. The late Permian was the warm and Humid (Neogi, 2011) (evidence from the fossil of antelope, Table 3). The geo-stratigraphy reveals that, clay beds (including the recent one) which might indicates an arid and semi arid climatic condition (Valdiya, 2016) in the region during the early Stone Age (Holocene). In such climatic condition shale formation of early Pleistocene era is very common facts and the Pleistocene is the synonyms with Paleolithic era and the early stone tool industry by hominids are found in this riverine area (Chakraborty, 2009). But the direct existence of early hominids cleared form the fact fossil of foot print found in Rampur, Bankura block (Fig. 3). Those foot print lies in shale layer which is the product of tertiary formation. Palaeontological analysis gives the idea about climatic changes of Gandeshwari rivulet zone (Dutta, 1976). The Holocene could offer a stable climate for a long time, during which agriculture and civilization could develop (Gutierrez, 1990). Many believe that the declining Milankovitch isolation is the case of the general cooling trend during Holocene (Gutierrez 1990).

Table 3

Palaeontological Sites (Evidences Of Climate Change) Gandeshwari River Basin (Climatic Phenomena During Pliocene To Holocene)

Sl No.	Location	Location Code & JL No	Geographical Location	Animal Fossil	Scientific Name of Animal	Part of Fossil
1	Jamthal Village, Near Shushunia Hill	02006500 & 8	23°23'22" N & 86°56'28"E	Giraffe (Arid animal)	Linn, Giraffe Camelopurdalis	End of the tibia
2	Jhikoria	02008400 &27	23°27'17" N & 86°55'24"E	Do	Do	Upper right 3rd molar, left upper 1st molar, left upper 3rd molar
3	Jhikoria Village	Do		Gray Leopard (humid animal)	Linn, Panthera Purdas	Equvssp. Right 1st lower premolar
4	Do	Do		Antelope (Humid animal)	Cervicapre Lnn	Molar
5	Gogra		23°27'13" N & 86°57'28"E	Swamp deer (Humid Climate)	Ceruvs Duvauceli Cuvier	Lower left 2nd molar
6	Kayerbani	02026900 & 212	23°25'50" N & 86°56'E	Zebra (Animal of dry climate)		Premolar
7	Shushunia	02008400 & 89	23°23'40" N & 86°58'40"E	Deer (Humid climate)	Cervus Duvauceli Cuvier	Fragments of antler
8	Sikaria	NA	NA	DO	DO	Do

Since 1916 no significant change in weather phenomenon has observed in its basin zone. The hill Shushunia (437m) is abruptly high from its surrounding plain. It is just like an isolated hill of bedrock standing conspicuously above the general level of the surrounding area. It is left as remnants of erosion, because of their more resistant rock composition; commonly they consist of quartzite or less jointed massive volcanic rocks (Mukherjee, 1995). This hill appears like a monadonack. This physical appearance, geological structure depicts that this land configuration is the result of humid climate since last thousand years (Gutierrez, 1990).

The weather phenomenon of last centuries has presented in the graphs (Fig 4, 5, 6, 7). The weather phenomenon (such as monthly average temperature, precipitation, average diurnal range of temperature through century) of last century depicts a steady trend in weather attributes. No significant weather trend has observed here since 1901 (on an average 40 year is the single unit of climate). Here it is clear that the seasonal fluctuation and slight variation in annual weather phenomenon are very normal fact but no significant trend has observed in weathered phenomenon (graded scale).

Result

Here the climate is ever changing and that its variation has been identified cyclic scale. The discussion of climatic evolution (through cyclic scale) with the help of palaeontological evidences and study of rock strata has provided complete information about palaeo-weather phenomenon. Recent world goes through various method of climatic study such as oxygen isotope, atmospheric composition, and sea level study so on. But the contemporary fluvial geomorphologic imprints on the earth's surface are the combine effect of under lying geology, climatic sequences. Here the survey and analysis of present situations explained its back ground.

It states that current geologic processes, occurring at the same rates observed today, in the same manner, account for all of Earth's geological features. Thus, it assumes that geological processes are essentially unchanged today from those of the unobservable past. The Uniformitarian slogan is, "the present is the key to the past" (D, 2002). The study of fossil (flora and fauna) is the way to get information about palaeo biotic world and as well as climatic condition too. Actually fossil study is nothing but the remnants study of the past event. Similarly present earth situation (in every aspect) is the living remnants of its past journey. If someone is thinking about the Human's cultural evolution, then the attitude and genetic combination of present alive homo-sapience helps to study its ancestor.

Here the river channel analysis on the basis of present gesture provides an idea about palaeo geomorphic conditions and simultaneously predicts future too. Gandeshwari rivulet zone is the container of geological history of azoic igneous formation, Proterozoic-orogeny, Permo-carboniferous glaciations, Gondwana shear zone, Pleistocene deposition and Tertiary terrain. The palaeontological study and the study of rock strata provide palaeo-climatic information of Gandeshwari rivulet zone. This region clearly depicts the evidences of series of climate changes; arid to semi arid climate, Pleistocene glaciations to sub humid climate in Quaternary (Holocene) era.

This small rivulet zone is the relicts of azoic, proterozoic, palaeozoic (carboniferous) and tertiary (lateritic terrain) formations with the phases of cold and warm to cold and then warm to humid phases simultaneously. The Gandeshwari river valley is a document site of sequential climatic variations of *Rarh* Bengal.

References:

Ahmad, A. K. (2007). Geochemistry of Mafic Dykes in part of Chotonagpur Gneissic Complex: Petrpgenetic and Tectonic Implications. *Geochemical Journal , vi*, 173-186.

Asthana, R. K. (2011, Feb). Dumortierite from Susunia Hill, Bankura District, West Bengal. *Current Science* .

Bhattacharyya, M. (1987). Stages of prehistoric culture in Rarh Bengal (A recent Exploration). In a. B. B.M. Pande (Ed.), *Archaeology and History: Essays in memory of A. Ghosh*, *1*, pp. 47-52. New Delhi.

Chakraborty, D. K. (2009). *Archaeology of Easten Indis: Chhotonagpur Plateau and West Bengal.* New Delhi: Munshiram Manoharlal.

Dutta, A. K. (1976). Occurrence of fossil lion and spotted hyaena from Pleistocene deposits of Susunia, Bankura, West Bengal. *Dutta, A K. (1976), Occurrence of fossil lion and spotted hyaena from PleistocenJournal Geological Society of India , 17(3)*, 386-391.

Ghosh, A. K. (2010, October). Exhumation History and Tectonics across Purulia-Bankura Shear Zone: Constraints from Apatite Fissuion Trck Analysis. *International Journal of Scientific & Engineering Research* , 1556-58.

Gutierrez, M. (1990). *Climatic Geomorphology.* London: Elsevier.

Mandal, A., & Ray, A. (2009). Petrological and Geochemical Studies of Ultramaficand Maficrocksfrom North PuruliaShear Zones (eastern India). *Journal ofGeological Society of India , 74*, 108-118.

Mukherjee, P. K. (1995). *A Text Book of Geology.* Calcutta: TheWorld Press Private Limited.

Neogi, S. (2011). Scope of Geoarchaeology in Depicting theEarly Hominis Environments in the Gandeshwari River Basin of Bankura District, WetBengal. *e-Ttraverse, TheIndian Journal of Spatial Science , II nO.2*.

Pal, T. K., & Nandi, S. (2014). Records of the Zoological Survey of India. *Occational Paper 337* (pp. 12-178). Kollkata: Zoological Survey of India, M- Block, New Alipore, Kolkata- 700 053.

Sankhyan, A. R., Dewangum, L. N., & Chakraborty, S. (2014, Aug.). *Re- Looking at Prehistoric Susunia, West Bengal, West Bengal*. Retrieved from www.researchgate.net/pub.

Talukdar, M., Chottopadhyay, M., & Saynal, S. (2012). Shear Controlled Fe Mineralization from Parts of South Purulia Shear Zone. *Applied Geo- Chemistry , 14* (4), 496-508.

uniformitarianism. (2016). Retrieved from https://en.wikipedia.ogr/wiki/uniformitarianism.

Valdiya, K. S. (2016). *The Making of India: Geodynamic Evolution.* (2nd, Ed.) Switzerland: Springer.

Figure 1
Study Area

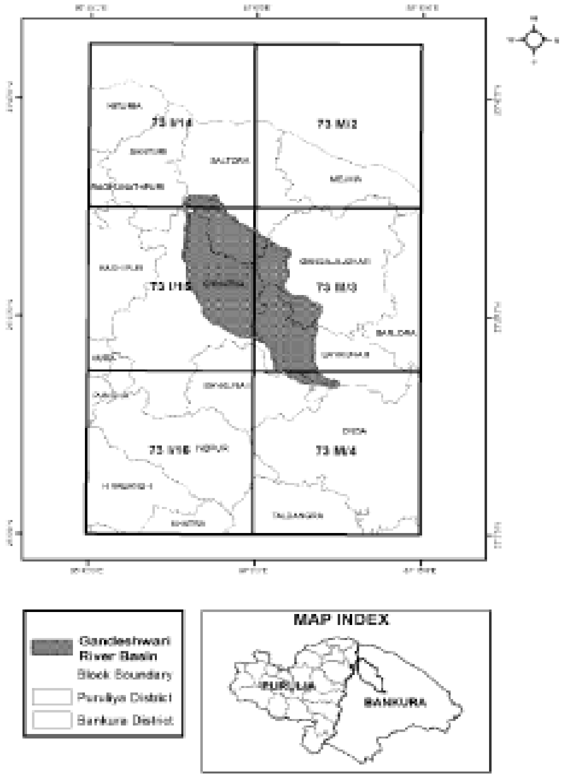


Figure 2
Gandeshwari River Basin

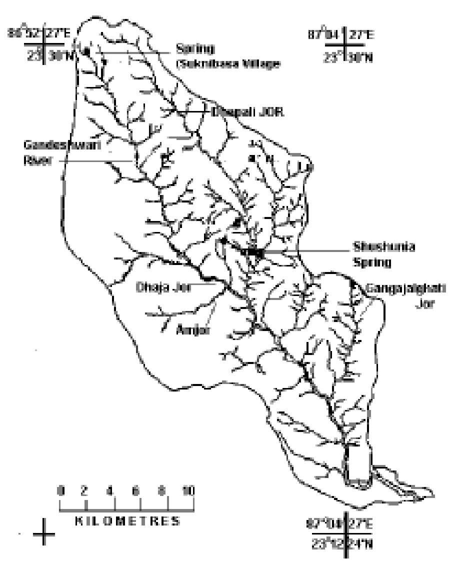
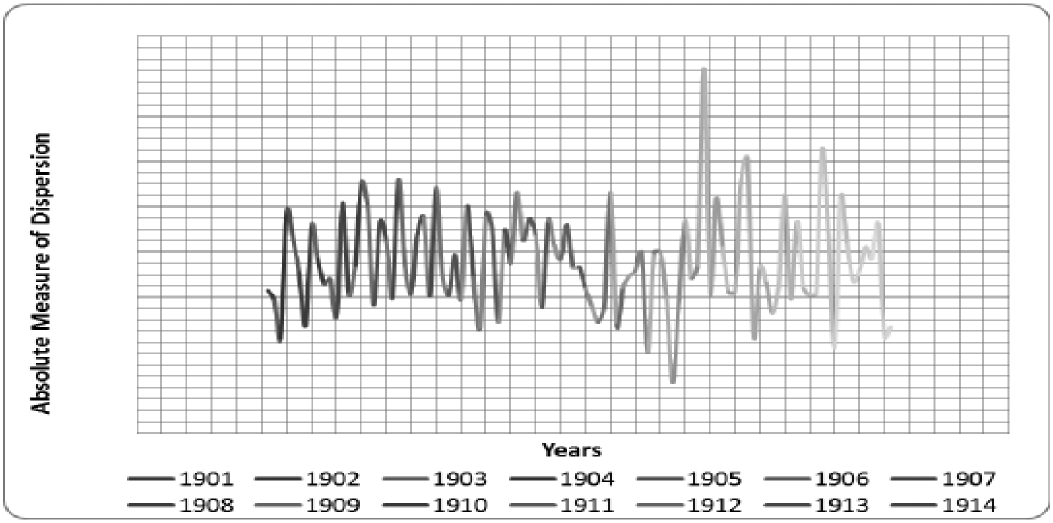


Figure 3

Fig 4

Rainfall Disper

(1901-2008) Gandeshwari Basin Area



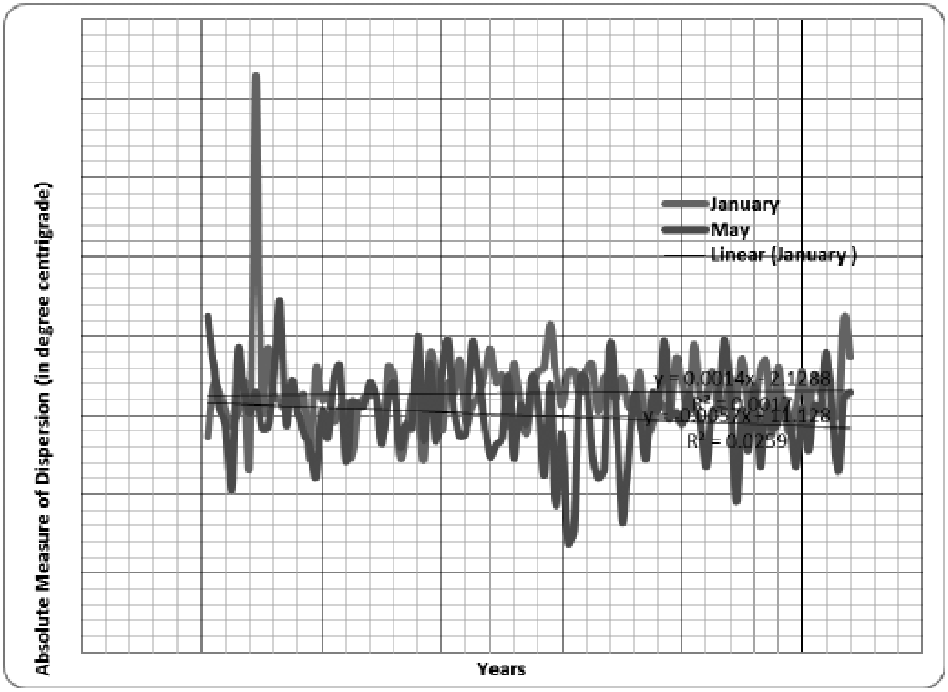
(Source: Indian Meteorological Portal)

Figure 5

Temperature Dispersion

(1901-2008)

Gandeshwari Basin Area

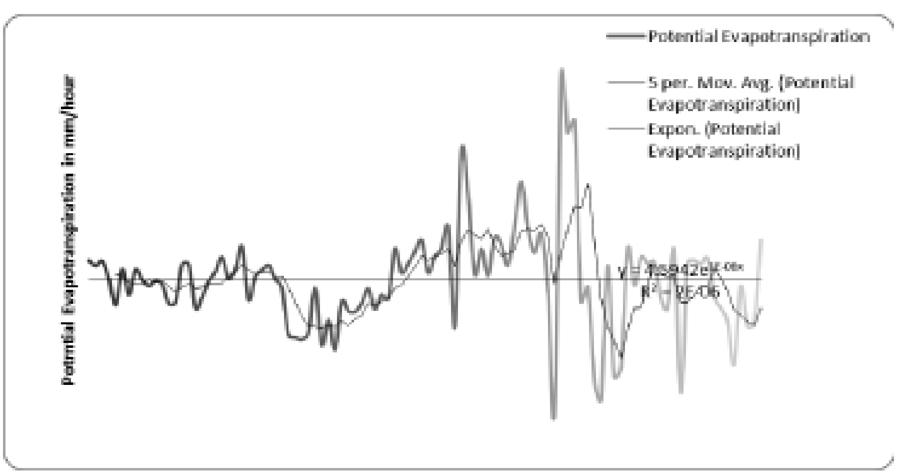


(Source: Indian Meteorological Portal)

Figure 6

Potential Evapotraspiration (Pet) Of Gandeshwari Basin

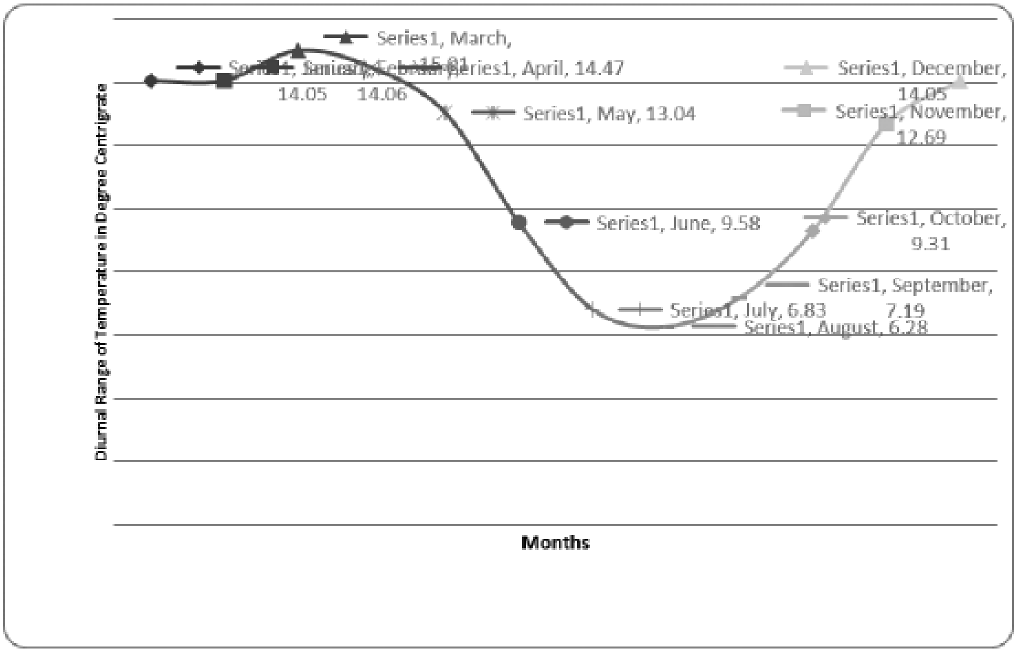
(1901-2002)



(Source: Indian Meteorological Portal)

Figure 7

Diurnal Range Of Temparature (1901-2012)



(Source: Indian Meteorological Portal)

18

Morphometry and Landuse Landcover Based Multi-Criteria Analysis for Assessing the Soil Erosion Susceptibility Using Landsat TM/ETM+ Digital Data : A Case Study of Sobha Watershed, a Part of West Bengal and Jharkhand

Mousumi Roy and Uttam Mukhopadhyay

Introduction

Soil erosion is a major environmental and agricultural problem worldwide. Although soil erosion is a natural process witnessed throughout the history, however in the recent years, it has greatly intensified (Lal and Stewart 1990; Morgan 2009). Each year, about 75 billion metric tons of soil is removed from the land by wind and water erosion, with most coming from agricultural land (Myers 1993). This degradation of the arable land imposes immense threat to the economy of a region (Pimentel et al. 1995). The threat is even greater in areas of complex plateau fringe like Purulia-Jharkhand, where it is the main driver behind several of the natural hazards such as land collapse and flash flood, often responsible for huge loss of life and property (Huggel 2004). Moreover, human activities such as deforestation, overgrazing and land use changes greatly influence the rate of soil erosion when compared to the natural agents (Pradhan 2010). For understanding and managing soil erosion, characteristics of the land which influence erosion need to be studied. Topography, landcover (LC), amount and intensity of rainfall and physicochemical properties of soil are the main variables which play a significant role in the erosion of the landscape (Christopherson 1997; Romshoo et al. 2012; Kavian et al. 2013). Studying these variables over a large spatial extent is a cumbersome task .Watershed level management is the most opted solution. Watershed management involves proper utilization of land, water, forest and soil resources of a watershed for optimum production with minimum hazard to natural resources (Biswas et al. 1999; Rashid et al. 2011; Meraj et al. 2012). Moreover, satellite based remote sensing coupled with GIS provides a platform for quick and efficient watershed management.

Study Area

The study area is located in Purulia, the westernmost district of the Indian state of West Bengal and a part of Jharkhand state in Chotonagpur Plateau is located between the graticule 22º42’19"N to 23º42’00"N latitude and 85º49’19"E to 86º54’25"E longitude. The study area comprises with Sobha watershed of Purulia district of West Bengal, India. The Sobha River is a tributary of Kistobazar River in the southern part of the Ajodhya hill which further moves toward south west and meets Subarnarekha River.

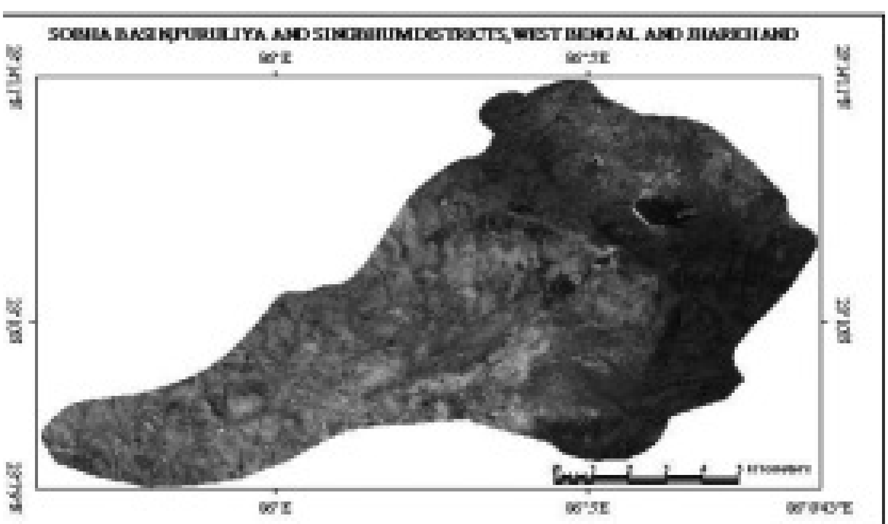
It is traversed by the tropic of cancer. This is located in the foothills of Ajodhya in Baghmundi P.S. and the main areas are Ajodhya, Baghmundi and Mathaburu etc. The Bay of Bengal and the Hooghly estuary are within 200 kms from the centre of the district. It is surrounded by Paschim

Medinipur, Bankura and Burdwan districts of West Bengal and Dhanbad, Bokaro, Hazaribag, East and West Singhbhum of Jharkhand state. Its physiographic location is also distinguishable as a zone of transition between the young alluvial plains of West Bengal and the ancient plateau of south-east Bihar.

Climatically, the area is sub-tropical and sub-humid, with hot wet summers and cool dry winters characterized by high evaporation and low precipitation with annual mean temperature of 25.6ºC and mean summer and mean winter temperature of 29.0ºC and 21.3ºC, respectively. The monsoon is the main source of precipitation, which shape a 'funnel' like meteorological function. It funnels the tropical monsoon current from Bay of Bengal to the sub-tropical parts of North West India. It starts in May and continues up to October. It has an annual average precipitation of 1393 mm. About 82% of the annual rainfall occurs during the monsoon which lasts roughly from June to September but uneven, scanty and erratic rainfall results in agricultural drought in the kharif season.

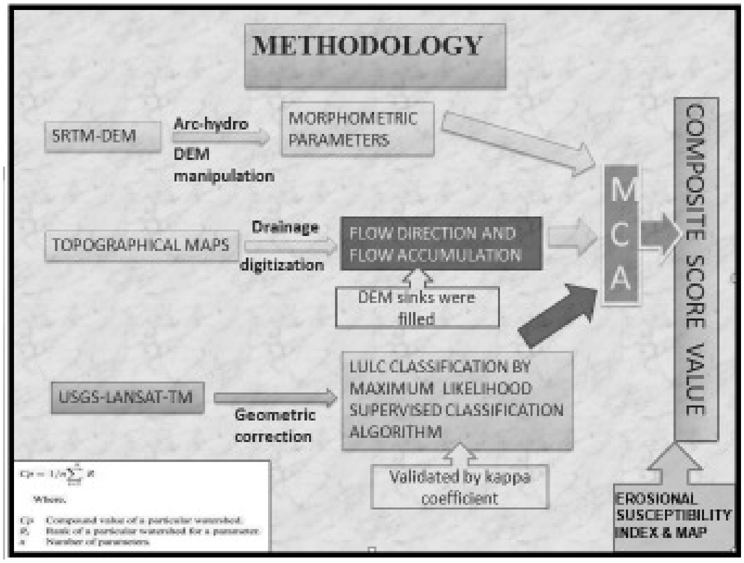
The main rivers passing through the district are Kangsabati, Kumari, Darakeswar, Subarnarekha and Damodar but the study area comprises Turga Nala, Kistobazar Nala and Daurigarha Nala. Soil erosion is the most prominent phenomenon of this area resulting huge deposition of fertile soil in the valley region. As a result the area is facing crisis due to depletion of top fertile soil and water loss. The study area is a 'White Zone' in respect of ground water status (i.e. 60% of available Ground annual recharge is in use). In general, during the rainy season the water table in the wells raises up to 1.00 to 3.50 m bgl till the end of October and gradually falls down to maximum of 6 to 14 m bgl during April-May.

Fig 1: location map



Geologically the area is a part of Chotanagpur Gneissic complex of Eastern Indian peninsular shield, lying to the north of Singhbhum craton. China clay occurrences of this area are invariably associated with granitic rocks and meta-sediments of the Chotanagpur Gneissic complex of Precambrian age. The topography is undulating with moderate to gentle slopes. It has a thick stratigraphic succession of mostly Archaean granitic gneiss and to a much lesser extent, Quaternary semi consolidated sediments, permo carboniferous sandstone, shale. Precambrian massive granites and quartzite sand with recent alluvium sediments deposition. Mineralogically these rocks are composed mainly of quartz, feldspar, muscovite, biotite, illite and kaolinite.

Database and Methodology



The present study mainly concerned to review and built strategies to reduce the adverse impacts of soil erosion of the study area and to enhance the use of satellite based remote sensing data coupled with the observational field data in a multi-criteria analytical (MCA) framework to estimate the soil erosion susceptibility of the watershed. For this both SOI (Survey of India) Toposheets (73I/4, 73E/16), LANDSAT TM and SRTM DEM data (30m. resolution) were used in GIS environment. At the outset, SRTM data used as input in Arc SWAT and delineate watershed as well as 37 sub-watersheds. Georeferencing of toposheets were done in TNT Mips 2014 and ARC GIS 10.1 version software and mosaic the same in order to subset the study region. The rectification method has been employed to obtain geometrically corrected subset image. Standard methods of Strahler's, Horton's were applied to examine morphometric characteristics. Watershed morphometry provides a complete description of the linkages between different land surface processes and different components of the land system such as geomorphology, hydrology, geology and LC (Astras and Soulankellis 1992; Ifabiyi and Eniolorunda 2012). Moreover the characteristic drainage system of a watershed has a strong impact on its infiltration capacity and runoff (Sharma et al. 1985). Some morphometric parameters directly serve as indicators of soil erosion intensity and have been termed as 'erosion risk assessment parameters'. These include the linear morphometric parameters such as drainage density, stream frequency, mean bifurcation ratio, drainage texture, length of overland flow and areal morphometric parameter like basin relief. These have a direct relationship with erodibility i.e. greater the values of these parameters; more is the erosion severity in the region and vice-versa. Whereas some of the shape morphometric parameters such as elongation ratio, circulatory ratio, form factor, basin shape and compactness coefficient have an inverse relation with erodibility (Nooka Ratnam et al. 2005). Based on these direct relationships for the linear and shape parameters, the highest value of a morphometric parameter was given rank 1; the immediate higher value was ranked 2, and so on. Whereas for the shape parameters, the lowest value of a morphometric parameter was given rank 1; the value lower than this was ranked 2 and so on. After assigning ranks to every parameter, an average of all the ranks was calculated to arrive at compound value (Cp).

The corrected satellite data was then processed for the LC classification using maximum likelihood supervised classification algorithm (Jensen 1996; Tso and Mather 2001; Fu 1976; Mortan 2007). While choosing various training samples for known land cover types, various image enhancement techniques were applied for homogeneity taking cognizance of the ground truth information. The classification was performed in a way that the classes generated are those which directly influence the soil erosion. Eight such LC classes were identified, viz., agriculture, wasteland, dense forest, degraded forest, agricultural fallow, dry fallow, water, exposer etc. The generated LC was validated in the field, Kappa coefficient for the final map was estimated using the formula shown (Lo and Yeung Albert, 2002). Estimation of the accuracy of the classified map is essential to assess its authenticity and kappa coefficient. The average of the ranks of all the parameters for a particular watershed is designated as compound value and represents the collective impact of all the parameters on erosion susceptibility of a sub-watershed. It is denoted as Cp, where Cp is the Compound value of a particular watershed. Here priority implies the necessity of land resource conservation and need to be implementing suitable remedial measures.

Table-1: Lists of Satellite Data Used For Analysis

Data Type				Month/Year of acquisition
Satellite	Sensors	Path/Row	Spatial Resolution (mts)	
Landsat-5	TM	140/44	30	6th Nov., 2011

Table- 2: Lists of Maps Used For Analysis

Data Type	Details	Data Source
Topographical Sheet	73 E/16, 73 I/4	Survey Of India, 1983
District Map With Blocks	West Bengal & Jharkhand	www.mapsofindia.com (4th November, 2014)

Table- 3: Software Used For Analysis

TNT MIPS of micro images Inc.
ERDAS Imagine of Leica Geosystem
ARC GIS 10.1

Result and Discussion

Erosional Susceptibility of Sobha watershed has carried out on the basis of morphometric characteristics and Landuse Landcover (LULC). 37 sub-watersheds have been generated in ARC SWAT software. Details of morphometric analysis and LULC of Sobha watershed has enumerated to examine erosional susceptibility.

A. Linear Parameters:

Average length of stream (L_{um}): It exhibits that total stream length decreases with increasing order. The total average stream length of all order segments in Sobha watershed is 151926.09m and highest average length is MWS 28 i.e. 21282.49m and lowest in MWS 18 i.e. 1235.10m.

Bifurcation ratio (R_b): Bifurcation shows a small range of variation for different regions or for different environment except where the powerful geological control dominates (Strahler, 1957). The Bifurcation ratio at sub-watershed level has been carried out in GIS environment. In Sobha watershed it ranges from 0.500 to 2.000 and the mean R_b in sub-watersheds is 1.053. The MWS 10, 15, 18, 24 and 30 are having highest R_b which exhibits low permeability and structural control over it.

Stream length ratio (L_{ur}): The stream length ratio of Sobha watershed ranges in 0.691 to 7.154 and changes of stream length ratio from one order to another indicating their late youth stage of geomorphic development. (Singh and Singh,1997). The highest stream length ratio observed in MWS 24 and lowest in MWS 16 and 25.

Stream frequency (F_s): generally high stream frequency is related to impermeable sub-surface material, sparse vegetation, high relief and low infiltration capacity of the region. The watershed has low stream frequency and it varies from sub-watershed to sub-watershed. The highest and lowest stream frequency occurred in MWS 30 and MWS 19 respectively.

B. Aerial Parameters:

Length of overland flow (L_g): It means the the length of the runoff of the rain water on the ground surface before it is localized into definite channels. It is highest in MWS 19 and lowest in MWS 7.

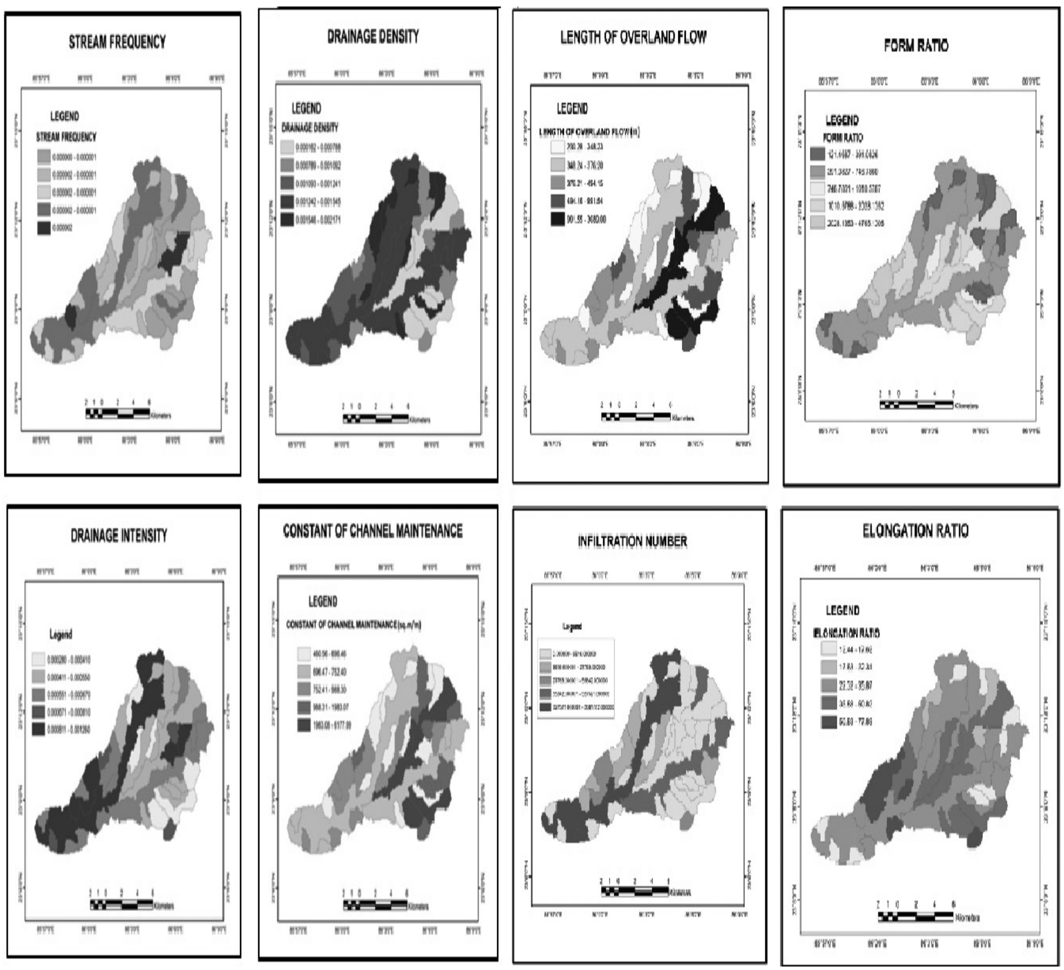
Drainage density (D_d): It is vital element of drainage morphometry to study the landscape dissection, runoff potential, infiltration capacity of the land, climatic condition and vegetation cover of the watershed. The drainage density of whole Sobha watershed indicates very low density which is only 0.04 m/m^2. Sub-watershed 7, 20, 15 are having high drainage density resultant of weak or impermeable subsurface material, sparse vegetation and rugged relief. Despite of this low drainage density in MWS 19, 11, 5 leads to coarse drainage texture and high permeable sub-soil material.

Constant of channel maintenance (C): It indicates the relative size of landform units in a drainage basin and has a specific genetic condition (Strahler, 1957). The total value of whole watershed is 34444.21 where MWS 7 has lowest value and MWS 19 has shows highest value.

Form ratio (F_f): This is an important dimensionless property which enumerates the shape of the basin. Form factor of Sobha watershed is 40917.32 and it ranges from 121.469 to 4765.13 in sub-watersheds. MWS 3 with highest form ratio showing high peak flow of shorter duration. Lowest form ratio observed in MWS 34. In short the shape of the watershed is quite elongated.

Elongation ratio (R_e): The elongation ratio runs between 12.44 and 77.89 for all sub-watersheds. The lowest and highest elongation ratio reveals in MWS 36 and MWS 2 respectively. Sobha watershed is having high relief and steep valley side with almost circular nature.

Fig 3:
Aerial Parameters



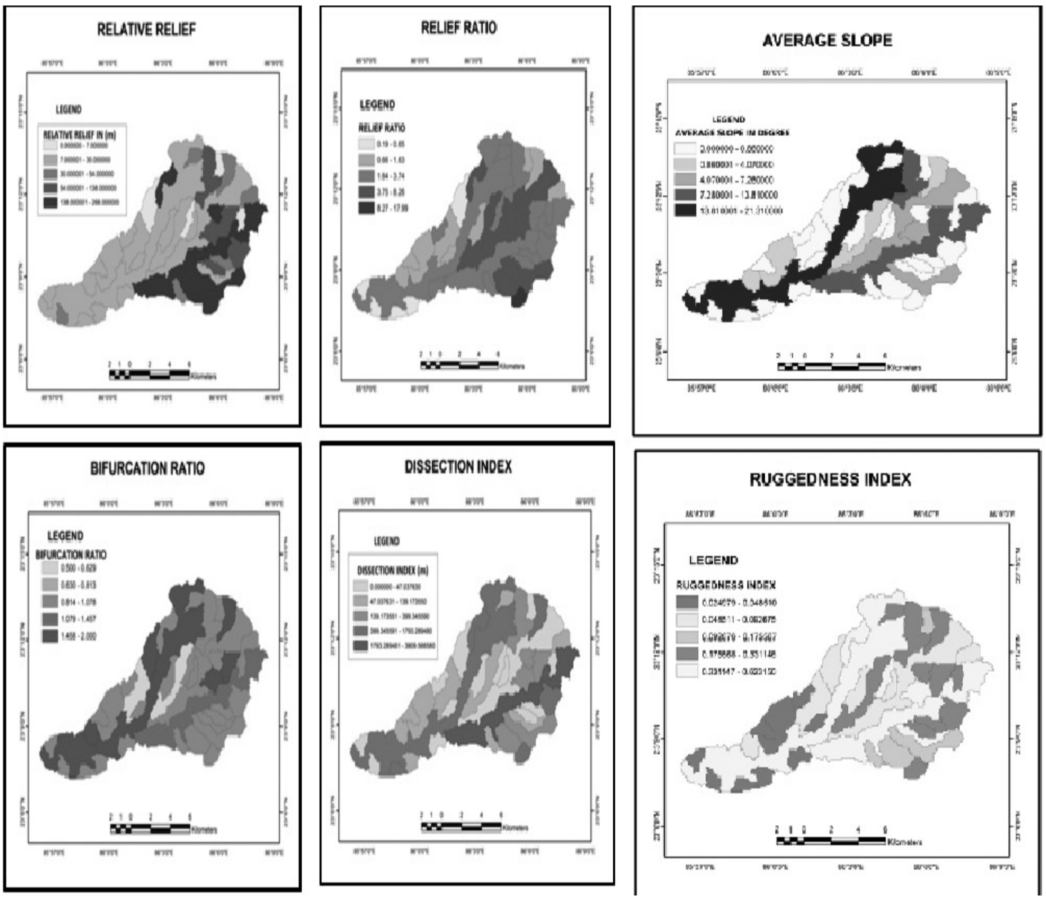
C. Relief Parameters

Relief ratio (R_h): The elevation differences between the highest and lowest points on the valley floor of a sub-watershed. The relief ratio normally increases with decreasing drainage area and size of sub-watersheds of a given drainage basin. It is highest in MWS 5 and lowest in MWS 36.

Ruggedness number (R_n): It is the product of the basin relief and the drainage density and usefully combines slope steepness with its length. The MWS 6, 3 7, 28 have highest value and implies more proneness to soil erosion where as MWS 36, 5, 33 show lowest value and indicate lower volume of soil erosion.

Fig4

Relief Parameters



On the basis of response of Landcover (LC) towards erosion, prioritization ranking was performed. Percent area of the class was used as an index for assigning ranks. Among all the sub-watersheds, the watershed having the maximum percentage of a class which directly causes erosion (e.g. in case of wasteland) was assigned rank 1. Agricultural land is the second dominant category in the study area and covers about 35 % of the total watershed. Land under agriculture is topographically flat and as a result water gets more time to infiltrate. Moreover, in such land the upper soil layer is strongly grasped by the root biomass of crops. These two combined effects make these land less susceptible to erosion. In sub-watersheds, the maximum area under agricultural land was observed in MWS37. Exposer About 30 % of the Sobha watershed is covered with impervious surface. Impervious surface class is that land where the soil is either altogether absent (e.g., exposed rock) or where soil surface is obstructed like in the case of encroachment. The erosion susceptibility of such a land was assumed to be zero, because there was no soil to get eroded. In a multi-criteria methodology used in this study, such areas shall contribute least to erosion susceptibility to the overall susceptibility of a given watershed. Therefore, the watershed which has the highest percentage of this class has the lowest contribution towards erosion susceptibility and the watershed which has the lowest percentage under this class contributes highest towardssusceptibility to erosion. Forests are the third dominant category in the watershed is about 20.98 % of its total area and comprises dense and degraded forests. Forests are among those LC classes which act against the forces of soil erosion. Rank 1 was assigned to the watershed having the lowest percentage of forest cover. Wasteland is any unutilized or degraded piece of land. It was assumed that such areas are prone to wind and water erosion. Therefore, the watershed with highest percentage of the wasteland was assigned rank 1. Such as other classes like water, wasteland, fallows (agricultural, dry) also assigned rank against their nature to erosion.

Table - 4: Cp Values For Erosional Susceptibility

BASIN_ID	CP_Value_ MORPHOMETRY	CP_Value_ LANDUSE
1	15.15	16
2	18.85	15.875
3	16.75	16.625
4	13.95	15
5	11.1	8
6	9.5	13.625
7	14.6	8.375
8	9.55	9.125
9	12.25	11
10	6.8	8.625
11	5.7	13.5
12	11.05	14.25
13	13.7	17.375
14	12.65	18.125
15	16.7	12.875
16	7.8	13.5
17	9.05	10.125
18	16.65	16.25
19	12.85	15
20	14.3	18.5
21	11.1	21.25
22	13.7	12.125
23	13.1	19.375
24	9.6	18.625
25	12.2	13.875
26	9.55	10.75
27	7.25	18
28	6.5	3
29	12.45	9.875
30	17.7	4.25
31	12.95	8.125
32	15.6	13.375
33	16.85	14.375
34	11.6	16.875
35	16.75	11.25
36	16.9	11.75
37	7.4	2

In this study, two components of land system viz, morphometry and LC were assessed for their roles in making an area susceptible to erosion. In order to find a single answer to their collective contribution towards the erosion susceptibility, we finally integrated both LC and morphometry showing a common high priority.

Inference

Sub-watersheds falling under high to critical class are under very severe erosion susceptibility zone. Thus need immediate attention to take up mechanical soil conservation measures gully control structures like check dams and grass waterways to protect the top soil loss. Sub-watersheds falling under moderate to low priority have very slight erosion susceptibility zone and may need agronomical measures to check sheet and rill erosion.

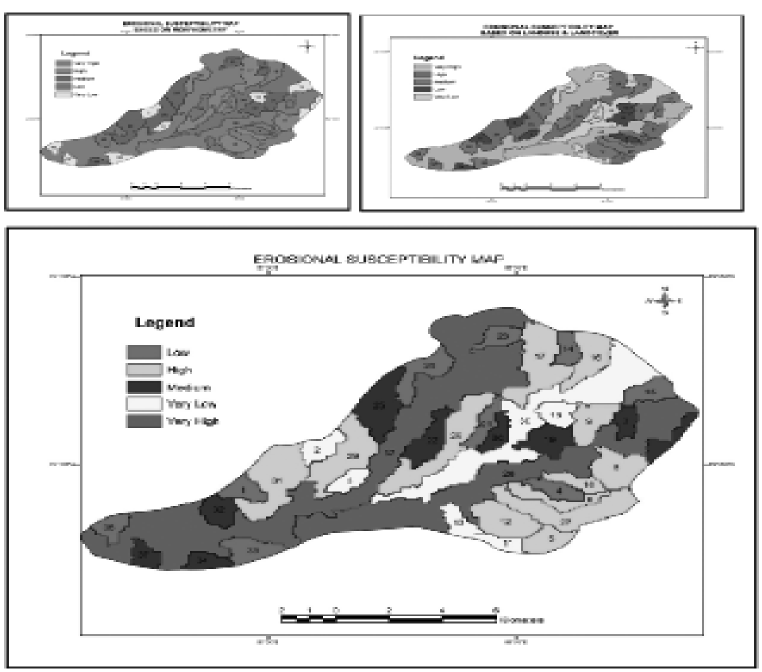
The contemporary approaches of RS & GIS used for morphometric and land cover evaluations in this study were found to be very appropriate in comparison to the conventional approaches. The present study was to fulfill its aim which was based on prioritizing the watersheds on the basis of their susceptibility to soil erosion and the appropriate measures for conservation of the land and water resources. As the identification of

critical areas is a prerequisite for developing and implementing best management practices, the research has been facing human presence in the form of deforestation, sand and gravel extraction, intensification in improper agricultural practices and reckless built up of check dams. The result of prioritization on the basis of morphometric analysis reveals that sub-watersheds 10, 16, 27, 28 & 37 falls under very high priority group i.e. they are highly susceptible to top soil erosion, whereas on the basis of LULC analysis 28 & 37 sub-watersheds are highly susceptible and thus falls under very high priority category. However, both LULC and Morphometry show a common high priority for 28 & 37 sub-watersheds. The conservation strategies recommended include building up of check dams. Contour farming, conversion of wastelands to agriculture, afforestation and reforestation under social forestry programme by indigenous species, and putting a stop to the overgazing of the pastures falling under sub-watersheds.

We believe that with more ground truth measurements like Runoff, Vegetation Cover, Soil Moisture in different MWS the accuracy of the model is ensured. Revised Universal Soil Loss Equation model (RUSLE, 2015) to estimate soil loss in Europe for the reference year 2010, within which the input factors (Rainfall erosivity, Soil erodibility, Cover-Management, Topography, Support practices) are modelled with the most recently available pan-European datasets and Linear Spectral Mixing model (MODIS, NASA) also give the more accurate result.

Fig 5

Erosional Susceptibility Map



Acknowledgement: We wish to thank Vidyasagar College, University of Calcutta for the technological support.We also wish to thank USGS, NASA for providing us with the Landsat Images.Ujjwal Bhandari, Gostha Biswas, Suvankal Kayal , Rohit Pramanick, Santanu Payra and Purbita Paul are acknowledged for assisting us in the field measurements.I take the opportunity to express my sincere gratitude to Mr. Ratnadeep Ray, Vidyasagar University for his resourceful guidance, constant encouragement and enlightening discussions during the course without which it would not have been possible for me to reach to this point. Comments from the anonymous reviewers are gratefully acknowledged.

References

J. I. Clarke, "Morphometry from maps," in *Essays in Geomorphology*, G. H. Dury, Ed., pp. 235–274, Elsevier, New York, NY, USA, 1966.

R. E. Horton, "Drainage basin characteristics," *Transactions of American Geophysics Union*, vol. 13, pp. 350–361, 1932.

R. E. Horton, "Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology," *Geological Society ofAmerica Bulletin*, vol. 56, pp. 275–370, 1945.

A. N. Strahler, "Hypsometric analysis of erosional topography," *Bulletin of the Geological Society of America*, vol. 63, pp. 1117– 1142, 1952.

A.N. Strahler, "Quantitative analysis of watershed geomorphology" *Transactions of American Geophysics Union*, vol. 38, pp. 913–920, 1957.

A. N. Strahler, "Quantitative geomorphology of drainage basin and channel networks," in *Handbook of Applied Hydrology*, V. T. Chow, Ed., McGrawHill, NewYork, NY,USA, 1964.

S. A. Schumm, "Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey," *Bulletin of the Geological Society of America*, vol. 67, pp. 597–646, 1956.

R. J. Chorley andM. A.Morgan, "Comparisonofmorphometricfeatures,UnakaMountains, Tennessee andNorth Carolina, and Dartmoor, England," *Geological Society of America Bulletin*, vol.73, no. 1, pp. 17–34, 1962.

P.W. Williams, " Morphometric analysis of polygonal karst in New Guinea" *Geological Society of America Bulletin*, vol. 83, no. 3, pp. 761–796, 1972.

L. M. Mesa, " Morphometric analysis of a subtropical Andean basin (Tucuman, Argentina)" *Environmental Geology*, vol. 50, no. 8, pp. 1235–1242, 2006.

P. Lyew-Ayee, H. A. Viles, and G.E. Tucker, " The use of GISbased digital morphometric techniques in the study of cockpit karst," *Earth Surface Processes and Landforms*, vol. 32, no. 2, pp. 165–179, 2007.

T. B. Altin and B. N. Altin, "Development and morphometry of drainage network in volcanic terrain, Central Anatolia, Turkey," *Geomorphology*, vol. 125, no. 4, pp. 485–503, 2011.

M. Buccolini, L. Coco, C. Cappadonia, and E. Rotigliano, " Relationships between a new slope morphometric index and calanchi erosion in northern Sicily, Italy," *Geomorphology*, vol. 149-150, pp. 41–48, 2012.

S. S. Vittala, S. Govindaih, and H. H. Gowda, "Morphometric analysis of sub-watershed in the Pavada area of Tumkur district, South India, using remote sensing and GIS techniques," *Journal of Indian Society of Remote Sensing*, vol. 32, no. 4, pp. 351–362, 2004.

R. Chopra, R. D. Dhiman, and P. K. Sharma, "Morphometric analysis of sub-watersheds in Gurdaspur district, Punjab using remote sensing and GIS techniques," *Journal of Indian Society of Remote Sensing*, vol. 33, no. 4, pp. 531–539, 2005.

H. Vijith and R. Sateesh, " GIS based morphometric analysis of twomajor upland sub-watersheds ofMeenachil river in Kerala," *Journal of the Indian Society of Remote Sensing*, vol. 34, no. 2, pp.181–185, 2006.

M. Rudraiah, S. Govindaiah, and S. S. Vittala, "Morphometry using remote sensing and GIS techniques in the sub-basins of Kagna river basin, Gulburga district, Karnataka, India," *Journal of the Indian Society of Remote Sensing*, vol. 36, no. 4, pp. 351– 360, 2008.

Arun, P. S.; Jana, R. & Nathawat, M. S. (2005). A rule based physiographic characterization of a drought prone watershed applying remote sensing and GIS. Journal of the Indian Society of Remote Sensing, vol. 33(2), pp. 20-189.

Bhat, S. A. & Romshoo, S. A. (2009). Digital Elevation Model based watershed characteristics of upper watersheds of Jhelum basin. *Journal of Applied Hydrology, vol. 21(2),* pp. 23-34.

Carlos, G. H.; ramon, J. B.; Artemio, C. & de Luisa, M. (2012). A regional analysis of the effects of largest events on soil erosion. *CATENA, vol. 95*, pp. 85-90.

Christopherson, R. W. (1997). Geosystems: An introduction to physical geography. Upper Saddle River: Prentice Hall.

Fohrer, N.; Haverkamp, S.; Eckhardt, K. & Frede, H. G. (2001). Hydrologic response to landuse changes on the catchment scale. *Physics Chemical Earth, vol. 26*, pp. 577-582.

Javed, A.; Khanday, M. Y. & ahmed, R. (2009). Prioritization of subwatersheds based on morphometric and land-use analysis using remote sensing and GIS techniques. *Journal of the Indian Society of remote Sensing, vol. 37,* pp. 261-274.

Kumar, R.; Kumar, S.; Lohani, A. K., Nena, R. K. & Singh, R.D. (2000). Evaluation of geomorphological characteristics of a catchment using GIS. *GIS India, vol. 9 (3),* pp. 13-17.

Morgan, R. P. C. (2009). Soil erosion and conservation. John Wiley & Sons.

Rakesh,K.; Lohani, A. K.; Sanjay, C. C. & Nema, R. K. (2000). GIS based morphometric analysis of Ajay river basin upto sarath gauging site of South Bihar. *Journal of Applied hydrology, vol. 14 (4),* pp. 45-54.

Yu, L.; Bojie, F.;Yihe, L.; Zhi, W. & Guangyao, G. (2012). Hydrological responses and soil erosion potential of abandoned cropland in the loess plateau, china. *Geomorphology, vol. 138 (1)*, pp. 404-414.

19

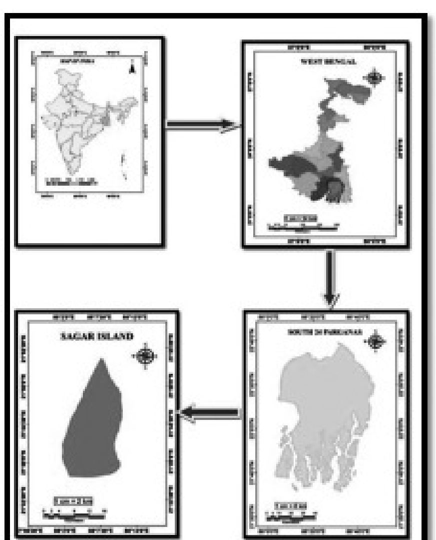
Identification and Mapping of Coastal Water bodies Using Remote Sensing and GIS Techniques of Sagar Island, South 24 Parganas, West Bengal, India

Ismail Mondal, Jatisankar Bandyopadhyay and Tanushree Maji, Subrata Sarkar

Introduction

Coastal zones are important boundaries, forming transition areas between terrestrial and marine environments. It's highly biological productive region and are also important components of global bio system. These zones have wealth of mixed species and genetically diversified habit and are major carbon sink and oxygen sources. Sagar Island is under increasing anthropogenic stresses due to growing population. Approximately 41% of the world's human population is living within 100 km of the coast (Martinez et al. 2007). Coastalwaterbodies have wet, spongy soils and are located in the transition zone between terrestrial land and ocean, and they include freshwater, saltwater and mixed areas. Due to these characteristics, waterbodies contain a diverse variety of wildlife and plants (Gibbes et al. 2009). Coastal waterbodies are a vital element of coastal zones and are valued for a wide range of ecological, economic and cultural reasons (Mackay et al. 2009). Some waterbodies provide coastal protection against destructive Natural events such as cyclones and storm tide inundations (Rebelo et al. 2009).

Fig: 1. Location Map



Aim: The study mainly focusing on the identification of water bodies as well as vegetation using remote sensing and latest spatial information model for optimal sustainable management plan of the coastal water body.

Objective

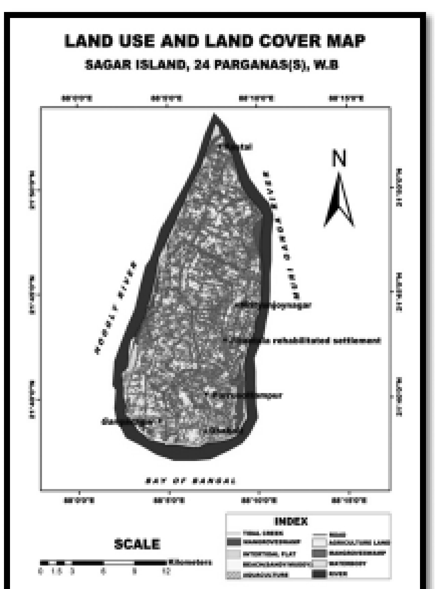
- Identification of terrain unit/geomorphologic unit and their spatial distribution and the existing land cover pattern.
- Optimum utilization of costal water body through the environment assessment.
- To examine the water quality.
- To extract the all inventory water bodies.
- To develop a basic understanding of the study area through coastal water body mapping and its' significance for changing scenario.

To find out optimum utilization plan of coastal water body through proper sustainable management.

Location of The Study

Sagar Island is an island in the Ganges delta, lying on the continental shelf of Bay of Bengal about 100 km (54 nautical miles) south of Kolkata. This Island under South 24 Parganas District in India State West Bengal. It belongs to the Republic of India and is governed by the State government of West Bengal. The island is large — with an area of 224.3 km², lying between 21°36' to 21°56' north latitude and 88°2' to 88° 11' east longitude. This Island, also known as **Gangasagar** or **Sagardwip**, is a place of Hindu pilgrimage. Every year on the day of **MakarSankranti**(14 January), hundreds of thousands of Hindus gather to take a holy dip at the confluence of river Ganges and Bay of Bengal and offer prayers (puja) in the **Kapil Muni Temple.**

Fig: 2.
Land Use and Land Cover Map



Land Use Land Cover Classes

The land use/land cover map is an appraisal of spatial information of the physical and social cover types (i.e. both natural and cultural/anthropogenic) on the existing scenario (. Andrade, et al 1998).Land use could be defined as anthropogenic/human activities (Cultivable land, homestead plantation/garden etc.). On the present day landscape is the vegetational (both natural and, cultural forests, plantation) and where as land cover is artificial construction (Settlement, road, embankments etc.)

Mapping of Water bodies

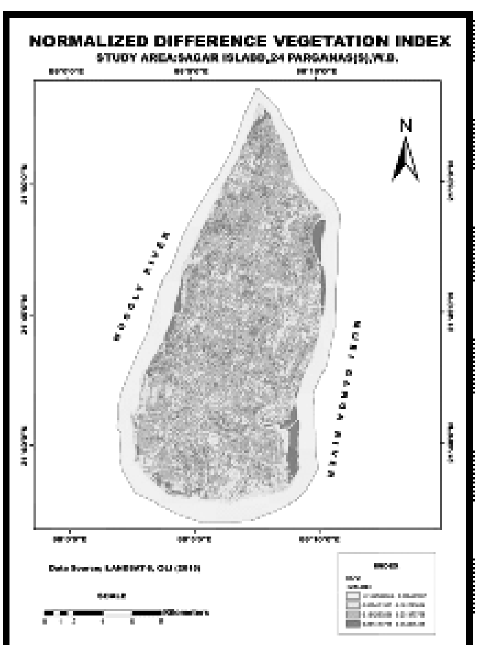
In the present study, the mapping of waterbodies was done following digital classification and onscreen visual interpretation. In this project, five indices known in literature that enhances various waterbody characteristics were used (McFeetres, 1986; XuHanqiu, 2006; Lacaux*et al*, 2007; Townshend and Justice, 1986; Tucker and Sellers, 1986) as given below:

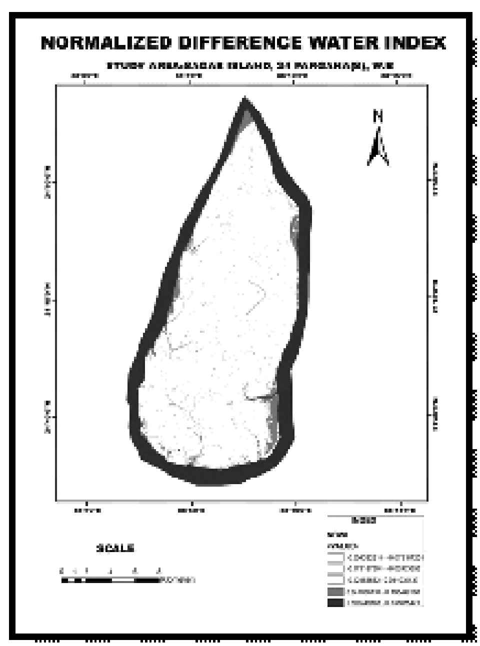
i) Normalized Difference Water Index (NDWI) = (Green-NIR) / (Green + NIR)

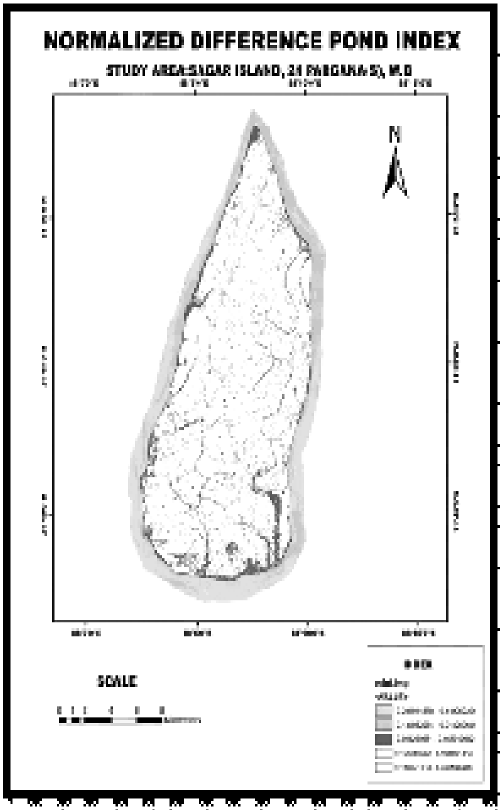
ii) Normalized Difference Vegetation Index (NDVI) = (NIR - Red) / (NIR + Red)

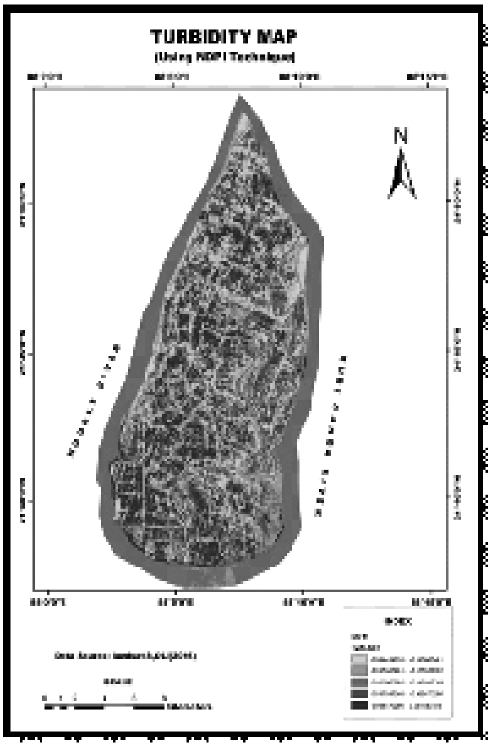
iii) Normalized Difference Pond Index (NDPI) = (MIR – Green / MIR + Green)

iv) Normalized Difference Turbidity Index (NDTI) = (Red – Green) / (Red + Green**)**









- Extraction of waterbody extent: NDWI, NDPI and NDVI image was used to extract the waterbody boundary through suitable hierarchical thresholds.
- Extraction of open water: NDWI was used within the waterbody mask to delineate the water and no-water areas.
- Extraction of waterbody vegetation: NDPI and NDVI image was used to generate the vegetation and no-vegetation areas within a waterbody using a suitable threshold.
- Turbidity information extraction: NDTI and NDWI image was used to generate qualitative turbidity level (high, moderate and low).

Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform. This is the basic index for measuring the 'greenness' of the earth's surface. To determine the density of green on a patch of land, researchers must observe the distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants.

By combining the two channels in a ratio or difference, allows the response to vegetation growth to be distinguished from the background signal. The method, developed by NASA is known as the Normalized Difference Vegetation Index (NDVI) and is given by the equation:

NDVI= (NIR-RED/NIR+RED)

Where RED and NIR correspond to channels 1 and 2 respectively The NDVI is more widely used than the Simple VI, however, because it scales between -1 (for snow and ice) and +1 (for complete vegetation cover)

In OLI image of study area (Sagar Island) apply NDVI modeler to detect the greenness of the area. It is clearly shown the high range in mangrove swamp area of Sagar Island and also in domestic area where vegetation are founded. Medium range is also representing the plantation area of Sagar Island. And first two classes are not classified as vegetation coverage so no vegetation coverage found in different type of water body and water content area (Bay of Bengal).

In this index the range of 0.231473728 to 0.454545468 indicates high density of mangrove and 0.161293854 to 0.231473728 indicates moderate density vegetation, like homestead orchard, agriculture land etc. and -0.184592664 to 0.161293854 indicates low density vegetation like algae or phytoplankton.

Normalized Difference Water Index (NDWI)

The normalized difference water index (NDWI) is derived using similar principles to the Normalized Difference Vegetation Index (NDVI). The NDVI index is calculated as follows: (NIR – Red) / (NIR + Red).

(Green – NIR) / (Green +NIR)

If the equation is reversed and the green band used instead of the red, then the outcome would also be reversed, the vegetation suppressed and the open water features enhanced (McFeeters 1996). The equation for an NDWI is:

Applying NDWI on study area (Sagar Island) to delineate open waterfeatures andenhance their presence in remotely-sensed digital imagery. The NDWI makes use of reflected near-infrared radiation and visible green light to enhance the presence of such features while eliminating the presence of soil and terrestrial vegetation features. It is suggested that the NDWI may also provide researchers with turbidity estimations ofwater bodies using remotely-sensed digital data. After using NDWI on OLI digital imagery of study area it is clearly shown the open water in part of Bay of Bengal.

In this index the range 0.195449168 to 0.335055471 indicates the highly open water features. Respectively 0.041036137 to 0.195449168 range and -0.02453652 to 0.041036137 are indicates some moderate and low types of water content. Other left two ranges are not classified as open water area those are part of Sagar Island.

Pond Detection Using NDPI Technique

A new index for remote sensing of small and temporary ponds has been derived: the so-called Normalized Difference Pond Index (or NDPI, hereafter). The NDPI combines the digital counts (DCs) for the MIR and green bands of the electromagnetic spectrum, as follows:

NDPI = (MIR- GREEN) / **(**MIR+GREEN**)**

Detecting ponds from the study area (Sagar Island) NDPI played a vital role. It is clearly shown in the NDPI several ponds are found in domestic area of Sagar Island. In the estuary and beach side no ponds are found that is normal as that area part of Bay of Bengal and also mangrove area are apart from ponds indication. The small size and complex distribution of ponds require the use of high-spatial resolution satellite Images for adequate detection. Here the use of

OLI images (30 m-resolution) allows for detailed assessment of spatial-temporal evolution of ponds, through the Normalized Difference Pond Index (NDPI), and NDTI. For example they represent nearly 65% of the total ponds during the peak of the rainy season, up to 90% at the end of the same season.

Delineation of Water bodybased on Turbidity (Using NDTI Techniques):

The NDTI initially designed to describe water turbidity, increases when water bodies become muddy and have spectral reflectance similar to bare soils so it was logically negatively associated with the presence of water. The Normalized Difference Turbidity Index (or NDTI hereafter) combines digital counts of the red and green bands of the electromagnetic spectrum, as follows:

NDTI = (RED-GREEN) / (RED+GREEN).

Turbidity **-** The cloudiness of water due to small individual particles can be measured as turbidity. Finally dispersed minerals, microscopic bacteria, algae; colloidal matter and organic debris affect turbidity. It directly affects the rate of photosynthesis the particles themselves or the decrease in light penetration can affect aquatic life. Benthic algae can perish and corals die from excess turbidity.

By applying this NDTI model to the image in ERDAS IMAGIN software, turbidity cover map was prepared and reduced for presentationaccordingly low, moderate and high values were assigned to the image and converted in GIS environment. This turbidity map encodes each category of turbidity (low, moderate and high) with a unique pixel value. In the study area NDTI modeler is help to detect the waterbodies which are based on turbidity in this area, in the presentation image of Turbidity Map, the range -0.008470296 to 0.034653466 represent high turbidity as the area is portion of tidal flat where mud sand both are present for this the area is part of high turbidity accordingly -0.025952902 to -0.008470296ranges represent the moderate turbidity where the huge mud flat is present and -0.064414635 to -0.025952902 are indicating the very low turbidity in some places. Very high turbidity is specially shown in the Sagar sea beach and also high turbidity shown scatterly in domestic area of Sagar where we found several ponds via NDPI and shown scatterly in the tidal creek. Moderate turbidity is found in some portion of Hooghly estuary and in mud flat and in mangrove swamp area of Sagar Island. Comparatively low turbidity shown in mainly domestic area of Sagar Island.

Water body Classification Mapping

It is necessary to develop a specific set of data collection procedures to accommodate mapmaking using remotely sensed imagery as the primary data source. For example, some water chemistry, salinity, water depth, substrate size and types and even some differences in vegetative species cannot be reliably ascertained from air photos or digital imagery used by the Service. Image analysts must primarily rely on physical or spectral characteristics evident on high altitude imagery to make decisions regarding water body classification.Preparing water body mapping of study area (SagarIsland) mainly used OLI data and digitized features form the Google Earth and also some information of water body during field visit session. Map of water body mainly based on extraction of water body from various indices then onscreen digitizing on Google Earth and composed by Arc GIS software.

Fig 7

Water Body Map

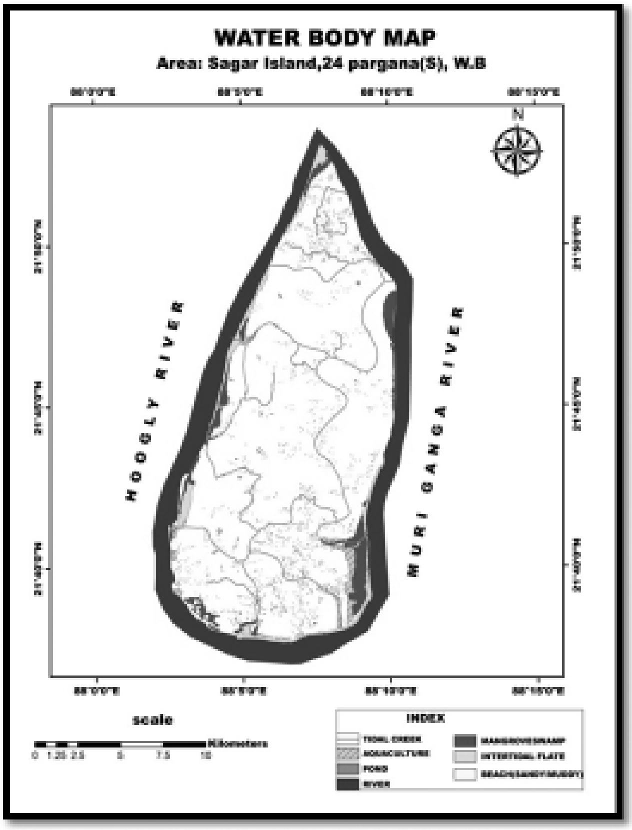
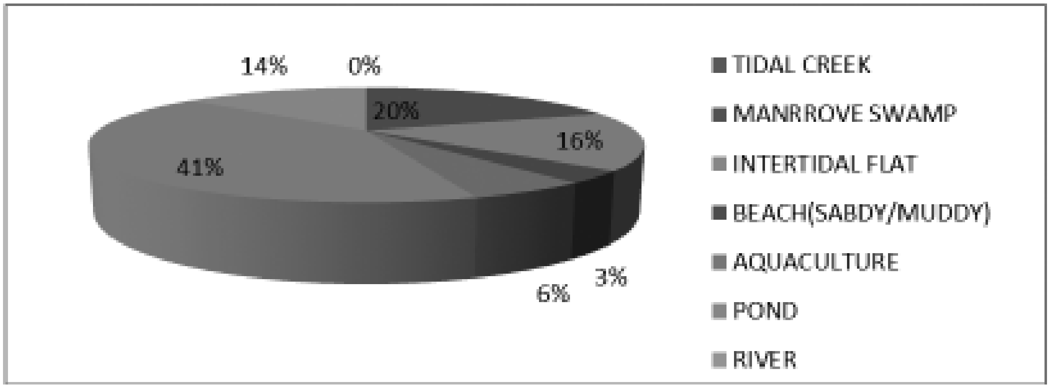


Table: 1

Costal Water body Area

Type	Water Body Area(Sq.M.)	Total Area (Sq.M.)	Area In %
Tidal Creek	11136		0.021979977
Mangrove Swamp	9879736		19.50039213
Intertidal Flat	8309720	50664294	16.40153122
Beach(Sandy/Muddy)	1701911		3.359192176
Aquaculture	2863104		5.651127794
Pond	20877246		41.20702047
River	7021441		13.85875623

Fig: 8
Percentage (%) With Pie chart



Mangrove Swamp

Mangrove swamps are coastal water bodies found in tropical and subtropical regions. They are characterized by halophytic (salt loving) trees, shrubs and other plants growing in brackish to saline tidal waters. These water bodies are often found in estuaries, where fresh water meets salt water and are infamous for their impenetrable maze of woody vegetation. Mangrove trees dominate this water body ecosystem due to their ability to survive in both salt and fresh water. In the study area mangrove swamps are specially found in Chemagai, area.

Fig: 9. Field Photo: Mangrove Swamp

Fig: 10. Field Photo:Aquaculture Land

Aquaculture

Aquaculture, also known as aqua farming, is the farming of aquatic organisms such as fish. Aquaculture involves cultivating freshwater and saltwater populations under controlled conditions, and can be contrasted with commercial fishing. The farming of fish is the most common form of aquaculture. It involves raising fish commercially in tanks, ponds, or ocean enclosures, usually for food. Aquaculture is a highly regulated industry, and these regulations may well keep fish farming. The main fishing zone in the study area is Chemagari Fishing zone some fishing farms are also shown in South and West portion, in this area fishing farm are occur at tidal flat side.

River and Tidal Creeks

A tidal creek, tidal channel, or estuary is the portion of a stream that is affected by ebb and flow of ocean tides, in the case that the subject stream discharges to an ocean, or sea.Tidal creeks are lie at the interface between the open estuary and surrounding watershed strongest relationships in the headwater areas. It is also drainage for storm water and Habitat. A tidal creek, tidal channel, or estuary is the portion of a stream that is r fishes, crabs. In Sagar tidal creek is found in side of mangrove swamp and some channels isshown at near about Chemagari fishing harbour.

Fig: 11. Field Photo:Tidal Creek

Fig: 12. Field Photo:Mud Flat

Tidal Flat

A nearly flat coastal area is alternately covered and exposed by the tides, and consisting of unconsolidated sediments. Morphologically tidal flats and vegetated water bodies have certain similarities as both are low gradient coastal flood plain alluvium surface. However tidal flats are distinguished by bed forms little relief between supratidal and inter tidal surface.Tidal flats are again classified in terms of sediment compositions, which are Mud and sand flat.

Mud Flats

Mudflats or mud flats, also known as tidal flats, are coastal waterbodies that form when mud is deposited by tides or rivers. They are found in sheltered areas such as bays, lagoons, and estuaries. Mudflats may be viewed geologically as exposed layers of bay mud, resulting from deposition of estuarine silts, clay and marine animal detritus. Most of the sediment within a mudflat is within the intertidal zone, and thus the flat is submerged and exposed approximately twice daily.

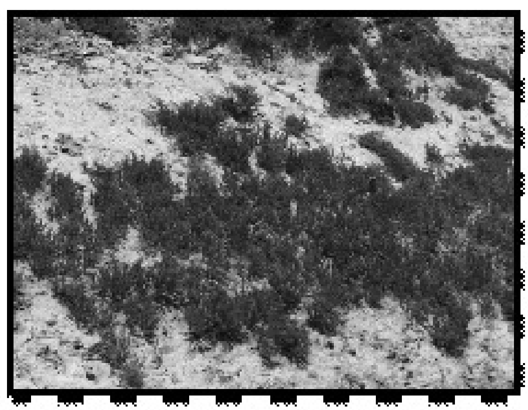
Generally mudflats are formed sediments supplied by nearby rivers.Mudflats are formed where there is sheltered water in river estuaries or behind spits. Silt and mud will be deposited either by gently rising and falling tides or by the river, these forms a zone of intertidal mudflats. The deposited material is not easily removed especially as flow velocities are low, and the length of time the area is not covered by water increases.

Pond

A pond is a body of standing water, either natural or manmade. Usually they contain shallow water with marsh and aquatic plants and animals. Here pond classified in the waterbody map. In the study area maximum ponds are found in domestic area in Sagar Island. Ponds are created especially for habitat restoration. Also there are some natural ponds those are may arise naturally in floodplain area as part of river.

Fig: 12. Field Photo:Mud Flat

Fig: 13. Field Photo:Salt Marsh



Sand Beach

A beach is a landform along the shoreline of an ocean, sea, lake, or river. It usually consists of loose particles, which are often composed of rock, such as sand, gravel. Beaches are the result of wave action by which waves or currents move sand or other loose sediments of which the beach is made as these particles are held in suspension. The water and the beach appear grey, as the land slopes into the Bay of Bengal, but the land and the water are both clean.

Salt Marsh

A salt marsh is known as a coastal salt marsh or a tidal marsh, is a coastal ecosystem in the upper coastal intertidal zone between land and open salt water or brackish water that is regularly flooded by the tides. In the present coastal areas of Bay of Bengal salt marsh and mangroves intermingles. Mainly some salt marsh is found between mangrove swamp areas in

Chandipure beach. The development of marshes is found in two significant physical set up of the coast

1. behind the frontal mangroves, 2. behind the beach ridges. Various salt marsh species colonize behind the shorefront mangroves such development of salt marsh is clearly observed in Chemagari of Sagar Island. The stability of the surface behind frontal mangroves provides a favorable environment factor for such marsh growth.

12. Conclusion:

The used approach in the present study proved very effective to fulfill the objectives with successful implementation. The present study, delineation and characterization of water bodies were carried out using remote sensing and GIS techniques. Land use land cover map were prepared by on screen digitization on Google Earth and unsupervised classification in ERDAS IMAGINE using OLI (LANDSET-8) data etc. which were carried the information about the study area. After visiting the study area and using the ground truth data it was the main guidance tool for on screen digitization of water bodies of Sagar Island. There are especially seven types of coastal water body found which are shown in Water body Map which is based on the ground truth information and some literature studies.

- The NDPI, NDTI and NDVI were used to identify ponds, water bodies based on turbidity and vegetation as guiding tools.
- Turbidity, surface water, vegetation coverage and also the pond classification could serve as guiding tool, in conservation prioritization of water body.
- Here NDVI was used to detect the distribution of vegetation, but in NDVI the behavior of vegetation inside and outside the ponds cannot be distinguished.
- Thus use of new index for remote sensing of small and temporary ponds has been derived: the so-called Normalized Pond Index, the NDPI makes it possible not only to distinguish small ponds and water bodies (down to 0.01 ha), but also to differentiate vegetation inside ponds from that in their surroundings.
- Land shaping, reclamation and re-excavation of sweetwater sources including step-cutting or terracing on inward-slopes of the ponds, these steps or terraces can be used for vegetable cultivation during dry periods

References

Chakrabarti, P (1987): Quaternary Geology and Geomorphology of Hooghly Estuary, Dist. 24 –Parganas, West Bengal. Unpublished Final Report of Geological Survey of India for FS 1984-85 and 85-86.

Chakrabarti, P (2012) (Former Chief Scientist, Deptt. Of Science & Technology, Govt. of West Bengal) Coastal Lowland and Water bodies(Ppt), West Bengal India,

L.S.S.O (1905) Indian Civil Service, Bengal District Gazetteers 24 Parganas.

Mondal, I, Bandyopadhyay, J, (2014): Coastal Zone Mapping through Geospatial Technology for Resource Management of Indian Sundarban, West Bengal, India, *International Journal of Remote Sensing Applications Volume 4 Issue 2*, June 2014.

Mondal, I, Bandyopadhyay, J, (2014): Environmental Change of Trans International Boundary Indo-Bangladesh Border of Sundarban Ichamati River Catchment Area Using Geoinformatics Techniques, West Bengal, India, 2014 Volume 4, Issue 3: 143-154.

Mondal, I, Bandyopadhyay, J, (2014*): Morphodynamic Change Of The Ichamati River And Land Use/Land Cover Changes Through Space And Time Using Remote Sensing And GIS Techniques North 24 Parganas, West Bengal, India, (Bagdah, Bongaon, Gaighata And Swarupnagar Block,* Hyderabad, India, December 9 – 12, 2014.

Mukherjee. R.K.(1938): *The changing face of Bengal*, Calcutta university press. Calcutta, 288p.

Niyogi D (1975) *Quaternary geology of the coastal plain in West Bengal*. Indian J Earth Sci 2:51–61

Paul, Ashis Kr. (2002): *Coastal geomorphology and Environment*. A.C.B Publication, Kolkata. P.582

Rennell, J.J (1781): *The Ganges and Brahamaputra Rivers: Royal society*. London Phylosophical Transactions, Vol. LXXI.

Panigrahy, S (2010): National Water body Atlas Goa, Sponsored by -Ministry of Environment and Forests, Government of India (As a part of the project on National Waterbody Inventory and Assessment, NWIA)

Bhattacharyya, S (2009) *Mapping and characterization of Inland Waterbodies using RS & GIS*

RAMSAR CONVENTION ON WATERBODIES-caring for waterbodies

Dambach, Peter (2012): Utilization of combined remote sensing techniques to detect environmental variables influencing malaria vector densities in rural, West Africa

Shiv Singh (2010): Environmental assessment of coastal water at Bakkhali (Bay of Bengal), West Bengal.

Kevin L. Erwin(2009): Waterbodies and global climate change: the role of waterbody restoration in a changing world,

A Method to Provide Baseline Mapping and Classification for Waterbodies in Queensland VERSION 1.2

J.P. Lacauxet (2006): Classification of ponds from high-spatial resolution remote sensing: Application to Rift Valley Fever epidemics in Senegal.

Chang-Qing, Ke (2010): Analyzing coastal waterbody change in the Yancheng National Nature Reserve, China.

20

Quantification and Mapping of Morphometric Parameters of Subarnarekha River Basin in Eastern India using Geo-Spatial Techniques

Rahaman Ashique Ilahi and Shyamal Dutta

Introduction:

Morphometry can be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms (Bates and Jackson 1987). Morphometric analysis is a set of procedures that characterize the geometric and compositional aspects of environmental systems, serving as indicators of the related form, structural arrangement and interaction between aspects and the network of fluvial channels in a watershed in situations and values that exacerbate hydrological and geomorphological issues. A systematic morphometric analysis helps to understand linear, areal, and relief aspects of the drainage basin. Basin morphometry is a means of numerically analyzing or mathematically quantifying various aspects of drainage channel and its characteristics that can be measured for comparison which includes, the number, length, drainage density and bifurcation of rivers as well as shape, area, relief and slope of the basin. Drainage characteristics of basin and sub-basin have been studied using conventional methods (Horton, 1945; Miller, 1953; Strahler, 1964). Morphometric analysis using remote sensing and GIS techniques have been well demonstrated by some of the researchers (Nautiyal, 1994; Srivastava et al., 1995; Srivastava, 1997; Nag, 1998; Agarwal 1998; Biswas et al., 1999; Shreedevi et al., 2001, 2004, Vittala et al., 2004; Reddy et al., 2004). As a common conclusion they indicated that remote sensing and geographical information system as powerful tools for studying basin morphometry and continuous monitoring. The basin morphometric characteristics of the various basins have been studied by many studied by scientists using conventional methods (Krishnamurthy and Srinivas 1995, Srivastava and Mitra 1995; Agarwal 1998; Biswas et al 1999, Narendra and Nageswara Rao 2006). The rapidly emerging spatial information technology viz., remote sensing, GIS, and GPS, has effective tools to overcome most of the problems of land and water resource planning and management on the account of usage of conventional methods of data process (Rao et al 2010). The uses of remote sensing data and GIS techniques in morphometric analysis of drainage basins have emerged as powerful tools in recent years. When morphometric analysis is incorporated with GIS technologies, it is termed as digital geo-morphometry. Geo-morphometry is the science of the quantification and analysis of the land surface (Pike and Wilson 1971). The morphometric analyses of different basins have been done by various scientists using earth observation data and GIS methods (Nongkynrih and Husain 2011; Waikar and Nilawar 2014; Withanage et al 2014).Present study have four fold objectives. These are a. identification of different elevation zones of basin area, b. Identification of Morphometric

Attributes regarding linear (stream ordering, Length, stream length ration, bifurcation ratio), Areal properties (Basin perimeter, Area) and form factor (Circularity ratio, elongation ratio) c. Area altitude relationship by Hypsometric curve and Stages of evolution and Identification of long profile of Subarnarekha Basin and erosional surfaces.

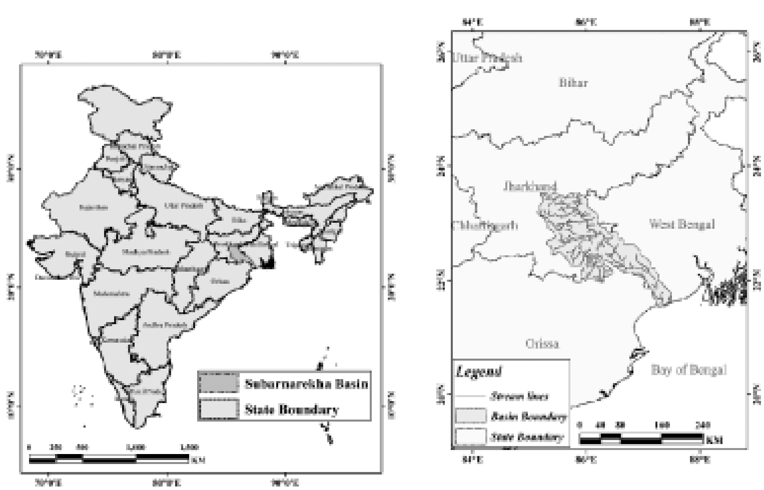
Methods and Database

Study Area

The Subarnarekha river basin bordered approximately between 21°40′N to 23°30′N latitudinal extension and 85°5′E to 87°30′E longitudinal extension (Fig. 1). This includes in addition to the entire Singhbhum district, part of the district of Ranchi (Jharkhand), Keonjhor, Balasore (Odisha), Puruliya and both the Medinipur of West Bengal covering an area of 19422.08 sq.km. The area comprises parts of six quarter inch sheets- 73 E, 73 F, 73 I, 73 J, 73 N, &3 O (Scale 1ich to 4miles, SOI) and in US Army Map numbers (RF: 1:250,000)NF 45-0, NF 45-02, NF 45-05, NF 45-06, NF 45-07, NF 45-10 and NF 45-11. It is one of the longest rivers of Eastern Peninsular India and makes a total run of about 500 km form source at Ranchi to Bay of Bengal to the east of Balasore. The Subarnarekha terrain in Ranchi, Singhbhum and Medinipur districts, is continuous with the eastern Ranchi Plateau with regard to its topographic forms with the Poraghat and Dalma ranges extending almost in east west direction. The basin is generally influenced by the South-West monsoon, which onsets in the month of June and extends up to October. During monsoons, the basin may receive a spell of copious rainfall followed by a long dry period. Of the rainfall, about 57% is lost by evapo-transpiration and 15% infiltrates into ground. The average annual rainfall for the basin is around 1400 mm. The climate in the sub-basin is tropical with hot summer and mild winters. The mean monthly temperature varies from 40.5°C (May) to 9.0°C (December). The highest temperature recorded is 47.2°C and the lowest is 2.8°C. Annual average maximum and minimum temperatures vary from 32.4°C to 18.0°C.

Fig 1

Location of Subarnarekha River Basin in Eastern India



In order to understand the form and features of the present landscape of the Subarnarekha basin it is necessary to consider briefly the geological history of the part of Precambrian metamorphic terrain of the south-eastern Chotanagpur Plateau. Except for the lower reaches of the valley the greater part of the basin consists of a very old continental area which has not been submerged science early Paleozoic times. The so called superficial deposits, mostly of Tertiary and Recent age (Dunn 1940, 1942), cover larger areas in the lower part of the basin. The following are the main geological formations represented in the Subarnarekha Basin (Mukhopadhyay, 1980)

Table 1

Main geological formations represented in the Subarnarekha Basin

Dhanjori Group	Alluvium Laterite Tertiary grits and gravels Newer Dolerites (Cuddapah or earlier) Singhbhum granite Lava Quartzite-conglomerate
……………………………………….*Unconformity*……………………………………..	
Iron Ore Stage	Basic and ultra-basic igneous rocks, Phyllites and tuffs with lenticular arkose, conglomerate and quartzite. Banded quartzite including hematite-quartzite (impersistent) Phyllites, lenticular conglomerates and basic igneous rocks
Chaibasa Stage	Mica, Schist, hornblende schist, quartz granulites and quartz schist.

Source:Mukhopadhyay,1980Techniques and Database

The morphometric variables have been generated through digital elevation model (DEM) using USGS-DEM 30 m (http://www.usgs.gov/) elevation data. The DEM is imported in ARC GIS 10.2 for basin delineation and other morphometric variable measurement and calculation. Thus, both the softwares ARC GIS 10.2 and ERDAS Imagine 9.3 are utilized in present work. The morphometric parameters such as linear, aerial and relief aspects of the Subarnarekha river basin were computed. Streams are extracted from Water Resource Information System (WRIS) (http://india-wris.nrsc.gov.in/wris.html) date provided by ISRO, which is fully web based GIS service in the field of fluvial analysis The morphometric investigation of the linear parameters of the basin includes stream order, bifurcation ratio, stream number, stream length and stream length ratio. The streams of the Subarnarekha Basin have been ranked according to Strahlers (1964) stream ordering system. Stream length measured from the mouth of a stream to drainage divide with the help of GIS software. This has been computed on the basis of the law proposed by Horton (1945) for all the suborders of the study area. The other linear morphometric parameters are computed using standard methods and formulae. The areal aspect of a drainage basin is concerned with X and Y axes calculations of drainage basin. The areal parameters, basin length, basin perimeter, basin area, form factor, stream frequency, drainage density, drainage texture, and infiltration number, are computed using stand techniques or formulae. The relief morphometry calculates basin in all three dimensions, i.e., it analyzes relief in X, Y, and Z axes. Relief morphometry deals with basin heights, slope, slope aspect, area height ratio, altimetric analysis, relief ratio, dissection index, and hypsometric analysis. The maximum relief is the highest elevation point of the basin and the minimum is of lowest point. The relative relief, an important aspect of terrain analysis, is calculated by the formula suggested by Melton (1957). Table 2 shows the various formulae/ techniques adopted for computation of relief aspects of the Subarnarekha Basin.

Table 2

Formulae adopted for computation of morphometric parameters:

Linear	**Morphometric parameters**	**Formula/definition**	**References**
	Stream order	Hierarchical rank	Strahler (1964)
	Bifurcation ratio	Rb = Nu / (Nu+1), where Nu = total no. of stream segments of the order u, Nu + 1 = number of segments of the next higher order	Schumm (1956)
	Stream number (Nu)	Nu = Rb(k–u), where Rb = constant bifurcation ratio; k = highest order of the basin; u = basin order	Horton (1945)
	Stream length (Lu)	Length of the stream (km)	Horton (1945)
	Mean stream length (Lsm)	Lsm= Lu /Nu, where Lu = total stream length of order u (km), Nu = total number of stream segments of order u	Strahler (1964)
Areal	Basin length	Channel length from one end to another wind of the basin	Arc measurement tool
	Basin perimeter	Total length of outer boundary of drainage basin (km)	Arc measurement tool
	Basin area	Area of the basin	Arc measurement tool
	Drainage density (Dd)	Dd = L / A, where L = total length of stream segments of a basin A = area of the basin	Horton (1932)
	Stream frequency (Fs)	Fs = Nu / A, where Nu = total no. of streams of all orders A = area of the basin (km2)	Horton (1932)
	Drainage texture (Dt)	Dt =Nu / P, where Nu = total no. of streams of all orders P=perimeter (km)	Horton (1945)

	Circularity ratio (Rc)	Rc=4ðA / P2, where A = basin area (km2), P = perimeter of the basin (km)	Miller (1953)
	Elongation ratio (Re)	Re=2"(A / ð) / Lb, where A = area of the basin (km2) and Lb = basin length (km)	Schumm (1956)
	Infiltration number (If)	If =Dd × Fs, where Dd=drainage density and Fs = stream frequency	Zavoiance (1985)
Relief	Hypsometric integral	(Mean elevation " minimum elevation) / (maximum elevation "minimum elevation)	Pike and Wilson (1971)

Results and Discussion

Linear morphometric parameters

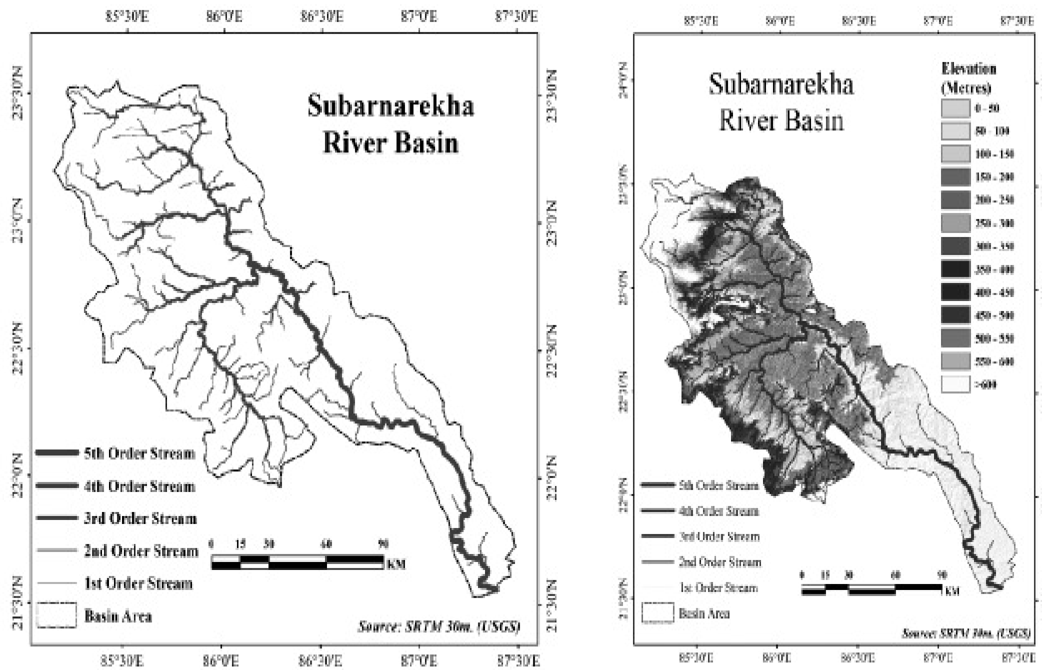
Linear aspects of the basin are closely linked with the channel patterns of the drainage network wherein the topological characteristics of the stream segments in terms of open links of the network system. Stream order is the measure of position of a stream in the hierarchy of tributaries (Leopold et al. 1964). It analyzes the branching pattern of a channel. The unequal distribution of the first-order segment of the basin depends largely on the size and shape of a drainage basin and partly on relief, geologic structure, climate condition, and vegetation cover. Strahler's (1964) technique adopted in the present work shows that Subarnarekha River is of fifth-order drainage basin (Fig. 2). The higher stream order is associated with greater discharge (Hajam et al. 2013).

Table 3

Linear aspects of Subarnarekha River Basin

Linear Order	Stream Length (km)	Mean Stream Length (km)	Cumulative stream Length (km)	Stream length Ratio	Stream Number	Bifurcation Ratio	Mean Bifurcation Ratio
1	1283.4	13.37	13.37	nil	96	4	2.8
2	541.4	22.56	35.93	1.68	24	6	
3	269.7	67.42	103.35	2.99	4	2	
4	58.9	29.9	133.25	0.44	2	2	
5	265.4	265.42	398.67	8.88	1	nil	
Total	2418.8	398.67			127		

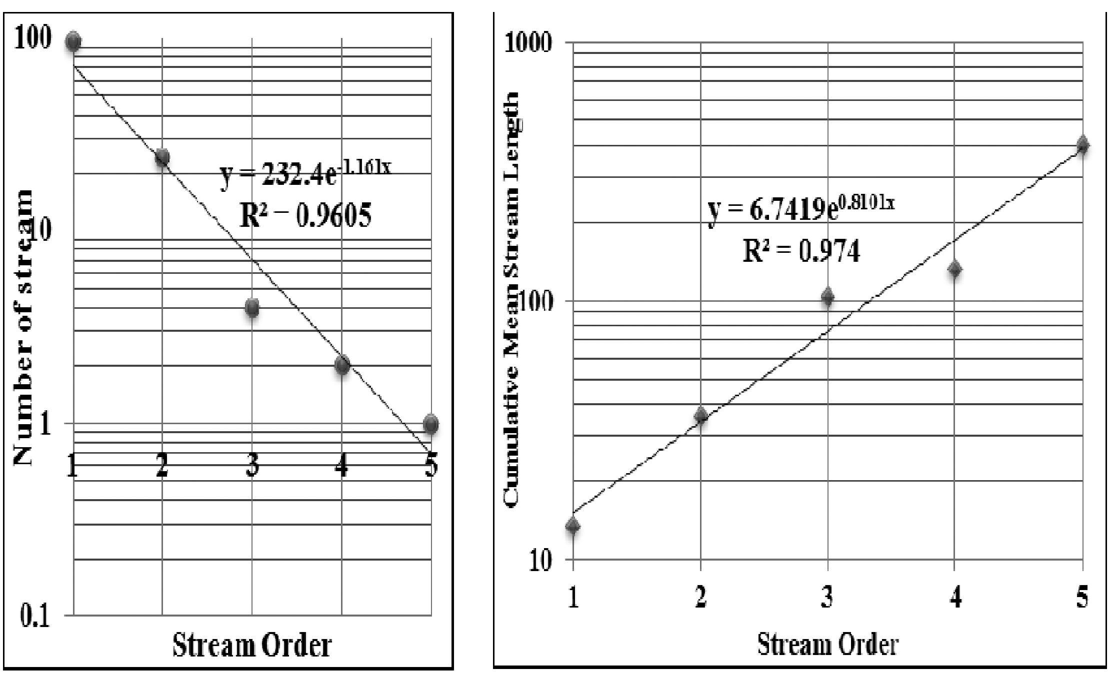
Fig 2:
Digital Elevation Model (DEM) (Right) and Stream Ordering of Subarnarekha River Basin (left)



The trunk stream, Subarnarekha through which all discharge of water and sediment passes, is a stream segment of highest order. The size of the basin and hierarchy of the basin is controlled by the order. The usefulness of the stream order depends on the premise that on an average, if a large sample is treated, order is directly proportional to size of the contributing watershed, channel dimensions, and stream discharge at the place in the system (Bindu et al. 2012). Ultimately, water volume capacity of the drainage basin is controlled by the river basin order. The term Bifurcation ratio is defined as the ratio of the number of stream segments of any given order to the number in the next higher order. The Subarnarekha River is classified as fifth-order drainage basin. The bifurcation ratio value of the area varies between 2 and 6 with a mean bifurcation ratio value of the basin of 2.8 (Table.3). The Subarnarekha Basin has altogether 127 streams linked with 5 orders of streams. The total number of stream is the maximum in the first order (96 Nos.) and gradually decreases with the increase of stream order. The total stream length of the Subarnarekha Basin is approximately 2418.8 km. The first-order stream shows maximum length (1283.41 km) and the minimum length is with the fourth-order stream (59.88 km). The mean stream length of study area is 13.37km for the first order, 22.56 km for the second order, 67.42km for the third order, 29.95 km for the fourth order, and 265.42 for the fifth order. The cumulative stream length for the basin is 398.67 km. The bifurcation data ranges between 2 and 6 with the mean 2.80 indicating that the basin falls under rolling basin category (Coats 1958, Horton 1945). The high bifurcation ratio is found in the first and second, which indicates that streams up to the second order are surging through highly dissected and steep gradient hilly terrain, which facilitates high overland flow and less water recharge into the sub-surface. Hence, groundwater potential is low in the zones of the first and second order stream in comparison to third and upper order streams of Subarnarekha River basin. Mean bifurcation ratio value (i.e., value 2.8) found in this basin is low than the such optimum levels in areas where geological structure definitely have dominant influence on drainage pattern (Chow 1964; Sreedevi et al 2009). Hajam et al (2013) also indicated that the higher mean bifurcation ratio value suggests less permeable rocks with high slope while lower bifurcation ratio value suggests higher permeable rocks with less structural control. Stream number is the count of stream channels in a given order (Horton 1945). Subarnarekha has altogether 127 streams linked with 5 orders of streams. The total number of streams gradually decreases with the increase of stream order. The data conforms to Horton's (1945) law of stream numbers which states that the number of stream segments of successively lower order in a given basin tends to form a geometric series beginning with the single segments of the highest order and increasing according to constant bifurcation ratio. The lower total stream number indicates relatively higher permeability and infiltration. Subarnarekha River basin shows a negative correlation between stream orders and stream numbers (co-efficient of correlation -0.98 and percentage of variance 96%; Fig. 3), which suggests that the several streams usually decreases in geometric progression as the stream order increases. The variations in lithological characters in the basin are possibly responsible for such inequalities in stream frequencies of each order. The stream length measured from mouth of a stream to drainage divide. The total length of stream segments is maximum in first-order streams and decreases as the stream order increases (Table 3).

Fig 3:

The relationships between a stream number and stream order (left) cumulative stream length and stream order (Right)



The source area of Subarnarekha consists of Ranchi plateau with mesas and buttes of highly erodible pebbly and sandy soils (Purkait 2002). The mean stream length is a characteristic property related to the drainage network and its associated surfaces (Strahler 1964). The mean stream length of study area increases with increase of the order. The cumulative stream length data of the Subarnarekha River show positive correlation with the stream order (co-efficient of correlation 0.987 and percentage of variance 97.4%; fig. 3), which conforms to Horton's law of stream length which states that the cumulative stream lengths of stream segments of successive higher orders increase in geometrical progression starting with the mean length of the first order segments with constant ratio. The stream length ratio is a parameter which has direct relationship with surface flow, discharge, and erosion stage of the basin. It varies between 0.44 and 8.8 indicating presence of highly resistant rocks, low slope, and topography in the terrain (Bindu et al. 2012). The stream length ratio (RL) between the streams of different orders of the Subarnarekha River basin is variable. This variation in stream length ratio from one order to another indicates that the Subarnarekha River basin is transient through late youth to early mature stage of development of fluvial geomorphic cycle (Singh and Singh 1997; Singh et al. 2003). Rivers do not follow straight path due to several topographic, structural, and slope changes.

Areal morphometric parameters

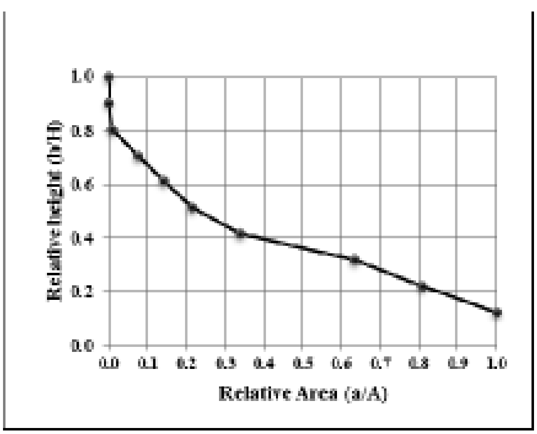
The areal aspects of a drainage basin reveal regional features like lithology, geological structure, climatic conditions, and denudation history of the basin. These aspects control the spatial arrangement, geometrical shape and form of drainage systems, river discharge, and runoff characteristics (Singh 1998). Basin length, basin perimeter, and basin area are important areal morphometric variables which are signature of shape, size, and genetic aspect of a drainage basin. Basin area is a good indicator of lithology, rock strata, dip angle, rainfall, and vegetation. The dip angle of bed rocks is inversely proportional to basin area. The huge basin area means that the master stream is longer and the slope of the terrain is low and vice versa. The computed values of basin length, perimeter, and area of Subarnarekha River basin are approximately 310.38 km, 968.6 km, and 19422.08 km^2, respectively. Form factor, elongation ratio, and circulatory ratio are calculated for basin shape. The basin shape is helpful tool which tells about basin stage. An ideal basin shape is a pear shape. Zero value confirms highly elongated shape and one indicates circular shape of the basin. There are three main categories of basin shape: circular, indented, and elongated.. The form factor value of the basin is low, which indicates elongated shape. Horton (1945) correlated form factor to predict flow intensity of the basin of a defined area. The low value of form factor means flatter peak flow for longer duration with less side flow for shorter duration and main flow for longer duration in the basin (Reddy et al. 2002; Kumar 2013). The elongation ratio, another parameter of basin shape, ranges between 0 and 1.0 over a wide climatic conditions and geologic types. Values near to 0 indicate highly elongated and near to unity indicates circular shape. The elongation value of the Subarnarekha Basin is also low and conforming to form factor, indicating elongated basin. The low value also indicates that the basin has low relief with moderate to high infiltration capacity and low runoff. The basin is also susceptible to moderate erosion and sediment load (Sreedevi et al. 2009). The basin circulatory ratio is controlled by lithology, slope, relief, basin area, elongation ratio, stream discharge, and ruggedness number. The basin circulatory ratio is correlated with basin area and ruggedness number in inverse proportion. If lithology is same over terrain, there is not much variation in basin shape. Flood flows of such elongated basins are easier to manage than of the circular basin. But in this case. Form factor, elongation ratio, and circulatory ratio values of the Subarnarekha Basin are calculated as 0.2, 0.51, and 0.26, respectively. All these form factor analysis indicates to narrow to typically narrow elongated shape of drainage basin. The drainage density and stream frequency of the basin is 0.124 km/km^2 and 0.006/km^2 respectively. The computed drainage texture value of the Subarnarekha Basin is 0.18 indicate coarse texture of the said basin. The infiltration number, a parameter of infiltration capacity of the basin, is 0.0007 which is very low based of the structure of underlying rock strata. The values of length, perimeter, and area of Subarnarekha Basin indicate that slope of the terrain is moderate to low and basin is highly weathered. This also shows that basin is in early mature stage and receives sufficient rainfall. The low circulatory ratio value of the Subarnarekha Basin again conforming to low form factor and elongation ratio values of the basin indicates elongated basin with moderate to low relief, high infiltration capacity, and sub-dendritic stage. The drainage texture depends on climate, vegetation, rock and soil characters, infiltration capacity, relief, and stage of development (Dornkamp and King 1971; Kale and Gupta 2001). The coarse drainage texture is associated with low drainage density, which is in turn dependent on infiltration capacity of the bed-rock (Ozdemir and Bird 2009). The drainage texture value of the Subarnarekha Basin falls under moderately coarse category (Singh 1998). The values also indicate that the basin has good permeability of sub-surface material and infiltration capacity, lower runoff, significant recharge of ground water, and old mature topography. The infiltration number, a parameter of infiltration capacity of the basin, is also very low for the Subarnarekha Basin (0.0007). The low infiltration number also indicates that the runoff will be very low and infiltration capacity is very high due to presence of highly permeable rocks/soil in the terrain.

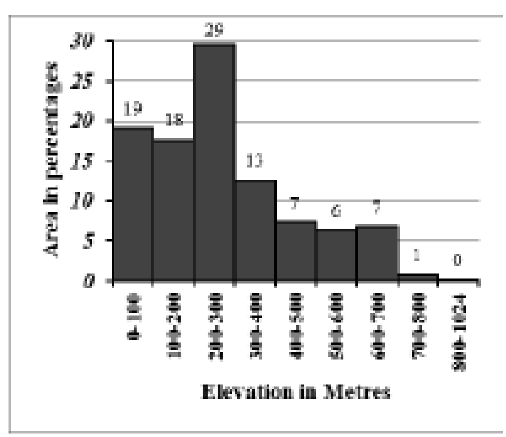
Relief Morphometry with Area-altitude relationship

Based on the regional charteristics as well as relief aspect of the basin whole Subarnarekha Basin is subdivided in five physiographic regions which also considers the slope and aspects of the region. These are: 1. above 550m. Regions mainly known as Ranchi Plateau and intervening hilly ranges, 2. Elevation 500 to 550m region mainly the escarpment area of Hundru falls, 3.Area between 200 to 400 m. is belonging to Central plain land, 4. Below 200 but above 50 metres region is mainly belong to lower course of river and plain land and 5. Below 50m. Region is coastal plain of Bay of Bengal. The basin relief is an important parameter to understand the denudational characteristics of the basin. It helps to interpret geomorphic processes and landform characteristics.

Fig 4

Area-Altitude relationship (left) and Hypsometric Curve of Subarnarekha River Basin (Right)

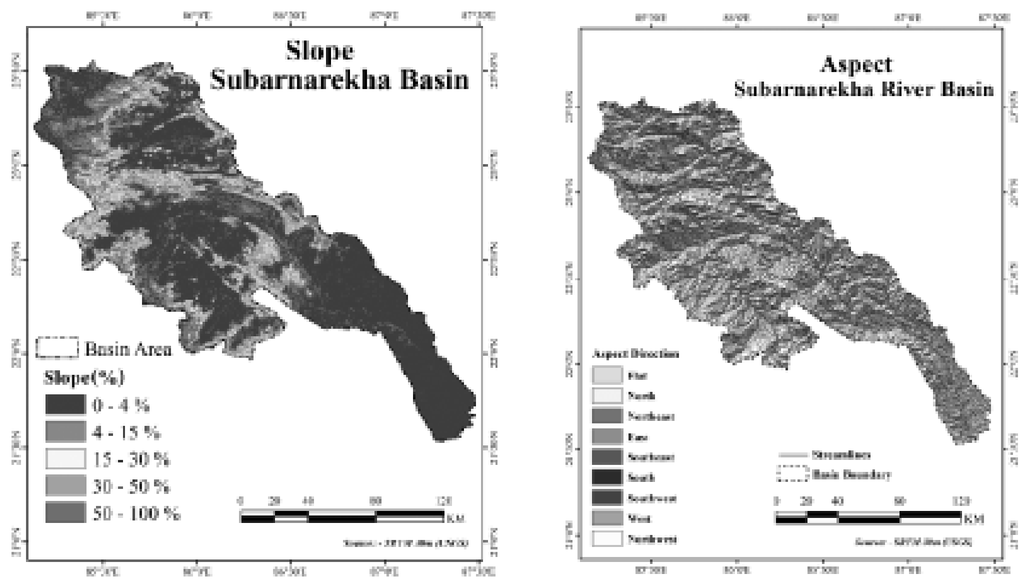




The highest relief of the Subarnarekha Basin is 1024 m and the lowest is 0 m in base level of Bay of Bengal. Pike and Wilson (1971) proved mathematically that the elevation-relief ratio (E), which is defined as E=(mean elevation"minimum elevation) / (maximum elevation" minimum elevation), is identical to the hypsometric integral but has the advantage that it is much more easy to obtain numerically. As per Davisian's cycle of erosion, the low HI value indicates that the terrain is in mature stage and very close to old stage. The area-height curve indicates actual area between two successive contours. The area-height curve of the Subarnarekha Basin (Fig.) shows that the 44 % of the basin has altitude above 300 m (fig. 4) The hypsometric integral (HI) values for the basin are computed as 0.37 which show the early mature stage of evolution in the Subarnarekha Basin.

Fig 5

Slope (Left) and Aspects of Slope in Subarnarekha River Basin (Right)



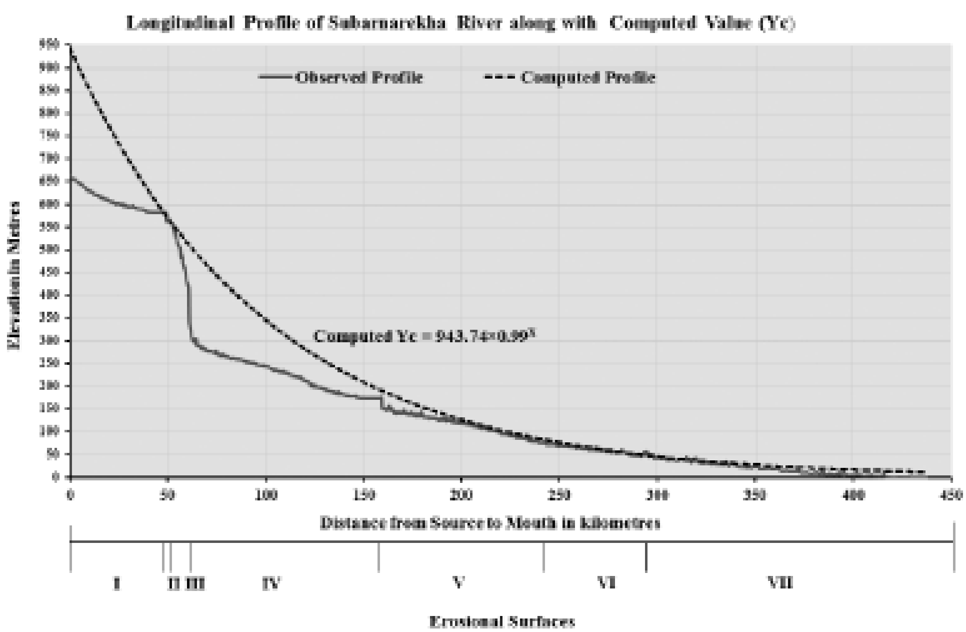
Slope is inclination of terrain from imaginary horizontal plane which depends upon the nature of terrain—lithology, structure, soil, vegetation, climate, landforms, and morphogenetic processes operating in the underlying rocks (Strahler 1952; Yehet al. 2009). Slope map of the Subarnarekha Basin shows that except for few areas in the central escarpment region, the basin has low slope (Fig 5). The low slope of the basin indicates high infiltration and less runoff (Sreedevi et al. 2009). Figure 5 (right) shows an aspect map of the basin. The basin is gently sloping towards south to south-east direction. The slope in any terrain is controlled by climate and morphogenetic processes operating in the underlying rocks (Strahler 1950, 1952; Yeh et al. 2009).

Analysis of River profile and landforms

River profile has two aspects: longitudinal profile and transverse profile. Longitudinal profile is a linear representation of drainage from source to mouth which accounts statistical values as well as geomorphic signatures like erosion surfaces. This profile for the Subarnarekha River has been drawn with the help of Arc GIS. It gives information about elevation value at different locations of river bed. Longitudinal river profile of the Subarnarekha River shows that it is originated at the elevation of 1024 m in the Ranchi Plateau while its base level is at 0 m in the Bay of Bengal (Fig. 6). There is one major break of slope near the falls of the Subarnarekha River in the long profile. An important break of gradient along this river occurs near Hundru Falls area which has been regarded as the lower knick point marked by abrupt drop of the thalweg in the southern limit of Upper course. A second break in the thalweg occurs near Ranchi but not so much pronounced like Hundru. Both these two knick point delineated the two bold Erosional Surfaces. These are Erosional Surface I & II. Rest of the Erosional surfaces (III, IV, V, VI and VII) is located below the elevation of 300 metres. Significant differences show between actual profile and Expected exponential curve indicates remarkable changes in base level and the effect of tectonic actions especially in the upper reaches of the river. Here exponential curve of the type $Yc = ab^{X} + k$ has been used where 'a' indicates altitude, 'b' indicates slope and k is a constant which involves a constant ratio of change and therefore a constant ratio of change in the amount of change. Over the long periods of geological time, denudation and chronological series of this river basin have not shown either a constant amount of change or a constant ratio of change mainly with regard to length and altitude.

Fig 6

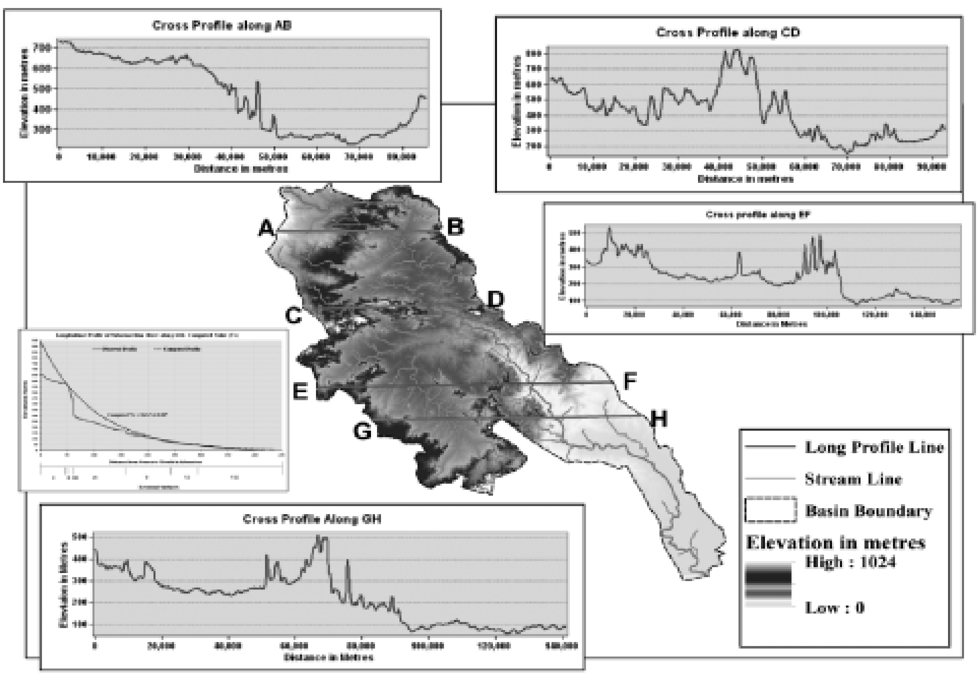
Longitudinal Profile from source to Mouth and Erosional Surfaces of Subarnarekha River Basin



The increasing series in long profile show an increasing amount of a change but a decreasing ratio of change. A number of important finding came out form the long profiles as well as from different cross profiles in the upper (A-B), middle(C-D) and lower courses(E-F and G-H) of Subarnarekha River Basin (Fig. 7). Numerous river terraces found in the lower and middles reaches of the river clearly show that changes in base level in different time span. It seems logical to assume that prior to the numerous changes in base level; a mature drainage system was present over the erosional surfaces above 550 m. The existing valley system exhibits the features of late matured stages of erosion cycles and different features of graded river. Each knick point or rejuvenation head mainly illustrated the initiation of new cycle consistent with recession of the knick by change of the base level. It also suggests the possible occurrence of uplifts-their magnitude and locations. The presence of inequalities in the long profile seems to have evolved in the development of differential weathering status.

Fig 7

Digital Elevation Model (DEM) along with Cross profiles in the different courses in the Subarnarekha River Basin



Conclusions

The quantitative analysis of morphometric indices i.e., channel morphology, drainage pattern, and landforms is an immense tools used in evaluating river basin and the watershed preference for soil, conservation of water and resource management at micro level. The morphometric analysis is of great importance in hydrological behavior of basin for water quality project, engineering works, public policies applications and flood forecasting, erosion control and environmental management, it is also essential for accurate modeling analysis. The morphometric parameters evaluated using GIS helped us to understand various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc. The interferometric SRTM radar data along with analysis from DEM showed satisfactory results in the morphometric characterization. This survey highlights the potential of radar metric products in the analysis of relief morphometry to serve as a basis for geomorphological mapping. Combined with other data (e.g., soil, use, vegetation cover, climate), such products can support diagnostics and environmental and land use analyses. The analysis carried out for the Subarnarekha River basin depicts that the basin is tending towards elongated shape. The morphometric parameters considered for the analysis include the linear, areal, and relief aspects of the Subarnarekha Basin, Chotanagpur Plateau, India, located in the tropical climatic region. Drainage network of the basin exhibits fifth-order basin with dendritic type which indicates the homogeneity in lithology and lack of structuralcontrol. The linear aspects indicated that the Subarnarekha River is sinuous and the basin has moderate to high resistant rocks with maximum geological structural controls. The areal aspects indicate that the basin is elongated. All morphological parameters in together indicates that the basin is in early mature stage of erosional development. It also suggests the possible occurrence of uplifts-their magnitude and locations. The presence of inequalities in the long profile seems to have evolved in the development of differential weathering status. The present study clearly indicated certain relationships. These include relationship among several attributes of the morphometric aspects which helped in assessing the topography and immensely contributed a basis for water resource development and management.

References

Agarwal CS (1998) Study of drainage pattern through aerial data in Naugarh area of Varanasi district, U.P. J. *Indian Soc. Rem. Sens., 26(4):* 169-175.

Bates RL, Jackson JA (1987) *Glossary of geology* 3d ed., Alexandria, Va., American Geological Institute, 788p

Bindu G,Neelkantan R, Ragunath R (2012) Assessment ofmorphometric characteristics of Chittar river basin, Triruvantpuram district, Kerala: a remote sensing and GIS based study. *Indian J Geomorph 1*:127–132

Biswas S, Sudhakar S, Desai VR (1999) Prioritization of sub watersheds based on morphometric analysis of drainage basin - A remote sensing and GIS approach. *J. Indian Soc. Rem. Sens., 27(3)*: 155–166.

Coats, DR. (1958) Quantitative geomorphology of small drainage basins of southern Indiana. Office of naval research,Geography Branch, Project NR 389–042, Technical report 10 Chow VT (1964) *Handbook of applied hydrology*. McGraw Hill Inc, New York, 1495p

Dornkamp, JC. King, CAM.(1971) *Numerical analysis in geomorphology, an introduction*. St. Martins Press, New York, 372p

Dunn, J.A. (1940) The Stratigraphy of South Singhbhum. *Mem.Geol Surv. India Vol. LXIII Pt. 3*

Dunn, J.A.(1942) The Economic Geology and Mineral Resources of Bihar Province. Mem.Geol Surv. *India Vol. LXXVIII* 10-12 pp.

Hajam, R.A., Hamid, A. Bhat, S. (2013) Application of morphometric analysis for geo-hydrological studies using geo-spatial technology—a case study of Vishav drainage basin. *Hydro Cur Res 4*:1–12

Horton, R.E. (1932) Drainage basin characteristics. *Am Geoph Union Trans 13*:350–361

Horton, R.E. (1945) Erosional development of streams and their drainage basin, Hydro physical approach to quantitative morphology. *Geol Soc Am Bull 56*:275–370

Kale, V.S., Gupta, A. (2001) *Introduction to geomorphology*. Orient Longman Ltd Calcutta

Krishnamurthy J, Srinivas G (1995) Role of geological and geo-morphological factors in groundwater exploration : A study using IRS LISS data. *Int. J. Rem. Sens., 16*: 2595–2618.

Kumar, N. (2013) Morphometric analysis of river catchments using remote sensing and GIS (a case study of the Sukri River, Rajasthan). *Int J Sci Res Publ 3*:1–6

Leopold, L.B., Wolman, M.G., Miller, J.P. (1964) *Fluvial process in geomorphology*. W H Freemen, Sanfransisco, 522p

Melton, MA. (1957) *An Analysis Of The Relation Among Elements Of Climate, Surface Properties And Geomorphology.* Dept of Geol, Columbia Univ, New York, 102p

Miller, V.C. (1953) *A Quantitative Geomorphic Study Of Drainage Basin Characteristics In The Clinch Mountain Area, Virginia And Tennessee*. Dept of Geol Columbia Univ, New York, pp 389–402

Mukhopadhyay, S.C. (1980) *Geomorphology of the Subarnarekha Basin.* The Chota Nagpur Plateau (Eastern India), The University of Burdwan

Nag, SK. (1998) Morphometric analysis using remote sensing techniques in the Chaka sub-basin purulia district, West Bengal. *J. Indian. Soc. Rem. Sens., 26*: 69–76.

Narendra, K., Nageswara, R.K. (2006) Morphometry of the Mehadrigedda watershed, Visakhapatnam district, Andhra Pradesh using GIS and Resources at data. *J. Indian Soc. Rem. Sens., 34:* 101–110.

Nautiyal, A.R. (1994) Eco-physiology of trees: A prerequisite to improve tree productivity. In: Forestry Research and Education in India (eds. Dogra PP, Dhiman RC) *Indian Nat. Acad. Sci*., pp. 106-122.

Nongkynrih, JM., Husain, . (2011) Morphometric analysis of the Manas river basin using earth observation data and geographical information system. *Int J Geomagn Geosci 2*:647–654

Ozdemir, H., Bird, D. (2009) Evaluation of morphometric parameters of drainage networks derived from topographic maps and DEM in point of floods. *Environ Geol 56*:1405–1415

Pike, R.J., Wilson, S.E. (1971) Elevation-relief ratio, hypsometric integral and geomorphic area-altitude analysis. *Geol Soc Am Bull 82(4):* 1079–1084

Purkait, B. (1983) Current directions in the Usri River point-bar, Bihar. *Ind J Earth Sci 10*:170–184

Rao, NK., Latha, SP., Kumar, AP., Krishna, HM. (2010) Morphometric analysis of Gostani River basin in Andhra Pradesh State, India using spatial information technology. *Int J Geomagn Geosci 1*:179–187

Reddy, OGE., Maji, AK., Gajbhiye, KS. (2002) GIS for morphometric analysis of drainage basins. *GIS India 4*:9–14

Schumm, SA. (1956) Evolution Of Drainage Systems And Slopes In Badlands At Perth Amboy, New Jersey. *Geol Soc Am Bull 67*:597–646

Strahler, A.N. (1964) *Qualitative Geomorphology Of Drainage Basins And Channel Networks*. In handbook of Applied Hydrology, *VT Chow (ed.):* 4.39-4.76

Shrivastava, VK., Mitra, D. (1995) Study of drainage pattern of Ranigang Coalfield (Burdwan District) as observed on Landsat-TM/IRS LISS-III Imagery. *J. Indian Soc. Rem. Sens., 23(4)*: 225-235.

Shrivastava VK (1997) Study of drainage pattern of Jharia coalfield (Bihar), India, through remote sensing technology. *J. Indian Soc. Rem. Sens., 25(1):* 41-46.

Sreedevi, PD., Subrahmanyam, K., Shakeel, A. (2005) The Significance Of Morphometric Analysis For Obtaining Ground Water Potential Zones In Structurally Controlled Terrain. *Environ Geol 47(3):*412–420

Sreedevi PD, Owais S, Khan HH, Ahmad S (2009) Morphometric analysis of a watershed of south India using SRTM data and GIS. *J Geol Soc India 73*:543–552

Singh S, Singh MC (1997) Morphometric analysis of Kanhar River Basin. *Natl Geog J India* 43:31–43

Singh RK, Bhatt CM, Prasad VH (2003) Morphological study of a watershed using remote sensing and GIS techniques*. Hydrol J* 26:55–66

Singh S (1998) *Geomorphology.* Prayag Pustak Bhawan Allahabad: 610-615p Longman Ltd Calcutta

Strahler AN (1952) *Dynamic basis of geomorphology*. Geol Soc Am Bull 63:923–938

Vittal SS, Govindiah S, Honne Gowda H (2004) Morphometric analysis of sub- watersheds in the pawagada area of Tumkur district, South India, using remote sensing and GIS techniques. *J Indian Soc Remote Sens 32*:351–362

Waikar, M.L., Nilawar, A.P. (2014) Morphometric analysis of a drainage basin using geographical information system: a case study. *Int J Multidiscip Curr Res 2*:179–184

Withanage, N.S., Dayawansa, N.D.K., De Silva, R.P. (2014) Morphometric Analysis Of The Gal Oya River Basin Using Spatial Data Derived From GIS. *Trop Agric Res 26(1):*175–188

Yeh, H.F., Lee, C.H., Hsu, K.C., Chang, P.H. (2009) GIS For The Assessment Of The Groundwater Recharge Potential Zone. *Environ Geol 58*:185–195

Zavoiance, I. (1985) *Morphometry of drainage basins (developments in water science)*. Elsevier Science, New York USA, 250p

21

Paleogeographic Analysis of Laterites in the North-Western Bengal Basin, West Bengal, India: Inference on Past Environment

Sandipan Ghosh, Sanat Kumar Guchhait and Srabani Bose

Introduction

To know the present physical phenomena and dynamic changes the contemporary researchers and geo-scientists have used the methodology of palaeogeography which aims to provide crucial information on the past physical environment, palaeoclimatic signatures, diagnostic landforms and geomorphic processes of past, ancient geological deposits and geo-archaeological signatures also. The landscape is a product of forms, materials of different origins and ages and the present day landscape has roots in relict and ancient environment with overprint of the Quaternary processes (Mishra et al., 2007; Deo and Rajaguru, 2014). The laterites of India are such geological unit which usually reflects relict weathered products of pre-Anthropocene palaeoenviornment, morpho-stratigraphic markers of past and unique paleogeomorphic evolution since Palaeogene (Milnes et al., 1985). Here the laterites and all ferruginous deposits are studied from the perspectives of palaeoclimatology and palaeogeomorphology, because these earth materials reflect a distinctive past geo-climatic episode which is not present in India and as well as in the north-western Bengal Basin (West Bengal).

It is quite impossible to travel far in India without observing the remarkable ferruginous crust to which F. Buchanan in 1807 gave the name of 'laterite' which is a near-surface natural hard ferruginous material used as brick (Tardy, 1992). Laterite can be defined as the reddish – brown coloured product of intense tropical weathering made up of mineral assemblages that may include iron or aluminum oxides, oxyhydroxides or hydroxides, kaolinite and quartz, characterized by a molar ratio, SiO_2: R_2O_3 (where, R_2O_3 = Al_2O_3+Fe_2O_3+TiO_2), and subjected to hardening upon exposure to alternate wetting and drying (Alexander and Cady, 1962; Maignien, 1966; McFarlane, 1976; Tardy, 1992). In the tropical geo-climatic settings, the processes of lateritisation (transfers of Fe), latosolization (residual accumulation of Fe), desilication (loss of silica from the profile) and rubification (reddening the regolith and soil horizons with iron oxides) are simultaneously operated to develop distinct horizons of laterite (Ghosh and Guchhait, 2015).

In West Bengal part of the Bengal Basin the detail regional and geomorphic descriptions of *Rarh* laterites are provided by Niyogi et al. (1970), Niyogi (1975), Biswas (1987), Chatterjee

(2008) and Chakraborti (2011) and the geological importance of laterites are discussed by Roy Chowdhury (1986), Banerjee (1993), Das Gupta and Mukherjee (2006), Ollier and Sheth (2008). The cradle of the world largest Ganga – Brahmaputra Delta is the Bengal Basin which is a structural depression (in between Indian plate and Eurasian plate) that the rivers filled up during the last ~ 150 Ma to its present configuration (Bandyopadhyay, 2007). The major peninsular river system of Damodar, Ajay, Mayurakshi, Brahmani, Kasai and Subarnarekha etc. are the chief carrier of ferruginous coarse sediments into the shallow marine condition of Bengal Basin shelf zone since Paleogene, forming later a north-south undulating secondary lateritic interfluves due to prolong lateritisation processes and minimal upliftment (Niyogi et al., 1970; Ghosh and Guchhait, 2015).

The information on stratigraphic or geomorphic relations, laterite – parent rock relationships, genesis of laterites and absolute age data are very scanty in this region of West Bengal. Basically the geomorphic evolution of laterites and exact age of duricrust are still not scientifically evaluated in this part of West Bengal. To resolve the aforesaid problems and to depict the unique characterization and palaeogeography of laterites, this work is initiated to analyse the different laterite profiles of Rajmahal Basalt Traps (RBT) and *Rarh* Bengal. The major objectives are as follows.

1. Analysing the lithofacies of laterite profiles to evaluate *in-situ* and *ex-situ* origin
2. Identifying the possible geological time span of lateritization event
3. Finding out the palaeoclimatic and palaeogeomoirphic importance of laterites

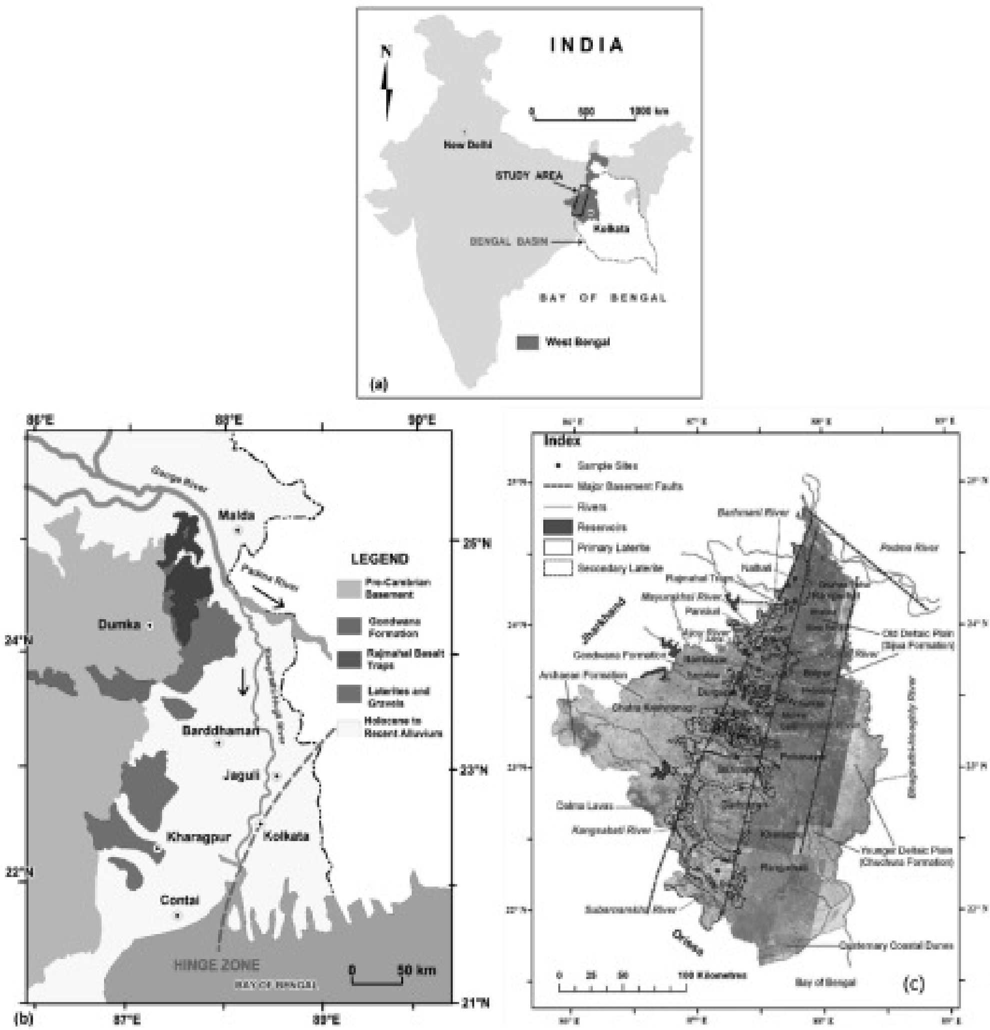
Study Area

The zone of laterites is the main spatial unit of study, bounded by the latitude 22° 00´ to 24° 30´ N and longitude 86° 45´ to 87° 50´ E (figure 1). In between 115 m and 35 m contours the *Rarh,* i.e. 'land of red soil' (Bagchi and Mukherjee, 1983; Sarkar, 2004), lateritic patches hold the remnants of thick forest cover which includes tropical deciduous plant species like *Shorea robusta, Madhuca indica, Terminalia chebula, Eucalyptus globulus, Tectona grandis* and *Acacia auriculaeformis* (Ghosh, 2008). Presently this region bears the characteristics of a tropical sub-humid type of monsoon climate (mean annual rainfall of 1200 to 1400 mm) and tropical wet-dry morphogenetic landforms.

The Bengal Basin (figure 1b), in the eastern part of Indian subcontinent (about 25° N latitude to about 7° S) between the Indian Shield and Himalayan mountain system, covers Bangladesh, parts of West Bengal, Tripura and the Bay of Bengal and it is well known for the development of a thick (~ 22 km) Early Cretaceous – Holocene sedimentary succession (Alam et al, 2003; Das Gupta and Mukherjee, 2006). The west – central part of West Bengal (i.e. north-western shelf zone of the Bengal Basin) is neo-tectonically influenced by the basin margin faults systems (viz., Chotanagpur Foothill Fault, Garhmayna – Khandoghosh Fault and Pingla Fault) and the zone of laterites is placed in between the fault systems as an uplifted interfluves (figure 1c).

Figure 1

(a) Location of study area and Bengal Basin in eastern part of India, (b) general surface geology of north-west part of Bengal Basin (modified from Das Gupta and Mukherjee, 2006), and (c) identified units of primary and secondary laterites (i.e. study area) with basement fault system in West Bengal, dissected by west – east flowing parallel rivers and merged with Older Deltaic Plain (Sijua Formation) of Bengal Basin at east (Ghosh and Guchhait, 2015)



Geologically this part of West Bengal was formerly developed as the stable shelf province of Bengal Basin which experienced severally marine regression and transgression since Miocene, related to climate change and neo-tectonic activity (Alam et al., 2003). Fringing the basalts of Early Cretaceous Rajmahal Basalt Traps, sandstones of Gondwana Formations (Permian – Silurian) and granite – gneiss of Archaean Formation at west and Late Quaternary Older Alluvium (Panskura and Sijua Formations) at east, the lateritic zone of *Rarh Bengal* is found at the north – western border of the Bengal Basin.

Methodology

Secondary Data Collection

To collect spatial information the topographical sheets (1 : 50, 000 scale) of Survey of India (SOI, 72 P/12, 73 M/3, M/4, M/6, M/10, M/11 and 73 N/1) and GSI (Geological Survey of India) district resource maps of Birbhum, Barddhaman, Bankura and West Medinipur districts are severally used in research. The outline map of *Rarh Bengal* is prepared in ArcGis 9.1 with the help of a base-map prepared by Bagchi and Mukherjee (1983). With help of shapefile format we have prepared thematic maps using option of subset in Erdas 9.1. To identify the lateritic zone we have used the post-monsoon GLCF (Global Land Cover Facility, http://glcf.umd.edu/data/landsat/) Landsat ETM+ images of 2000 – 2001 (path/row – 138/43, 138,44, 138/45, 139/43, 139/44, 139/45 and 140/44). The ASTER (Advanced Space Borne Thermal Emission and Radiometer) elevation data with 30 m resolution of 2011 is collected from the website of Earth Explorer (http://earthexplorer.usgs.gov/).Alongside we have used the unpublished geological expedition reports of GSI, Eastern Region which are regularly provided in the official website (http://www.portal.gsi.gov.in).

Samples Site Selection

To know the palaeogeneisis of laterites we have studied different laterite profiles of *Rarh* Bengal districts (viz., Birbhum, Bardhhaman, Bankura and West Medinipur). Detailed field investigations of weathering archives and litho-facies are conducted in the sample sites (figure 1c) of Nalhati (24° 17´ 47´´ N, 82° 49´ 28´´ E), Pinargaria (24°12´13´´ N, 87°40´13´´ E), Ghurnee Pahar (24°15´43´´ N, 87°39´11´´E), Dubrajpur (23°47´12´´ N and 87°25´19´´ E), Sriniketan (23°41´31´´ N and 87°40´31´´ E), Hetodoba (23°26´45´´N and 87°32´07´´E), Bishnupur (23°05´28´´ N and 87°16´15´´ E), Garhbeta (23°05´28´´ N and 87°16´15´´ E) and Rangamati (22°24´42´´N, 87°17´55´´E), covering the span of study area.

Dating of Laterite Samples

Optically stimulated luminescence (OSL) dating is applied here to find the accurate age of facies. OSL dating method uses minerals (quartz and feldspar) that are common in most environments making the technique applicable in the tropical landscapes of ferruginous deposits. The precise method of luminescence dating was reviewed, elaborated and used by Aitken (1998), Botter-Jensen (1997), Prescott and Robertson (1997) and Rittenour (2008). Routine OSL dating of quartz can give ages from 10 +- 3 a to 150 ka (Stokes, 1999, Duller, 2004). For accurate chrono-stratigraphic age detection, OSL dating of laterite lithofacies is done in the samples of Sriniketan (Birbhum), Bishnupur (Bankura) and Garhbeta (West Medinipur).

The formation of secondary iron-oxides (hematite) by chemical weathering processes allow palaeomagnetism to be used to date ferruginous regolith material. The palaeomagnetic data of laterite samples are collected from the writings of Schmidt et al., (1983) and Kumar (1986). The data of $^{40}Ar / ^{39}Ar$ dating is used here to date the primary laterites. Crytomelane [$K_x Mn_{8-X}^{IV} Mn_x^{III} O_{16}$, n H_2O] is a major Mn-oxide of many lateritic Mn-ore deposits in south India (Bonnet et al., 2015a). This mineral is a suitable chronometer for of $^{40}Ar / ^{39}Ar$ step heating dating of weathering processes in the lateritic soils including duricrusts and manganiferous ore dposits (Bonnet et al., 2014, 2015a; 2015b; Beauvais et al., 2016).

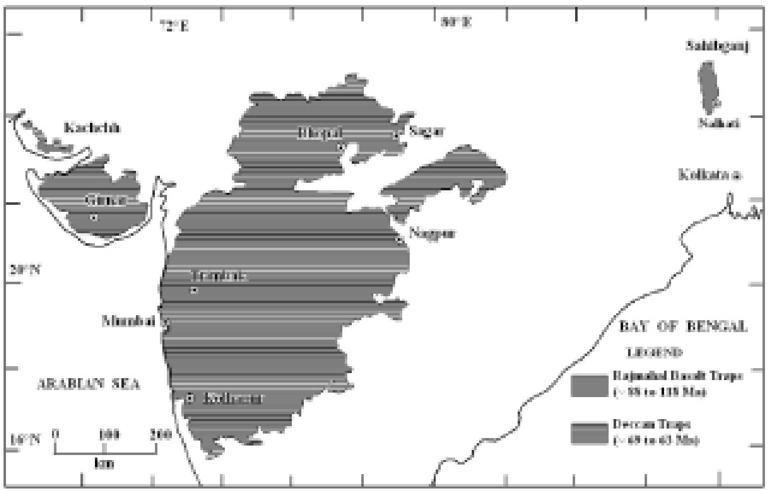
Analysis of Laterite Profiles

Laterites over RBT

There is lacking to explore the tropical weathering profiles in the region of Rajamahal Basalt Traps (RBT, figure 2) which is recognized as the oldest volcanism in Jurassic - Cretaceous period. RBT is one of important part of Chotanagpur Plateau (located at east of Jharkhand, fringing West Bengal) which has the oldest plant fossils (under the cover of laterites) dating back 150 – 200 million years.

Figure 2

Spatial distribution of Deccan Traps and RBT in India (modified from Krishnamurthy et al., 2014)



In the section of Baramasia (24°12´12´´N, 87°40´29´´E) three distinct domains (i.e. lithomarge, mottle zone and duricrust) of laterite profile (figure 3) are clearly observed, corresponding to the ideal profile of Thomas (1974), Tardy (1992) and Ollier and Sheth (2008). The saprolite-alteration domain (i.e. strongly weathered basalt – lithomarge) are normally located below the ground water table (i.e. saturated zone), that is in permanently wet condition, having a depth of more than 11.5 metre. In this profile fine saprolite or lithomarge is observed in between 6.5 and 8.3 metre depth and the structures of the parent rock (i.e. basalts) and the original volumes are almost preserved. The basalts of RBT is constituted of plagioclase, pyroxene, opaque and glass with intergranular to intersertal texture.

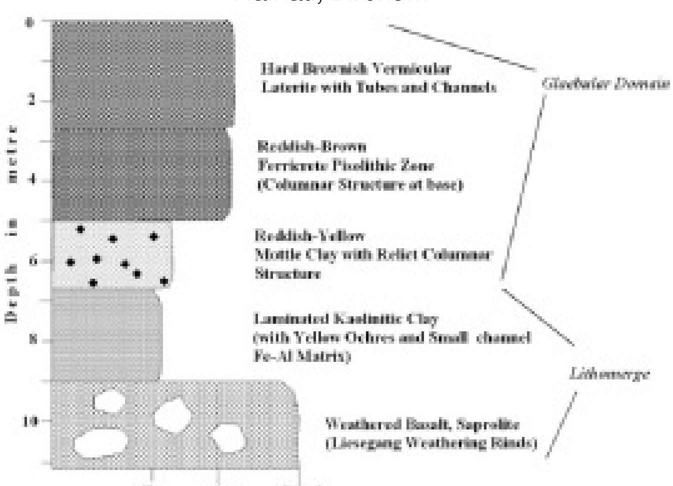
The dominant minerals are secondary kaolinite [$Al_2Si_2O_5(OH)_4$)] and ferruginous hydroxides in amorphous phase. An excessively leached lithomarge (Tardy et al, 1991) corresponds to pallid zone is found here, underlining the mottled zone and separating by red bands of laminated lithomarge and ferruginous grit. The mottle zone (2.85 – 6.5 metre depth) reflects abundance Fe-mottles, mostly of a brown red colour, is diffuse glaebules and result in a concentration of iron which precipitates mainly as goethite and as hematite together with kaolinte matrix. Due to intensive leaching of kaolinte, macrovoids (tubules and alveoles) are formed. Importantly lithorelictual Fe-mottles are accumulated, reflecting the palaeostructure of weathered Rajmahal basalt. The massive ferricrete zone (0.52 – 2.85 metre depth) corresponds to a progressive accumulation of iron and as a consequence, to a progressive development of hematitic iron nodules. Another well developed and well preserved laterite profile of about 11 m thick, will all its attributes of primary laterites (ferricrete zone of > 4.0 m thick) is exposed at Nalhati hillock (24° 17´ 47´´ N, 82° 49´ 28´´ E) near Nalhati, Birbhum district (figure 4).

Figure 3

Field photographs showing (a) glimpse of secondary laterite hard crust zone (a), massive primary ferricrete zone (b) and mottle zone with ferruginous litho-relicts of RBT (c) at Baramasia section (height of man is 1.8034 m), and (b) formation of ferricerete at upper horizon and development of mottles in channels and tubes in lower horizon at the Baramasia section (length of scale is 30 cm).

Figure 4

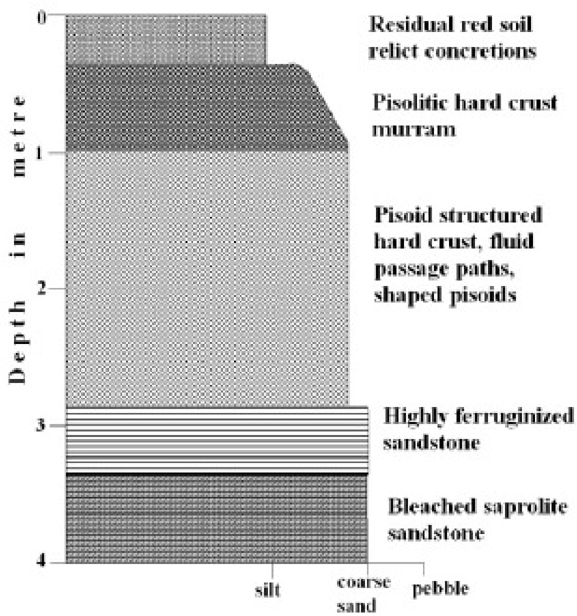
Well-developed sub-surface section of primary laterite on the weathered Rajmahal Basalt in Nalhati, Birbhum



Laterites over Gondwana Sandstones

At the sample site of Dubrajpur, Birbhum (23°47´12´´ N and 87°25´19´´ E) the *in-situ* residuum laterite profile is found over the Gondwana sandstone beds (Silurian age) with characteristic ferruginous residual soil, a loose murram horizon, hard crust, ferruginized sandstone and altered saprolitic sandstone (figure 5). The residual and partially developed soil generally forms a 25 to 35 cm thin soil cover consisting of relict ferricrete concretions and coarse sand grains. The presence of loose murram (i.e. dismantled horizon of ferricrete) over the duricrust is not a continuous phenomenon but wherever it is present, it occurs as 30 to 40 cm thick unit, constituting of ferricrete nodules, circular to amoeboid shaped concretions of iron and sand balls. Hard structured massive duricrust ranges in thickness from 2.0 to 2.65 m and may be divided into pisolitic ferricrete (up to 1.0 m depth) and pisoid structured ferricrete (1.0 to 2.8 m depth). This part is characteristically rich in globular pisolites and fluid passage paths. The duricrust is underlain by very hard ironstone or highly ferruginized sandstone layer, varying thickness from 10 to 65 cm. This layer is underlain by altered sandstone or saprolitic sandstone of 45 to 50 cm thickness (exposed thickness).

Figure 5:
Development of pisolitic hard crust on highly ferruginized sandstones of Gondwana Group in Dubrajpur, Birbhum



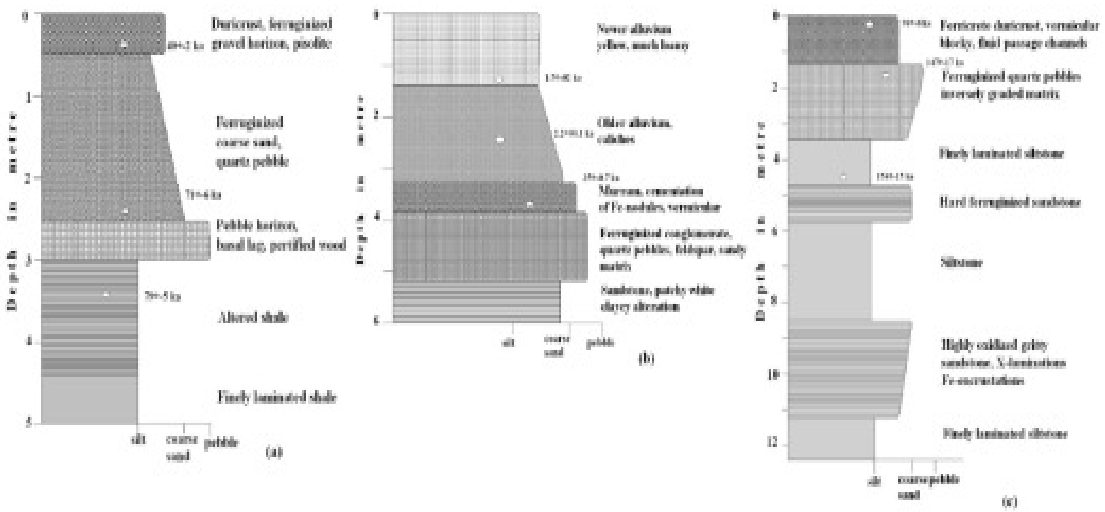
1.1 Laterites of *Rarh* Bengal

The *ex-situ* laterite profile of Sriniketan, Birbhum (23°41´31´´ N and 87°40´31´´ E) is characterized by (1) pebble horizon (2.6 to 3.0 m depth), (2) ferruginized coarse sand (0.55 to 2.6 m depth) and (3) duricrust (up to 0.55 m depth) (figure 6a). Pebble horizon is characterized by a lag deposits, constituting of pisoids, quartz pebbles and petrified woods of varying sizes set in a ferruginized matrix of sands. The ferruginous duricrust appears as a conglomerate ferricrete and Gmg (i.e. inverse to normal grading matrix-supported gravels) fluvial facies.

In the exposed profile of Bishnupur, Bankura (23°05´28´´ N and 87°16´15´´ E) one conglomerate ferruginous unit un-conformably overlies the grey coloured coarse sandstone unit (figure 6b). The Paleogene sandstone unit is un-conformably overlain by a ferruginized conglomerate unit (3.8 to 5.1 m depth) which is oligomictic in character with pebbles of dominantly quartz and little feldspar. The upper part of this conglomeratic ferricrete duricrust (3.2 to 3.8 m depth) is represented by murram with iron-stained quartz pebbles of 1 to 2 cm in size and ferricrete nodules in a ferruginized sand sized matrix (Gmg facies).

Figure 6

(a) Formation of ex-situ ferruginized duricrust with gravel horizons on finely laminated shale in Sriniketan, Birbhum, (b) successive lithofacies of newer alluvium, older alluvium and vermicular ferruginous hard crust in Bishnupur, Bankura, and (c) development of Early Quaternary ferricrete and ferruginized quartz pebbles on finely laminated alternate siltstone and sandstone sequences in Garhbeta, West Medinipur (age in ka derived from OSL dating of samples)



The right bank of Silai River, exposes a vertical profile (figure 6c) of almost 12 to 14 m thick package of alternate sandstone – siltstone sequence with overlying ferruginized sequence of fining upward fluvial sediments at Gongoni, Garhbeta of West Medinipur district. The upper layer of duricrust with pebble horizon (1.5 to 3.3 m depth) un-conformably overlies the Neogene siltstone unit (3.3 to 4.8 m depth). The highly ferruginized clay layers (4 to 8 cm thick) occurring in between sandstone and siltstone lithofacies are constituted of brown coloured iron oxide cemented quartz – a highly ferruginized quartz arenite.

Age Determination of Laterites Through Dating Techniques

On the basis of pole positions and comparisons with the apparent polar wander paths age assignments have been made by Schmidt et al. (1983). It is concluded that the ages of Indian laterites are grouped as follows: Late Tertiary, Mid-Tertiary, Early Tertiary or Early Tertiary – Late Cretaceous (Schmidt et al., 1983). So in respect of equatorial drift of Indian plate (Late Cretaceous – Early Palaeogene) this geologic unit of Rajmahal was getting early favourable climate for lateritization (Kumar, 1986). According to the reconstruction of palaeolatitudes, it is found that southern India spent a longer time in the equatorial zone, *i.e.* between 53 million years and < 32 million years (Sychanthavong and Patel, 1987). The age of lateritic weathering has also been roughly estimated on the basis of palaeomagnetic properties of iron-oxides formed in laterites around 16°N (Schmidt et al., 1983).

Sankaran et al. (1985) have applied TL dating for age estimation of laterites and found that the age varies from 2.15 to 3.58 x 10^5 years. The OSL dating of collected samples of *ex-situ* laterite sections, both lateritized and non-lateritized sediments, reveals that the lateritization process was started in Neogene and restricted within Middle to Late Pleistocene (~150 to 35 ka) and did not continue in Holocene times. It has been learned from ^{40}Ar / ^{39}Ar dating that the peninsular India experienced six major phases of lateritic weathering, viz. ~53 to 50 Ma, ~40 to 32 Ma and ~30 to 23 Ma in the plateau tops and ~47 to 45 Ma, ~24 to 19 Ma and ~9 Ma in lowlands, pediments and valleys (Bonnet et al., 2015a; 2015b; Beauvais et al., 2016). The results of ^{40}Ar / ^{39}Ar dating of laterite samples (Bonnet et al., 2014) and other dating information (Schmidt et al., 1983; Kumar, 1986; Sychanthavong and Patel, 1987; Tardy et al., 1991; Bourman, 1993; Widdowson and Cox, 1996; Rajaguru et al., 2004; Mishra et al., 2007; Retallack, 2010) imply that basalts of RBT were weathered intensively to form *in-situ* ferricrete in between ~ 36 and 26 Ma (Late Eocene – Oligocene) and may had been dissected mostly since Neogene under favourbale lateritization climate (becoming source materials of *ex-situ* secondary laterites).

The possible age (figure 6) of secondary laterites as determined by OSL method for the Sriniketan section (table 1), shows that the age of sedimentation or time of cut off from the sunlight for the hard crust (0.45 m depth) is 40 +- 2 ka. The un-conformably overlying ferruginized sandstone – pebble horizon definitely indicates its time of deposition in between 79+-5 ka and 71+-6 ka, i.e. well within Pleistocene epoch. The layer of ferruginous hard crust with gravels was probably developed in Late Pleistocene (well within ~ 125 ka to 10 ka BP). The age as determined from the samples for Bishnupur section shows the age of sedimentation of the murram zone is more than 35 +-0.7 ka and again the ferruginous crust is assigned as age of Late Pleistocene. In Garhbeta section the ferruginous hard crust (0.3 m depth) was cut off from the sunlight before 96+-8 ka. Yet again the laterite hard crust is assigned an age of Late Pleistocene, but the lower ferruginous lithofacies of pebbles and siltstone were developed in Middle Pleistocene (> 350 ka to 130 ka).

Table 1

Summary of U, Th and K elemental concentrations, annual dose rate, equivalent dose and optical ages of ex-situ laterite samples from the study area

Sriniketan Section

Sl No.	Sample No.	Sample Horizon	Depth in m	No. of Discs	U (ppm)	Th (ppm)	K %	Equivalent Dose (avg) in Gray	Dose Rate Gray/ka	Age (avg) ka
1	OSLD 1	Hard Crust	0.4	45	1.94	11.93	0.88	78-2	1.9+-0.09	40+-2
2	OSLD 2	Ferruginized Sandstone - Pebble	2.5	45	1.17	8.56	1.63	153-9	1.1+-0.01	71+-6

3	OSLD 3	Siltstone	3.4	41	1.71	14.17	1.63	203-9	2.5+-0.01	79+-5
Bishnupur Section										
4	OSLD 4	Younger Alluvium	1.6	12	2.95	17.04	0.95	35+0.4	2.33+-0.03	1.5+-0.2
5	OSLD 5	Older Alluvium	2.5	12	3.81	18.17	1.18	6.2+0.5	2.8+-0.01	2.2+-0.1
6	OSLD 6	Murram	3.9	42	3.56	37.59	0.65	12+2	3.4+-0.02	35+-0.7
Garhbeta Section										
7	OSLD 7	Hard Crust	0.3	48	4.34	16.42	0.43	214-14	2.23+-0.01	96+-8
8	OSLD 8	Pebble Horizon	1.9	45	1.61	11.44	0.4	205-21	1.4+-0.08	147+-17
9	OSLD 9	Siltstone	4.8	36	1.63	13.71	0.68	264-21	1.7+-0.09	154+-15

Source: Chakraborti (2011)

Classification of Laterites

In this region we have recognized two broad types of laterites – (1) primary laterites and (2) secondary laterites. Merely the hard laterites on Rajmahal Basalt-traps and Gondwana Formations (mainly sandstones) have massive appearance (*in situ* weathering) reflecting horiozns of primary laterites, vermicular ferruginous crust, mottled zone with lithomarge kaolinite clay (pallid zone) and deeply weathered sandstones and basalts. The secondary laterites (overlying on fluvial sediments) are specifically found in the heart of *Rarh* Bengal as the dissected interfluves in the surrounding regions of Rampurhat, Illambazar, Bolpur, Kanksa, Ausgram, Bishnupur, Garhbeta and Kharagpur etc.

At Pinargaria (24°12´13´´ N, 87°40´13´´ E), Ichhanagar (24°22´33´´ N, 87°47´26´´ E), Chaukisal (24°19´59´´ N, 87°41´31´´ E), Mathurapahari (24°03´03´´ N, 87°36´39´´ E) Pansuiri (23°46´39´´ N, 87°16´47´´ E), Bhadulia (23°48´42´´ N, 87°13´44´´ E), Dubrajpur (23°47´12´´ N and 87°25´19´´ E), and Saharjora (23°24´36´´ N, 87°14´32´´ E) the litho-sections of primary laterites are characterized by well developed horizons, starting from (1) saprolite of weathered basalts and sandstones, (2) lithomargic clay or pallid zone, (3) mottled zone with litho-relicts of weathered basalts and (4) ferricrete. *In-situ* lateritization generally means tropical basal chemical weathering of parent rocks (transforming primary minerals to secondary minerals, intensive downward leaching of silica and upward translocation of Fe and Al-oxides) and development of lateritic hard crust from the weathered rock or saprolite (figure7).

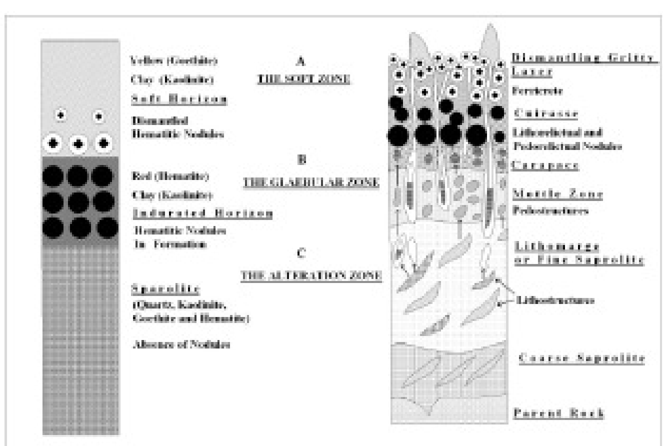
Figure 7

(a) A primary laterite profile on weathered basalt (having columnar structure) at Ghurnee Pahar, Birbhum, and (b) weathering rinds and core stones (saprolite) of Rajamahal basalts in weathered medium at Nalhati, Birbhum

A model of *in-situ* development of laterite profile (development of alteration saprolite zone, glaebular mottle-ferricrete zone and the upper soft zone of Fe-nodules) is depicted in figure 8 to understand the complete formation of laterite layers. The principal indication of intensive deep basal (i.e. sub-surface) weathering and ferruginous transformation is evidenced from the spheroidal weathering, weathering rinds, lieseganag structures and core stone like appearance of basaltic saprolite in the sample sections (figure 8). The relict structures of weathered basalt are found in the mottle zone, having elongated tubes and channels of hematite, Al-goethite and kaolinite.

Figure 8

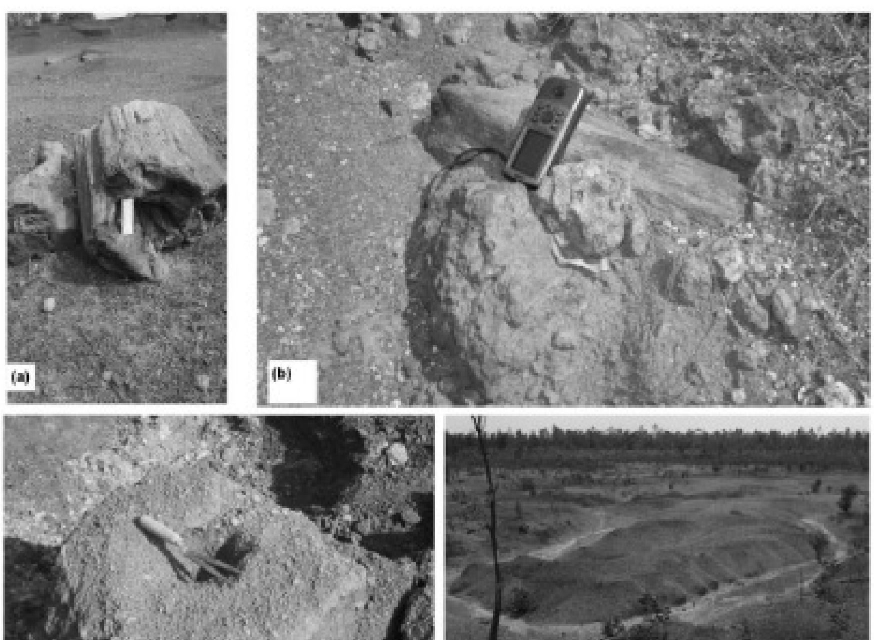
An applicable schematic model (modified from Tardy, 1992) depicting in-situ development of laterite profile with successive formation of coarse saprolite, lithomarge, mottle zone, ferricrete and gritty layer due to deep basal weathering of parent rock (similar signatures of lateritization found in the sections of Baramasia, Nalhati and Icchanagar)



The re-lateritization of transported ferruginous materials (i.e. *ex-situ* laterites) is mainly observed in the eastern part of *Rarh* Bengal, especially in the lithosections of in Bolpur (23°40´18´ N, 87°39´10´´ E), Sriniketan (23°41´31´´ N and 87°40´31´´ E), Kanksa (23°28´45´´ N, 87°27´45´´ E), Panagarh (23°27´10´´ N, 87°31´51´´ E), Patryasayer (23°12´35´´ N, 87°31´17´´ E), Garhbeta (22°51´34´´ N and 87°20´28´´ E) and Rangamati (22°24´42´´N, 87°17´55´´E) etc. Alternative kaolinte clay and sandstone – siltstone sequences is overlain by some lenticular channel fill deposits, consisting of various size fragments of quartz grains, pisoids of *in-situ* laterites and larger or out-sized clasts with petrified woods. The crude large scale X-bedding sandstone unit of Bishnupur is almost a clast-supported conglomerate with ferruginized sand sized matrix of predominantly quartz and feldspar. These quartz clasts are mostly well rounded to sub-rounded, smooth surface and flat without any striations which reflects fluvial origin. The variable pisoid shapesof secondary laterites are constituted by two elements – (1) a nucleus of variable nature surrounded by a cortex composed of concentric limonite and goethite and (2) pisoid of mono-nucleus and bi-nuclei composed of sand and clay. The occurrences of large scale petrified dicotyledonous fossil woods (probably Miocene to Eocene age) (figure 9) with ferricrete nodules and channel lag deposits in the *ex-situ* profiles bear the evidence of secondary lateritization up to Late Pleistocene (according to age determined by OSL dating).

Figure 9

Miocene to Eocene dated dicotyledonous fossil woods found (a) at a laterite quarry of Maluti, Shikaripara (Jharkhand) and (b) at a gully bed of Bhatina, Birbhum, (c) gravel lithofacies of ex-situ ferruginous hard crust at Hetodoba, Barddhaman, and (d) progressive badland development on the terrain of secondary laterites and gravel litho-units at Kanksa, Barddhaman



Palaeocimatic Importance of Laterites

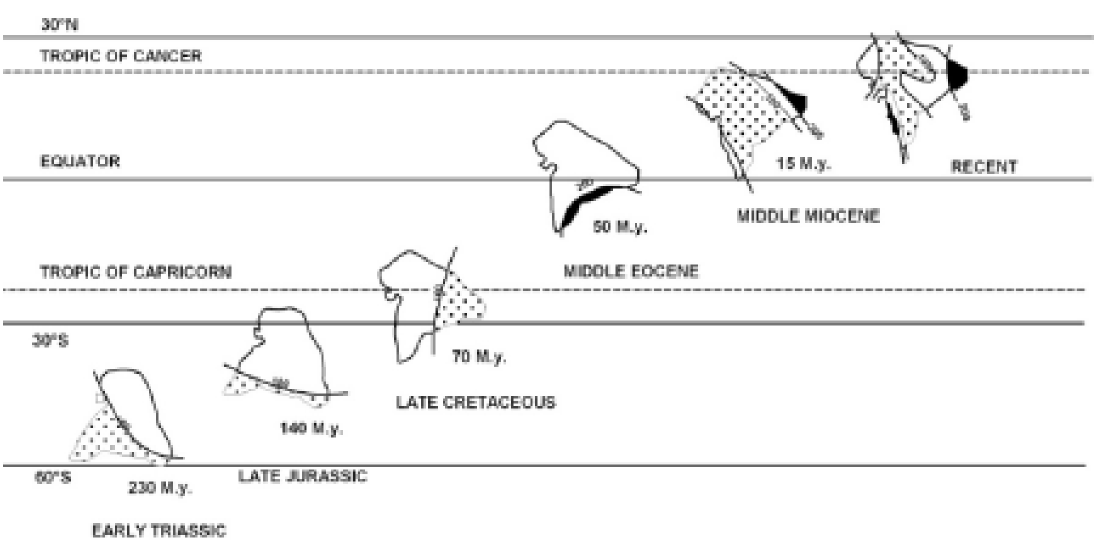
In the history of plate drift through millions of years, those continents which travelled or had been travelled across tropics, must bear the imprints of laterites and bauxites. So the residual laterite profiles are the fossil type formed in past geological ages when climatic conditions were favourbale for lateritization (Kumar, 1986). The laterites reflect an unique palaeoclimate which was characterized by the contrasted seasons (wet – dry), high temperature throughout the year (28° – 35° C), annual average relative humidity of the air nearer to 60 percent, annual rainfall lower than 1700 mm and long dry seasons during which a relatively low thermodynamic activity of water and atmospheric relative humidity decreases (McFarlane, 1976; Tardy et al., 1991). While bauxites and aluminium enrichment can stand lower temperature (> 22° C) and are favoured by a higher thermodynamic activity of water and a higher relative humidity of the air (> 80 percent) (Tardy, 1992).

Laterites are regarded as palaeoclimatic indicator and morpho-stratigraphic marker. The primary and secondary laterites of study area reflect following palaeoclimatic conditions.

- These laterites were generally formed under an oxic atmosphere in the presence of abundant terrestrial biomass in an acidic environment (Retallack, 2010), elevated atmospheric carbon dioxide, exceptional fossil wood preservation and intense deep basal weathering of rocks and as well as Neogene gravelly sediments of the north-western Bengal Basin.
- It is now evidenced that climatic conditions were favourbale for lateritization from Cretaceous to Palaeocene times for during that period (figure 10), the Indian continent crossed the zone between 30° S and 0°latitude (Schmidt et al., 1983; Kumar, 1986; Tardy et al., 1991).

Figure 10

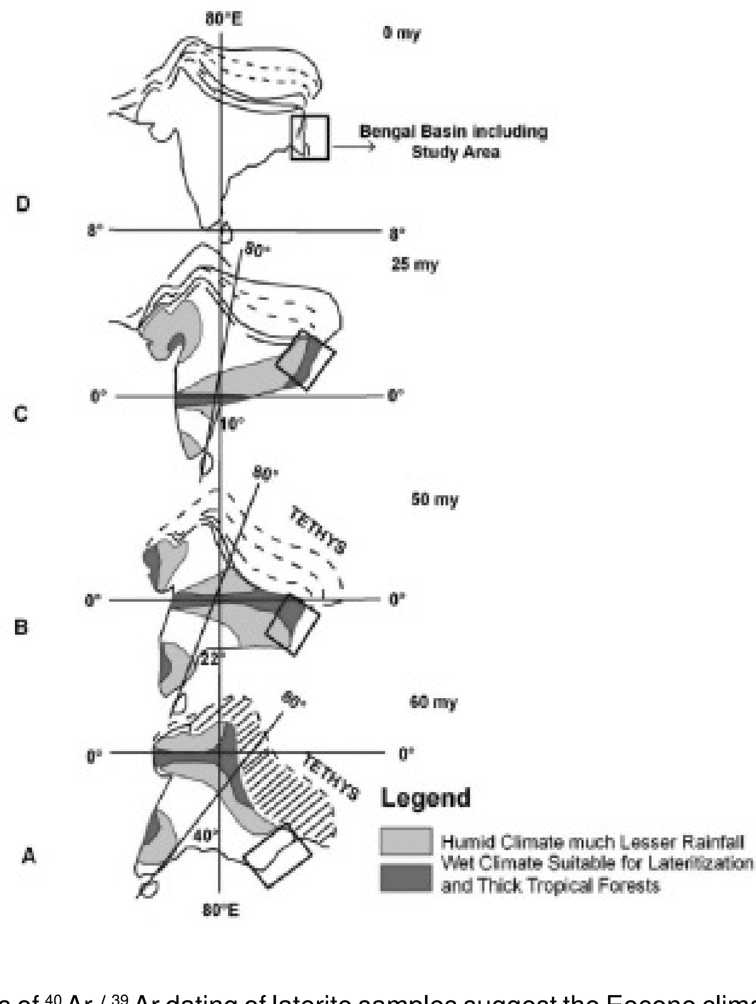
Palaeogeographic reconstruction of Indian plate and its entry to the region of tropics since Early Triassic. Onset of lateritization process was started in Middle Eocene. Numbers shows the relative values of precipitation through geological times and no units are implied (Modified from Tardy et al., 1991; Alam et al, 2003)



The Indian Plate was rotated in an anticlockwise direction since Palaeocene (Sychanthavong and Patel, 1987), after that particular linear laterite *Rarh* belt of NE – SW direction (formerly as E – W coinciding with the alignment of perfect tropical zone for lateritization) had crossed the equatorial zone while the total rotation was 50° in between Palaeocene and Present (figure 11). At that time span most of the primary laterites of *Rarh Bengal* (especially in the Rajmahal Basalt Traps) were developed.

Figure 11

A, B, C, and D, Palaeoclimatic reconstruction of the Indian Plate (including demarcated study area) and its rotation since Early Paleocene, during its course of drifting across the equatorial zone with the distribution of laterites (modified from Sychanthavong and Patel, 1987)



The results of ^{40}Ar / ^{39}Ar dating of laterite samples suggest the Eocene climatic optimum of lateritization and the early beginnings of Asian monsoons at ~ 40 Ma (Bonnet et al., 2015a). The presence of hematite (Fe_2O_3) and boehmite (AlO(OH)) are dehydrated minerals related to less humid and warmer tropical climatic conditions. Therefore the presence of *Rarh* laterites signifies a special warm and seasonal contrasted palaeoclimate which is not found in present decade throughout the study area.

- From the model for Oligocene (Chatterjee et al., 2013) it is evident that by that time India had drifted mostly to the north of the equator and the hot and humid climate continued. Thus it is evident that by Eocene epoch, climate conducive for deep and sustained chemical weathering of rocks for the formation of laterite profiles had set in the peninsular India.
- From the geoarcheological point of view (Deo and Rajaguru, 2014) in the initial stage of Acheulian activity (~ 1 Ma) the climate was wet and it turned semi-arid around 0.8 Ma and later. The overall tendency of increasing semi-arid to dry climate with intermittent wet phase (favourable for lateritization) from Neogene to Late Pleistocene had been observed through the occurrences of thin ferruginous crust or deposits in several levels of the lithosections. There was a strong dominance of tropical wet – dry palaeoclimate up to Late Pleistocene (96+-8 ka to 35+-0.7 ka).

Palaeogeomorphic Evolution of *Rarh* Laterites

The evolution of *Rarh* laterites is directly connected with the Stable Shelf Zone of Bengal Basin, experiencing maximum marine transgression, sediment depositions, tectonic uplifts and lateritization. The whole of the present day Bengal Basin (including Stable Shelf) was under marine water until Mio – Pliocene epoch and the strandline grazed the eastern margin of Peninsular Shield, i.e. much inland (towards west of study area) from the present day Orissa – Bengal coastline (Vaidyanadhan and Ghosh, 1993). The dominance of kaolinite clay with presence of hystrichospheriods (in the pores of clay beds) indicates lacustrine to fluvio-lacustrine condition of deposition in Neogene (Mukherjee et al., 1969). The Stable Shelf Zone is separated by the Chotangapur Foot-hill Fault (CFF) at west and the Medinipur –Farraka Fault (MFF, or called Pingla Fault) at east. Within this tectonic shelf the *Rarh* laterites of West Bengal (NNE – SSW axis) was developed when the sea finally transgressed from this region since LateNeogene. At that time, the Indian plate had been crossed the intense weathering zone of equatorial climate which was favourbale for lateritization.

The terrain of *Rarh* laterites are genetically linked with inversion of relief and active tectonics. Inversion of relief refers to an episode in landscape evolution when a former valley bottom becomes a ridge, bounded by newly formed valleys on each side (Pain and Ollier, 1995; Ollier and Sheth, 2008). Inversion of relief occurs when materials on valley floors are, or become, more resistant to erosion than the adjacent valley slopes (Pain and Ollier, 1995). The lateral movement of water on hillsides carried weathering products from upper slopes to lower sites, when drainage was often impeded and so chemical precipitation was likely (Ollier and Sheth, 2008). Gradually up to Neogene the valley with filled with ferruginous materials and prolong lateritization formed ferricrete within Late Pleistocene. The surrounding terrain was eroded to form next valleys and the present summits or interfluves of duricrusted mesas were formed.

In the model (figure 12) we reconstructed the event that up to end of Neogene the transported ferruginous materials (due to erosion of primary plateau laterites) re-deposited in the faulted Stable Shelf of Bengal Basin (under marine condition) by the drainage system of peninsular rivers as oldest fan-deltaic to para-deltaic formation in between Chotonagpur Foothill Fault (CFF) and Medinipur Farakka Fault (MFF) (figure 12). Since Early Pleistocene the sea started regressed from that region and those valley sites of sediment deposition were subjected to further lateritization up to Middle Pleistocene and forming duricrust at top of most of *ex-situ* laterite profiles.

Figure 12

A schematic model of Rarh laterite evolution, showing (a) erosion of primary laterites and ferruginous fan-deltaic depositions by rivers and stream in shelf zone of Bengal Basin in between Chotanagpur Foot-hill Fault (CFF) and Medinipur – Farakka Fault (MFF) up to Neogene, and (b) recession of sea, exposure of ferruginous sediments to lateritization climate (Early – Late Pleistocene), re-lateritization to form secondary Rarh laterites, neo-tectonic uplift, badland erosion to develop isolated summits of duricrusted mesas and inversion of relief

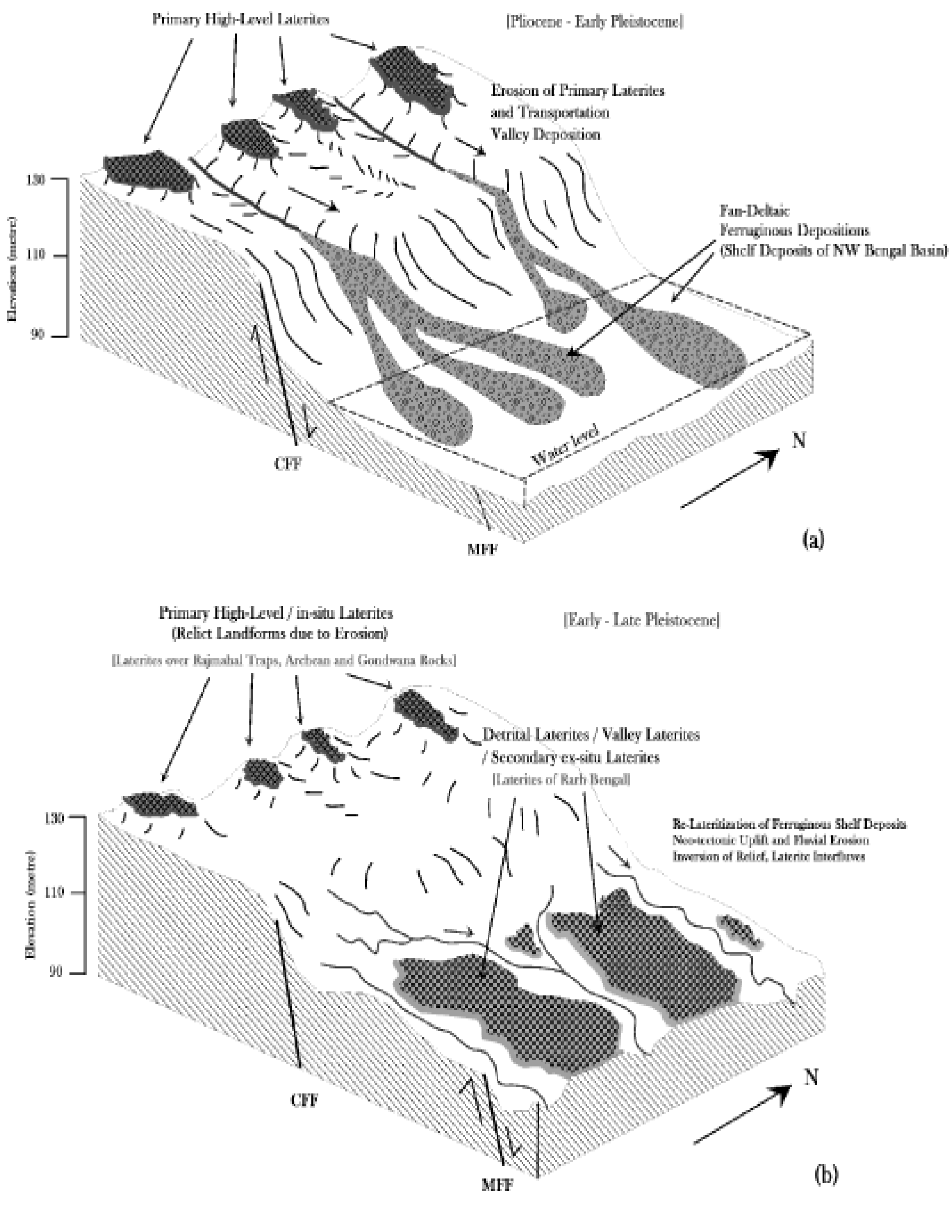
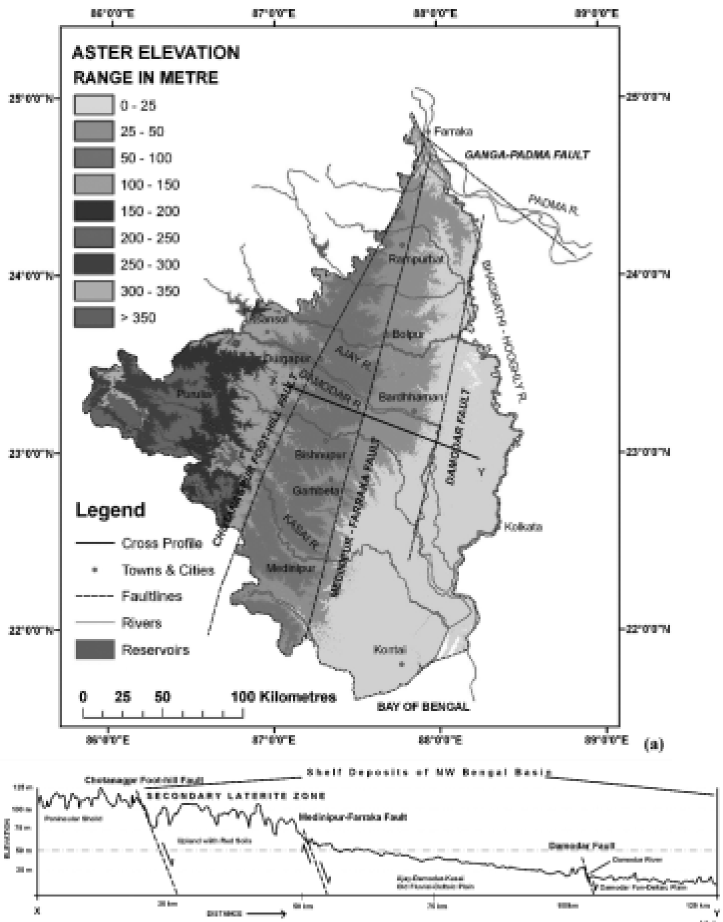


Figure 13:
(a) Distribution of laterites in relation to topography and major basement faults of She lf zone, *viz.,* GPF (Ganga Padma Fault), CFF (Chotanagpur Foothill Fault), MFF (Medinipur Farraka Fault or Pingla Fault) and DF (Damodar Fau lt) (Ghosh and Guchhait, 2015) in the north-western Bengal Basin (using Landsat ETM+ mosaic SFCC ima ge, 2000 – 2001), and (b) west to east elevation cross profile (X– Y) with emplacement of faults and development of lateritic *Rarh* region (Ghosh and Guchhait,2015)



The gradational occurrences of top lateritized and bottom un-lateritized gravel lithofacies (increasing fining towards the bottom) with numerous buried dicotyledonous fossil woods (Eocene to Miocene age) at the *ex-situ* laterite sections (Late Pleistocene age) denote a gradual uplift and seismo-tectonic event of the area during the deposition of coarse sand and gravels with ferruginous materials in between Pliocene and Early Pleistocene. Additionally there was a marine regression and uplifts in this shelf zone of Bengal Basin (i.e. *Rarh Bengal*) after the end of Miocene-Pliocene. Since Early Quaternary the unit between MFF and CFF started to uplift (figure 13) due to re-activation of basin basement faults during occasional Himalayan upheaval and active tectonics of Bengal Basin (Ghosh and Guchhait, 2015). Then during 6 – 7 ka the eastern unit of Tectonic Shelf (between MFF and Damodar Fault) was subjected to subsidence (Singh et al., 1998) and the western lateritized unit (i.e. *Rarh* Bengal) was subjected to relief inversion due to neo-tectonic uplifts and consecutive fluvial erosion in Holocene times. Increased precipitation during the ~ 15 to 5 ka period of peak monsoon recovery probably increased discharge and promote incision and wide spread badland formation (Sinha and Sarkar, 2009). As fluvial erosion proceeds, the valley floor becomes a ridge and interfluves (i.e. laterites of *Rarh* Bengal) bounded by newly formed Late Quaternary valleys on each side.

Conclusion

From the profile analysis and discussion of tectono – climatic evolution, the geomorphic history of primary laterites of RBT and secondary *Rarh* laterites are reconstructed here and the palaeogeographic phenomena are recognized to unearth the origin of ferruginous deposits in the north-western Bengal Basin. If we recreate the geological clock of laterite evolution, then we can categorized broadly three major events – (1) two widespread volcanisms in Cretaceous Period as Rajmahal Volcanism (~ 88 to 118 Ma) and Deccan Volcanism (~ 69 to 63 Ma), (2) Paleocene to Mid-Pliocene *in-situ* intense lateritization and formation of primary high-level laterites (mostly occurred in ~ 36 to 26 Ma), and (3) Pliocene to Late Pliestocene *ex-situ* lateritization of deposited ferruginous materials and formation of secondary low-level laterites (up to 35 ka). It has been found that formation of *in-situ* ferricrete was stopped Early Pleistocene but the formation of iron-impregnated materials and pisoliths were still continued up to Late Holocene. Geomorphologically the *ex-situ* laterites of *Rarh* Bengal now exhibit an inversion of relief with continuos gully erosion. This region is recognized as former palaeovalleys of ferruginous depositions (i.e.palaeofan-deltaic deposits in the western shelf zone of Bengal Basin) which were re-lateritized or re-cemented with gravels, pebbles and ferricrete nodules and developed secondary duricrusts up to Late Pleistocene.

References

Aitken, M.J., 1998. *An Introduction to Optical Dating*. Oxford University Press, New York.

Alam, M., Alam, M.M., Curray, J.R., Chowdhary, M.L.R., Gandhi, M.R., 2003. An overview of the sediment geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history. *Sediment Geology, 155 (3-4),* 179-208.

Alexander, L.T., Cady, J.G., 1962. Genesis and hardening of laterite in soils. *United States Department of Agriculture, Technical bulletin, 1281*, Washington D.C., pp. 1 – 90.

Bagchi , K., Mukherjee, K.N., 1983. *Diagnostic Survey of Rarh Bengal (Part II*). University of Calcutta, Calcutta.

Bandyopadhyay, S., 2007. Evolution of the Ganga – Brahmaputra Delta: A Review. *Geographical Review of India, 69 (3),* 235 – 268.

Banerjee, P.K., 1993. Quaternary Tectonics And Climatic Record In Tropical Weathering Profiles. *Current Science, 64 (11 – 12),* 921 – 923.

Beauvais A, Bonnet NJ, Chardon D, Arnaud N, Jayananda (2016) Very long-term stability of passive margin escarpment constrained by 40Ar/39Ar darting of K-Mn oxides. *The Geological Society of America* doi:10.1130/G373031.1

Biswas, A., (1987).Laterities and Lateritoids of Bengal. In: Datye, V.S., Diddee, J., Jog, S.R., Patial, C. (Eds). *Exploration in the Tropics.* K.R.Dikshit Felicatiobn Committee, Pune, 157-167.

Bonnet N, Arnaud N, Beauvais A, Chardon D (2015a). Deciphering post-Deccan weathering and erosion history of south India Archean rocks from cryptomelane ^{40}Ar – ^{39}Ar dating. *Geophysical Research Abstracts, 17*, 9114.

Bonnet N, Beauvais A, Chardon D, Arnaud N (2015b) Evolution of the south-west Indian continental divergent margin: constraints from ^{40}Ar – ^{39}Ar dating of lateritic paleolandsurfaces. Geophysical Research Abstracts, 17, 9377.

Bonnet, N.J., Beauvais, A., Arnaud, N., Chardon, D., Jayananda, M., 2014. First $^{40}Ar/^{39}Ar$ dating of intense Late Palaeogene lateritic weathering in peninsular India. *Earth Planetary Science Letters, 386*, 126 – 137.

Botter-Jensen, L., 1997. Luminescence techniques: instrumentation and methods. *Radiation Measurements, 27 (5 – 6),* 749 – 768.

Bourman, R.P., 1993. Perennial problems in the study of laterite: a review. *Australian Journal of Earth Sciences, 40 (4),* 387 – 401.

Buchanan, F., (1807). *A Journey from Madras through the countries of Mysore, Kanara and Malabar (3 volumes)*. East India Company, London.

Chakraborti, S., 2011. Final report on Qauternary laterites in the western districts of West Bengal – their geomorphology, stratigraphy, genesis and implications for climate change. Geological Survey of India, Kolkata.

Chatterjee S, Goswami A, Scotese CR (2013) The longest voyage: tectonic, magmatic and palaeoclimatic evolution of the Indian plate during its northward flight from Gondwana to Asia. Gondwana Research, 23, 238 – 267.

Chatterjee, N., 2008. Laterite terrains of the Chotanagpur Plateau fringe region (case study of the Mayurakshi Basin, eastern India). *Indian Journal of Landscape System and Ecological Studies, 31 (1),* 115 – 130.

Das Gupta, A.B., Mukherjee, B., (2006). *Geology of N.W. Bengal Basin*. Geological Society of India, Bangalore, 1-154.

Deo S G, Rajaguru S N (2014) Early Pleistocene environment of Acheulian sites in Deccan upland: a geomorphic approach. In: Paddayya K, Deo S G (eds) Recent Advances in Acheulian Culture Studies in India – ISPQS Monograph 6, Indian Society for Prehistoric and Quaternary Studies, Pune, pp 1 – 22.

Ghosh S, Guchhait S (2015) Characterization of primary and secondary laterites in northwestern Bengal Basin, West Bengal, India. *Journal of Palaeogeography, 4 (2),* 203 – 230.

Krishnamurthy, P., Mahoney, J.J., Gopalan, K. and MacDougall, J.D. (2014) Clinopyroxene compositions in the Deccan and Rajmahal Traps and their bearing on magma types and evolution. *Journal of Asian Earth Sciences, v.84,* pp. 102 – 107.

Kumar, A., (1986). Palaeolatitudes and the age of Indian laterites. *Palaeogeography Palaeoclimatology Palaeoecology, 53*, 231 – 237.

Maignien, R., 1966. *Review of research on laterites*. UNESCO, Paris, pp. 1 – 148.

McFarlane, M.J., 1976. *Laterite and Landscape*. Academic Press, London.

Milnes AR, Bourman R, Northcote KH (1985) Field relationships of ferricretes and weathered zones in southern South Australia: a contribution to 'laterite' studies in Australia. *Australian Journal of Soil Research 23*: 441 – 465.

Mishra, S., Deo, S., Rajaguru, S.N., 2007. Some observations on the laterites developed on Deccan Trap: implications for the Post-Deccan Trap denudational history. *Journal Geological Society of India, 70,* 469 – 475.

Mukherjee, B., Rao, M.G., Karunakaran, C., 1969. Genesis of kaolin deposits of Birbhum, West Bengal. *Clay Minerals, 8,* 161 – 170.

Niyogi, D., 1975. Quaternary geology of the coastal plain in West Bengal and Orissa. *Indian Journal of Earth Sciences, 2*, 51 – 61.

Niyogi, D., Mallick, S., Sarkar, S.K., (1970). A preliminary study of laterites of West Bengal, India. In: Chatterjee, S.P., Das Gupta, S.P. (Eds.), Selected Papers Physical Geography (vol.1). 21st International Geographical Congress, Calcutta, National Committee for Geography, 443-449.

Ollier,C.D., Sheth, H.C., 2008. The high Deccan duricrusts of Indian and their significance for the 'laterite' issue. *Journal of Earth System Science, 117 (5)*, 537-551.

Pain, C.F., Ollier, C.D., (1995). Inversion of relief – a component of landscape evolution. *Geomorphology, 12,* 151 – 165.

Prescott, J.R., Robertson, G.B., 1997. Sediment dating by luminescence: a review. *Radiation Measurements, 27 (5 – 6),* 893 – 922.

Rajaguru SN, Deo SG, Mishra S, Ghate S, Naik S, Shirvalkar P (2004) Geoarchaeological significance of the detrital laterites discovery in the Karha Basin, Pune District, Maharastra. *Man and Environment XXIX (1):* 1 – 6.

Retallack, G.J., 2010. Lateritization and bauxitization events. *Economic Geology, 105*, 655 – 667.

Rittenour, T.M., 2008. Luminescence dating of fluvial deposits: applications to geomorphic, palaeoseismic and archaeological research. Boreas, 37, 613 – 635.

Roy Chowdhury, M.K., 1986. Concepts on the origin of Indian laterite in historical perspective. Proceedings of Indian National Science Academy, 52 A (6), 1307 – 1323.

Sankaran, A.V., Nambi, K.S.V., Sunta, C.M., (1985). Thermoluminescence of laterites: applicability in dating. *Nuclear Tracks, 17 (5),* 177 – 183.

Sarkar, P.R., 2004. *Rarh- The Cradle of Civilization*. Ananda Marg Publication, Kolkata.

Schmidt, P.W., Prasad, V., Raman, P.K., 1983. Magnetic ages of some Indian laterites. *Palaeogeography Palaeoclimatology Palaeoecology, 44*, 185 – 202.

Singh, L.P., Parkash, B. and Singhvi, A.K., 1998. Evolution of the Lower Gangetic Plain landforms and soils in West Bengal, India. Catena, 33, 75 – 104.

Sinha, R., Sarkar, S., 2009. Climate-induced variability in the Late Pleistocene – Holocene fluvial and fluvio-deltaic successions in the Ganga Plains, India. *Geomorphology, 113 (3 – 4),* 173 – 188.

Sychanthavong, S.P.H., Patel, P.K., (1987). Laterites and lignites of northwestern India and their relevance to the drift tectonics of the Indian Plate. *Current Science, 56 (10),* 469 – 473.

Tardy, Y., (1992). Diversity and terminology of laterite profile. In: Martini, I.P., Chesworth, W. (Eds.), *Weathering, Soils and Paleosols*. Elsevier, Amsterdam, pp. 379 – 405.

Tardy, Y., Kobilsex, B., Paquet, H., 1991. Mineralogical composition of geographical distribution of African and Brazilian peri-Atlantic laterites: the influence of continental drift and tropical paleoclimates during the past 150 million years and implications for India and Australia. *Journal of African Earth Sciences, 12 (1 – 2)*, 283 – 295.

Vaidyanadhan, R., Ghosh, R.N.(1993). Quaternary of the east coast of India. *Current Science, 31 (6),* 231 – 232.

Widdowson, M., Cox, K.G., (1996). Uplift and erosional history of the Deccan Traps, India: Evidence from laterites and drainage patterns of the Western Ghats and Kankan Coast. *Earth and Planetary Science Letters, 137*, 57-69.

22

Changing Cropping Pattern In The State Of West Bengal, India: A Geographical Analysis

Sathi Sampad Roy and N. C. Jana

Introduction

West Bengal is one of the major agricultural states in India and agriculture occupies a key place in the economy of the state and has been the single largest contributor in terms of the share of the gross domestic product. Total food grain production in West Bengal was roughly 16 million tons contributing 7.4 percent of the country's total food grain output and ranked 4th among the major states in India during 2006-07. With rice output of 14.51 million tons in 2006-07, the state led all the major states in production of rice and contributed nearly 16 percent of the country's total rice output. The share of the state in food grains production has been increasing steadily during the past two and a half decades. In rice production, the share increased by 2 percent in 2006 as compared with the figure in 1980, although it remained roughly at the same level during the 1990s. In the production of Pulses, on the other hand, the share of West Bengal to the national economy declined considerably in the 1980s, it improved in the next decade and then declined further sharply. The contribution of West Bengal to the national economy in terms of its shares of output for major crops over different periods is shown in Table-1.

Table-1

Share of West Bengal to All-India (in percentage): Output of Food grains

Crops	1980-81	1990-91	2000-01	2006-07	2010-11
Rice	13.9	14.1	14.6	15.9	16.2
Wheat	1.3	1.0	1.5	1.1	1.2
Pulses	2.3	1.4	2.0	1.1	1.0
Total Food grains	6.4	6.4	7.0	7.4	7.8

Source: Government of West Bengal, Economic Review 2011-12

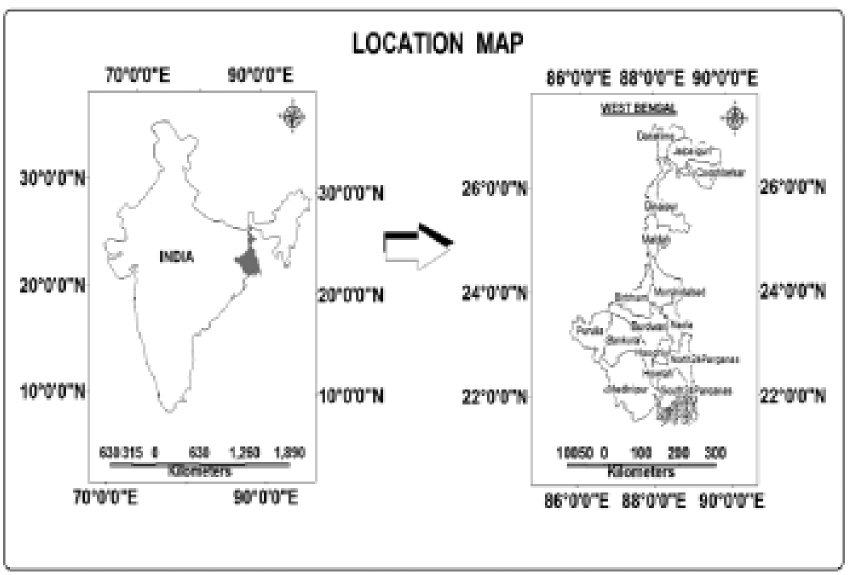
Cropping Pattern means the production of area under various crops at a point of time. It is a dynamic concept and it changes over space and time. The cropping pattern of a region is closely influenced by the geo-climatic, socio-economic, historical and political factors (Hussain, M. 1996). Cropping pattern is controlled by several factors such as topography, terrain, slope, soils and availability of water for irrigation, use of fertilizer, pesticide and manure. Change in cropping pattern in a particular span of time clearly indicates the changes that have taken place in the agricultural development.

To work out degree of the crop concentration in a region, location quotient method has been used by various geographers. Crop concentration means areal density of individual crop or crop concentration reveals the variation in the density of any crop in a given region at a point of time (Chouhan, 1987). Likewise crop diversification has also a great relevance in agricultural geography. It refers to the variety of crops. If larger number of crops grown in an area during a year by occupying equal proportion of cropland, the higher is crop diversification. It helps to understand the impact of physical and socio-economic condition on agricultural mosaic. Study of crop diversification reveals the contemporary competition among the crops for an area and scope for rotation and effect on double cropping, per hectare productivity and total production. Continuous cultivation of a crop reduces soil fertility and absorbs soil nutrient which directly affects yield rate. To maintain soil fertility crop rotation is important. To make a suitable and scientific crop policy the study of changing cropping pattern possesses a great importance.

Study Area

The state of West Bengal is situated between North 21°38' to 27°10' latitudes and East 85°50' to 89°50' longitudes. It is bordered by Jharkhand and Bihar on the west, Bangladesh on the east, Assam and Sikkim and the country Bhutan on the north-east, Orissa on the south-west and Nepal on the north-west.

Fig. 1



The geographical area of the state is 88,752 sq.kms and its population is 90.32 million in 2012.

Objectives of the Study

The main objectives of the present study are as follows:

1. To study the changes in cropping pattern during 1980-81 and 2010-11.

2. To study the crop concentration and its variation in West Bengal during 1980-81 and 2010-11.
3. To analyze the productivity index of different crops (mainly food grains) during 1980-81 and 2010-11.
4. To assess the agricultural efficiency and identify the area of crop diversification in West Bengal during 1980-81 and 2010-11.

Database and Methodology

Secondary data have been collected from various published reports of West Bengal. Mainly the Statistical Handbook of West Bengal 2011-12 has been used.

Crop Concentration

Crop concentration refers to the variation in the density of crop or crops in a region or an area at a certain period of time or point. Percentage of area under each crop to total cropped area is calculated. To find out crop concentration Bhatia's (1965) method is used, which is as follows:

$$\text{Index of crop concentration} = \frac{\text{Area under 'x' crop in the component areal unit}}{\text{Area under all crops in the component areal unit}} \div \frac{\text{Area under 'x' crop in the entire region}}{\text{Area under all crops in the entire region}}$$

Agricultural Efficiency

Agricultural Efficiency is the aggregate performance of various crops in regard to their output per hectare but the contribution of each crop to agricultural efficiency is relative to its share of cropland. Various scholars have contributed different methods and techniques to measure agricultural productivity of a region like Kendall (1939), Shafi (1960), Khusro (1964), Sapre & Deshpande (1964), Bhatia (1967) and Jasbir Singh (1976). In the present paper Bhatia's method has been used to measure agricultural efficiency. The formula is as follows:

$$\mathbf{Iya = Yc/Yr * 100}$$

Where Iya= yield index of crop 'a', Yc = the hectare yield of crop 'a' in the component areal unit, Yr = the hectare yield of crop 'a' in the entire region.

$$\mathbf{Ei = \frac{Iya * Ca + Iyb * Cb + \ldots\ldots\ldots + Iyn * Cn}{Ca + Cb + \ldots\ldots\ldots + Cn}}$$

Where, Ei is the agricultural efficiency index, Iya, Iyb,……….,Iyn are the yield indices of various crops, and Ca, Cb,…….Cn are the percentage of cropland under the different crops.

Productivity Index

To study the index of productivity coefficient many scholars devised various formulas like Enyedi (1964), Shafi (1972 and 1974). Here, Enyedi's formula has been used to measure the productivity index of different crops.

$$\mathbf{Productivity\ Index = Y/Yn \div T/Tn}$$

Where,

Y is the total production of the selected crop in unit area.

Yn is the total production of the same crop on national scale.

T is the total cropped area of the unit area.
Tn is the total cropped area on national scale.

Crop Diversification

Crop diversity which refers to variety of crop is an important component of crop geography of a region (Hangaragi, 2010). Higher the level of agricultural technology, lesser is the degree of diversification. Generally, rich farmers prefer to specialize in selective crops while the poor and subsistent farmers are generally interested in the diversification of crops which allow poor farmers to grow several crops to meet their family needs. Uncertain weather especially erratic rainfall is the main cause of crop diversification.

Here, Gibbs and Martin's (1962) formula has been used to determine the crop diversification.

$$\textbf{Index of diversification} = 1 - \sum_x{}^2 / \left(\sum_x\right)^2$$

Where, x is the percentage of total cropped area occupied by each crop. If the value is relatively close to 1, the diversification is relatively high. If the value is not close to 1, the diversification will be low.

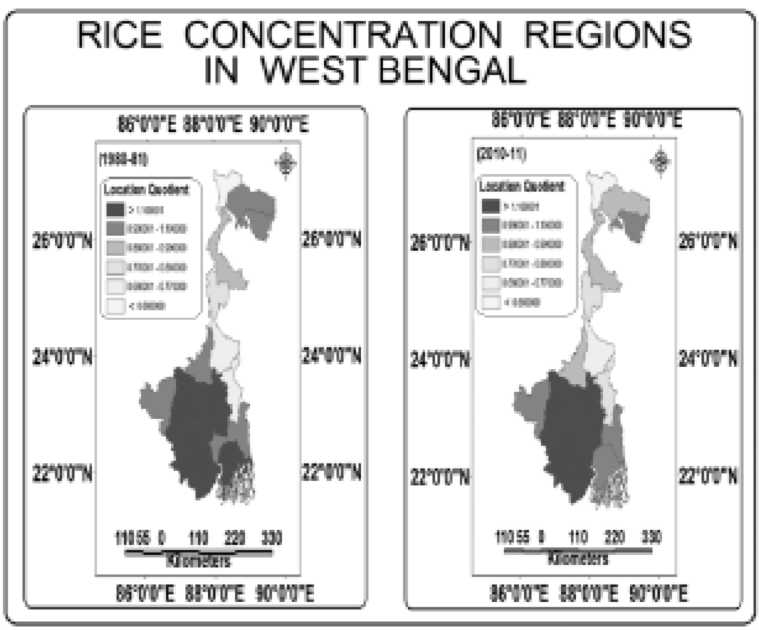
Results and Discussions

Crop Concentration

Rice

Bhatia's (1965) crop concentration indices for different crops (mainly food grains like rice, wheat, cereals and pulses) have been calculated for the study period of 1980-81 and 2010-11 for West Bengal. The calculated values of rice concentration indices have been divided into six classes i.e., <0.660000 as very low concentration, 0.660001 to 0.770000 as low concentration, 0.770001 to 0.880000 as moderately low concentration, 0.880001 to 0.990000 as moderately high concentration, 0.990001 to 1.100000 as high concentration, and >1.100001 as very high concentration.

Fig. 2

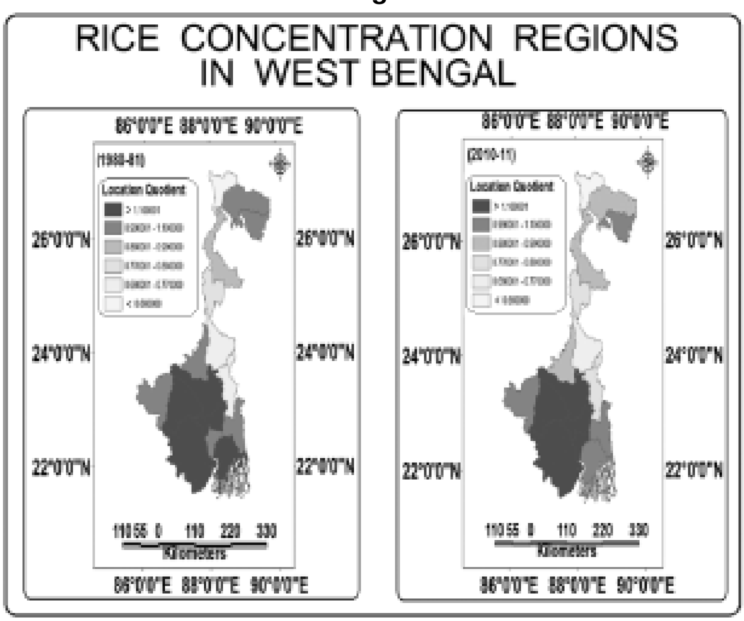


It is evident from Fig. 2 that very low rice concentration was recorded only in Darjeeling both in 1980-81 and 2010-11 and low and moderately low rice concentration was recorded in Nadia, Murshidabad and Maldah district respectively in 1980-81 whereas in 2010-11 only Murshidabad was included under low rice concentration region. Moderately low concentration in rice cultivation was recorded in Maldah and Nadia. In 1980-81 where only Dinajpur was under moderately high rice concentration region, in 2010-11 the region covered two more districts with Dinajpur i.e., Jalpaiguri and Birbhum. Similarly in 1980-81, high and very high rice concentration regions were covered by Jalpaiguri, Coochbehar, Birbhum, North 24 Parganas, Howrah, Purulia and Bankura, Burdwan, Hooghly, Midnapur and 24-Parganas (S) respectively whereas in 2010-11 only Coochbehar, North and South 24 Parganas, Purulia were classified under high concentration region and very high concentration in rice cultivation was observed in rest of the districts like Burdwan, Birbhum, Howrah, Hooghly, Midnapur, Bankura.

Wheat

For analyzing concentration of wheat in West Bengal for the year 1980-81 and 2010-11 the calculated values have been classified into six classes i.e., 0 to 0.690000 as very low concentration, 0.690001 to 1.380000 as low concentration, 1.380001 to 2.070000 as moderately low concentration, 2.070001 to 2.760000 moderately high concentration and 2.760001 to 3.450000 as high concentration and 3.450001 to 4.140000 as very high concentration.

Fig. 3



It is evident in Fig. 3 that maximum portion of the state is under very low concentration index of wheat. In 1980-81 Darjeeling, Jalpaiguri, Purulia, Bankura, Birbhum, Burdwan, Howrah, Hooghly, Midnapur, North and South 24 Parganas were classified under very low concentration region of wheat. In 2010-11 no such changes was noticed in South Bengal only in North Bengal Jalpaiguri got replaced by Coochbehar. In 1980-81 low concentration in wheat production was recorded in Coochbehar, Dinajpur, Birbhum but in 2010-11 low concentration was recorded only in Jalpaiguri and moderately low concentration in Dinajpur, Birbhum whereas in 1980-81 moderately low concentration was noticed in Maldah and moderately high concentration and high concentration of wheat production was found in Nadia, and Murshidabad respectively. In 2010-11 moderately high, high and very high concentration of wheat production was observed in Nadia, Maldah and Murshidabad respectively.

Table-2:
Crop Concentration Indices of different food grains in West Bengal

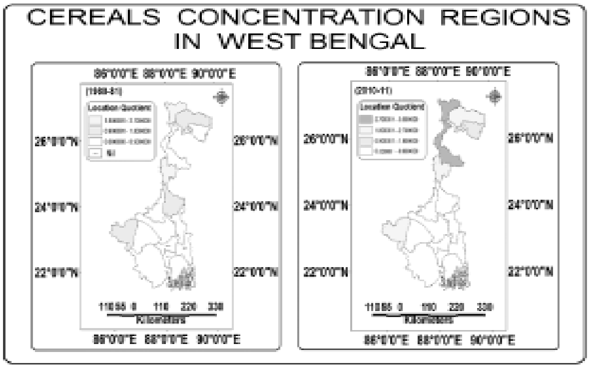
Districts	**1980-81**				**2010-11**			
	Rice	***Wheat***	***Cereals***	***Pulses***	***Rice***	***Wheat***	***Cereals***	***Pulses***
Burdwan	1.12	0.36	0.1	0.33	1.12	0.03	0.04	0.16
Birbhum	1.02	1.01	0.21	0.79	0.4	1.935	0.05	1.6
Bankura	1.115	0.51	0.15	0.22	1.1	0.26	0.11	0.03
Midnapur	1.1	0.18	0.08	0.64	1.11	0.09	0.09	0.32
Howrah	1	0.15	%	1.62	1.11	0.03	0.05	0.24
Hooghly	1.11	0.48	%	0.35	1.12	0.02	0.04	0.04
24 Parganas (N)	1.04	0.55	%	0.96	1.05	0.54	0.04	0.92
24 Parganas (S)	1.1	0.035	0.075	0.67	1.07	0.11	0.05	1.14
Nadia	0.69	2.47	0.38	3.15	0.82	2.1	0.465	4.01
Murshidabad	0.69	3.38	1.47	2.36	0.75	3.72	0.46	3.15
Dinajpur	0.989	1.365	0.67	0.83	0.95	1.64	2.84	0.29
Maldah	0.772	1.59	1.9	2.01	0.82	3.035	2	2
Jalpaiguri	1.09	0.61	0.94	0.31	0.97	1.22	2.68	0.47
Darjelling	0.59	0.35	2.1	0.18	0.57	0.55	3.59	0.49
Coohbehar	1.09	0.85	0.32	0.3	1.03	0.62	1.72	0.525
Purulia	1.06	0.12	1.735	0.68	1.01	0.205	1.82	1.62

Source: Computed by the Authors

Cereals

For analyzing concentration index of cereals in West Bengal for the year 1980-81 and 2010-11 all the calculated values have been divided into four groups i.e., 0 to 0.900000 as low, 0.900001 to 1.800000 as moderate, 1.800001 to 2.700000 as high and 2.700001 to 3.600000 as very high concentration. In 1980-81 moderate concentration in the production of cereals was recorded in Purulia, Murshidabad, Jalpaiguri and in 2010-11 only Coochbehar was classified under this category. High cereals concentration was found in Darjelling and Maldah in 1980-81 and Jalpaiguri, Maldah and Purulia in 2010-11. In 1980-81 low concentration was recorded in Dinajpur whereas in 2010-11 very high concentration of cereals production was found in Darjeeling and Dinajpur. In this respect a magnificent change was marked in production of cereals in Dinajpur. Rest of the districts was classified under low concentration region of cereals production.

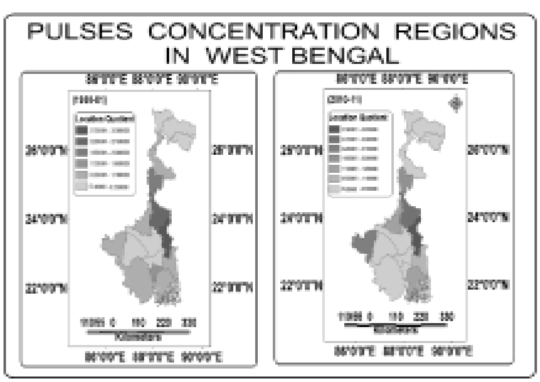
Fig.4



Pulses

For analyzing Pulses concentration regions in West Bengal for the year 1980-81 and 2010-11 all the calculated values have been divided into seven classes i.e., 0 to 0.550000 as very low, 0.550001 to 1.100000 as low, 1.100001 to 1.650000 as moderately low, 1.650001 to 2.200000 as moderate, 2.200001 to 2.7500000 as moderately high, 2.7500001 to 3.300000 as high, and 3.300001 to 3.8500000 as very high concentration. In 1980-81 very low concentration in the production of pulse was recorded in Darjeeling, Jalpaiguri, Coochbehar in North Bengal and Birbhum, Burdwan and Hooghly in South Bengal. Besides, in 2010-11, very low concentration in pulses production was recorded in two more districts in South Bengal i.e., Howrah, Midnapur and one in North Bengal i.e., Dinajpur in addition to the districts covered in 1980-81. In 1980-81 low concentration was recorded in Purulia, Midnapur, Birbhum, North and South 24 Pargana, Dinajpur whereas in 2010-11 low concentration was recorded only in North 24 Parganas and Birbhum, South 24 Parganas was classified under moderately low concentration region. In 1980-81 only Howrah was under moderately low concentration region of pulse production. In both 1980-81 and 2010-11 moderate concentration was recorded in Maldah and Purulia was categorised under moderately high concentration region of pulse production in 2010-11. In 1980-81 this class was occupied by Murshidabad. In 2010-11 Murshidabad was under

Fig. 5



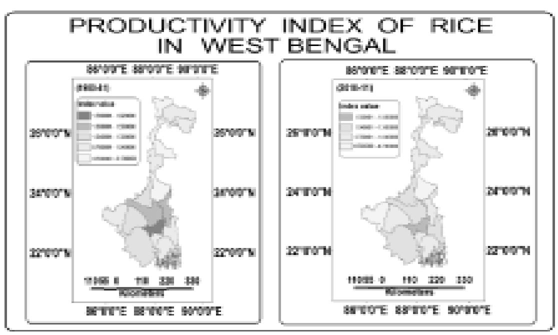
high concentration and very high concentration in pulse production was recorded in Nadia. In 1980-81 Nadia also recorded high concentration of pulse production in West Bengal.

Productivity Index

Rice

For comparing the level of productivity in rice production of different districts in West Bengal between 1980-81 and 2010-11 the calculated values have been classified into five classes i.e., 0.520000 to 0.780000 as very low productive region, 0.780001 to 1.040000 as low productive region, 1.040001 to 1.300000 as moderate productive region, 1.300001 to 1.560000 as high productive region and 1.560001 to 1.820000 as very high productive region. In 1980-81 Darjeeling, Dinajpur, Murshidabad had very low productivity level whereas in 2010-11 slight improvement in production level was recorded in Dinajpur and Purulia lost its productive capacity more and degraded from low productive region to very low productive region. In 1980-81 high productivity was recorded in Nadia and Burdwan and very high productive capacity was recorded in Hooghly i.e., 1.75 (productivity index) in the production of rice. That means Hooghly is 175 percent more productive than other districts of West Bengal. In 2010-11 this productive capacity goes down though Hooghly retained its position but it’s productive capacity decreased i.e., 1.4 (productivity index).

Fig.6



Wheat

For analyzing the level of productivity in wheat production productivity index of wheat for 1980-81 and 2010-11 has been calculated and mapped. All the calculated values have been classified into five classes i.e., 0 to 0.770000 as very low, 0.770001 to 1.540000 as low, 1.540001 to 2.310000 as moderate, 2.310001 to 3.080000 as high and 3.080001 to 3.850000 as very high productive region. During 1980-81 very low and low productivity in wheat production was recorded in Darjeeling, Jalpaiguri and Coochbehar in North Bengal and nine districts of South Bengal. In 2010-11 moderate productive capacity in wheat production was recorded in Birbhum, Nadia, and Dinajpur whereas in 1980-81 Birbhum and Nadia were under low and high productive regions respectively. In 2010-11 Murshidabad lost its productive capacity and was classified under very low productive region. Besides, 3.29 productivity index was recorded in Maldah during 2010-11 which was 1.6 during 1980-81. Maldah had highest productivity capacity among all other districts in producing wheat in 2010-11.

Fig.7

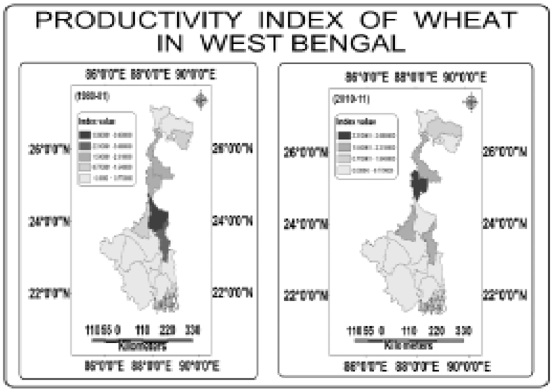


Table-3

Productivity Indices of different food grains in West Bengal

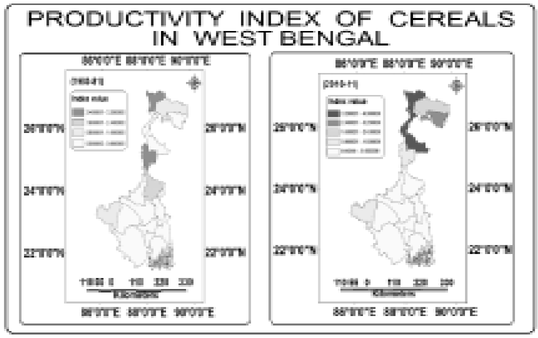
Districts	1980-81 *Rice*	*Wheat*	*Cereals*	*Pulses*	2010-11 *Rice*	*Wheat*	*Cereals*	*Pulses*
Burdwan	1.44	0.44	0.07	0.33	1.2	0.03	0.02	0.2
Birbhum	1.14	1	0.14	0.86	1.2	2.015	0.02	2
Bankura	1.14	0.43	0.3	1	1	0.19	0.05	0.015
Midnapur	1.06	0.19	0.06	0.44	1.13	0.05	0.03	0.38
Howrah	1	0.15	%	1.5	1	0.03	0.015	0.2
Hooghly	1.75	0.75	%	0.25	1.4	0.02	0.02	0.02
N 24 Parganas	0.83	0.6	%	0.8	1.125	0.56	0.025	1
S 24 Parganas	0.86	0.06	0.01	0.86	0.86	0.11	0.03	1.14
Nadia	1.5	2.5	0.33	3.05	0.83	1.87	0.33	4.017
Murshidabad	0.75	3.125	2	2.39	0.75	0.63	0.625	3.25
Dinajpur	0.72	2.11	0.55	0.89	1.01	1.78	3.78	0.23
Maldah	0.8	1.6	3.7	3.2	1	3.29	1.2	1.86
Jalpaiguri	0.8	0.6	0.8	0.4	0.8	0.95	2.2	0.31
Darjeeling	0.7	0.6	3.9	0.4	0.6	0.4	3.98	0.4
Coohbehar	0.8	0.8	0.2	0.4	1	0.49	2.8	0.46
Purulia	1	0.1	1	0.6	0.67	0.2	1	0.49

Source: Computed by the Authors

Cereals

Fig.8 shows productivity index of cereals of West Bengal for two different time periods i.e., 1980-81 and 2010-11. The calculated values have been classified into five classes i.e., 0 to 0.800000 as very low, 0.800001 to 1.600000 as low, 1.600001 to 2.400000 as moderate,

Fig. 8

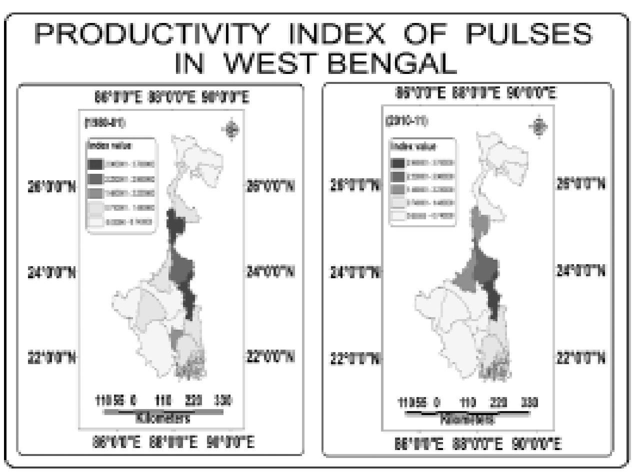


2.400001 to 3.200000 as high and 3.200001 to 4.000000 as very high productive regions. In 1980-81 high productivity level in the production of cereals was recorded in Maldah and Darjeeling whereas in 2010-11 Maldah lost its productive capacity and classified under low productive region and Dinajpur recorded highest productivity capacity along with Darjeeling. In 1980-81 the productivity index of Dinajpur was only 0.55. Likewise, Murshidabad also lost its productive capacity. In 1980-81 its productivity index was 2 and in 2010-11 it became 0.625. Rests of the districts are in more or less same condition during 1980-81 and 2010-11.

Pulses

For comparing the productive capacity of pulses in different districts of West Bengal in between 1980-81 and 2010-11 productivity index of pulses has been calculated and mapped. The calculated values are classified into five categories i.e., 0 to 0.740000 as very low, 0.740001 to 1.480000 as low, 1.480001 to 2.220000 as moderate, 2.220001 to 2.960000 as high and 2.960001 to 3.700000 as very high productive region.

Fig.9



It is evident in Fig.9 that during 1980-81 in Purulia, Burdwan, Hooghly, Midnapur of South Bengal and Darjeeling, Jalpaiguri and Coochbehar of North Bengal, very low productive capacity of pulses was recorded and during 2010-11 Bankura, Howrah and Dinajpur districts were added. Dinajpur and Bankura had low productive capacity in 1980-81 (index of productivity lies between 0.740001 and 1.480000). But in 2010-11 it decreased further and productivity index became <0.740000. Low productive capacity was recorded both in North and South 24 Parganas during 1980-81 and 2010-11. Besides, in 1980-81 moderate productive capacity was recorded in Howrah but in 2010-11 it lost its capacity and was categorized under very low productive region. In 2010-11 moderate productive capacity was recorded in Maldah and Birbhum whereas in 1980-81 Maldah's productivity index was very high i.e., in between 2.960001 to 3.700000. But in 2010-11 very high productivity level in the production of pulses was recorded only in Nadia and the district Murshidabad has same productive capacity in both the study periods.

Crop Diversification

Index of crop diversification in West Bengal has decreased from 1980-81 to 2010-11. Only in Birbhum, Dinajpur, Jalpaiguri, Darjeeling and Coochbehar diversification index has increased which indicates lesser development in agricultural technology. These districts are lagging behind in agriculture that's why poor farmers compelled to grow several crops instead of one specialized crop. Because intensive farming needs standard machineries, HYV seeds, supply of proper chemical fertilizer, favourable climatic condition and good irrigation facility etc. Among all districts Hooghly, Burdwan, Howrah has very less diversification index i.e., 0.01, 0.02, 0.02 respectively which was 0.11, 0.1, and 0.26 in 1980-81. Highest diversification index was recorded in Darjeeling (0.54) in 2010-11 followed by Nadia (0.43), Maldah (0.43) etc. In 1980-81 highest crop diversification index was found in Murshidabad (0.58) which became 0.5 in 2010-11.

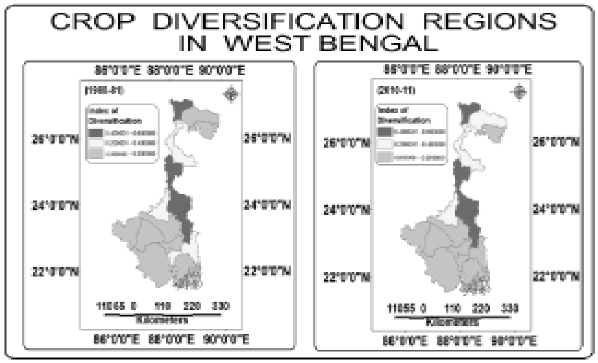
Table-4

Crop Diversification in West Bengal

Districts	1980-81	2010-11	Districts	1980-81	2010-11
Burdwan	0.1	0.02	Nadia	0.56	0.43
Birbhum	0.23	0.29	Murshidabad	0.58	0.5
Bankura	0.1	0.04	Dinajpur	0.28	0.3
Midnapur	0.13	0.03	Maldah	0.52	0.43
Howrah	0.26	0.02	Jalpaiguri	0.15	0.25
Hooghly	0.11	0.01	Darjeeling	0.53	0.54
N 24 Parganas	0.21	0.12	Coohbehar	0.145	0.16
S 24 Parganas	0.12	0.09	Purulia	0.19	0.19

Source: Computed by the Authors

Fig.10



Agricultural Efficiency

On the basis of agricultural efficiency statistics based on the yield of four major crops (food grains) produced in the state six efficiency classes have been determined. These are follows:

- **Very high efficiency areas (130.000001 to 143.000000)**

This category comprised the district Hooghly in 1980-81. But in 2010-11 no district has been found in this category. Efficiency level goes down. In 1980-81 per hectare production of mentioned crops was higher than others in Hooghly.

- **High efficiency areas (117.000001 to 130.000000)**

This category comprised only Burdwan district in 1980-81. High level of irrigated areas, fertile soils were the main cause of high efficiency level. In 2010-11 no districts have been found under this category. In comparison with 1980-81 comparatively low level of engagement in agricultural activity is the prime cause of this.

Table-5

Agricultural Efficiency in West Bengal

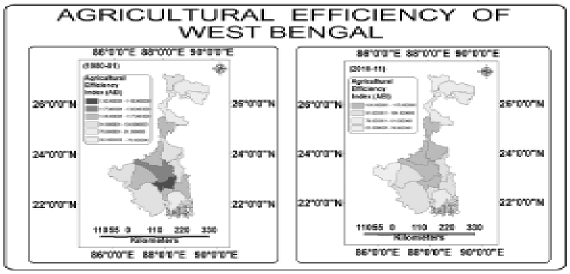
Districts	1980-81	2010-11	Districts	1980-81	2010-11
Burdwan	125.13	109.24	Nadia	94.39	101.385
Birbhum	112.64	109.37	Murshidabad	93.37	105
Bankura	106.88	94.46	Dinajpur	81.39	88.5
Midnapur	94.61	100.705	Maldah	106.57	112.47
Howrah	113.05	97.2	Jalpaiguri	79.71	81.635
Hooghly	137.16	114.09	Darjelling	101.23	73.15
N 24 Parganas	114.06	100.03	Coohbehar	73.255	89.49
S 24 Parganas	90.25	85.74	Purulia	93.31	61.085

Source: Computed by the Authors

- **Moderately high and moderately low efficiency areas (104.000001 to 117.000000 and 91.000001 to 104.000000)**

Moderately high efficiency areas includes Maldah, Birbhum, Bankura, North 24 Parganas, Howrah and moderately low efficiency areas includes Darjeeling, Purulia, Midnapur, Nadia, Murshidabad in 1980-81 whereas in 2010-11 Murshidabad, Burdwan, Hooghly were categorized under moderately high efficiency areas instead of high and very high efficiency areas.

Fig. 11



- **Low efficiency areas (78.000001 to 91.000000)**

In 1980-81 Jalpaiguri, Dinajpur, South 24 Parganas were under this category and in 2010-11 Coochbehar was added with these districts.

- **Very low efficiency areas (65.000000 to 78.000000)**

In 1980-81 only Coochbehar was under this category but in 2010-11 Darjeeling and Purulia were categorized under this area by losing its efficiency level from moderate to very low.

Findings

The analysis in the present paper reveals the following:

- There is great influence of geographical factors on crop concentration in West Bengal.
- Crop concentration is inversely related to crop diversification.
- High degree of crop concentration in South Bengal is a result of suitable agro-climatic, soil condition and availability of required water.
- The cropping pattern in West Bengal has been skewed mainly towards the production of food grains.

Conclusion

Keeping in view the above findings it is clear that food grain production is the main thrust in the agricultural sector of West Bengal. North Bengal is still lagging behind the southern part of Bengal in terms of the degree of crop concentration due to physiographic limitations and unfavourable agro-climatic conditions, which necessitate appropriate planning measures. It may, however, be mentioned that adequate interventions are required not merely to augment the production of crop but also to create congenial environment for the development of agro-based industries and agri-business towards employment generation for youths.

References

Bhatia, S.S. (1965): *Patterns of crop concentration and diversification in India,* Economic Geography: 40-55

Chouhan T.S. (1987): *Agriculture Geography: A Case Study of Rajasthan State,* Academic Publication, Jaipur.

Economic and Statistical Handbook of West Bengal 2011-12.

Enyedi, G.Y (1964): *Geographical Types of Agriculture*, Budapest, Applied Geography in Hungary.

Gibbs, J. and Martin, W. (1962): *Quantitative techniques in Geography: An introduction,* R. Hammond and P.S. MC Gullagh. Clerendon Press, Oxford, pp.21.

Hangaragi, S.S. (2010): Patterns of Crop diversification in Bagalkot, District of Karnataka*, The Deccan Geographer*, Vol.48, No.1 pp. 49-57.

Kendall, M.G. (1939): The Geographical Distribution of Crop Productivity in England, *Journal of the Royal Society*, pp.21-48.

Hussain, Majid (1996): *Systematic Agricultural Geography*, Reprinted 2004, Rawat Publication, Jaipur and New Delhi, pp. 217, 218.

Sapre, S.G. and Deshpande, V.D. (1964): Inter district Variations in Agricultural Efficiency in Maharashtra State*, India Journal of Agricultural Economics*, pp.242-252.

Shafi, M. (1960): Measurement of Agricultural Efficiency in Uttar Pradesh, *Economic Geography*, pp. 296-305.

Singh, Jasbir (1976): *Agricultural Geography,* Tata McGraw Hill Publishing Co. Ltd. New Delhi, pp.176.

West Bengal Development Report, Planning Commission, Government of India, 2010.

23

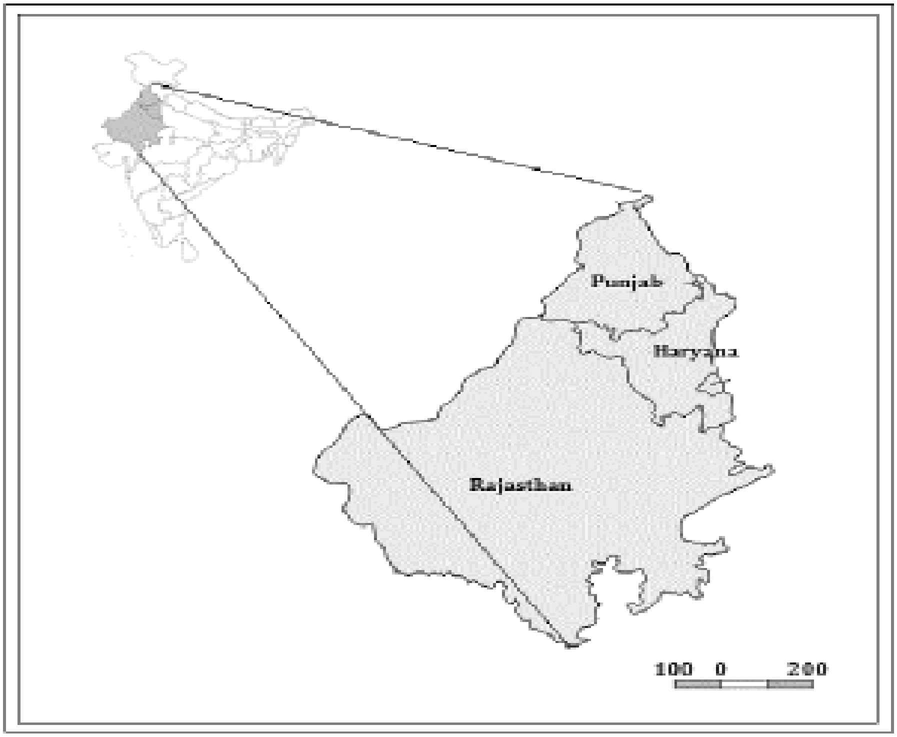
Mapping the Sinking Groundwater Resources of Northwest India

Shekhar Kumar

Introduction

A vast literature exists studying the problems of groundwater in India in general and in northwest India in particular. A recent study by NASA has postulated that “Meeting Humanities increasing demand for fresh water and protecting ecosystems at the same time will be one of the most difficult and important challenges of this century. The US also estimates a 40 percent short fall in the global water supply by 2030. Within a decade 1.8 billion people are projected to be coping with severe water scarcity and two thirds of the global population could be living with stressed water supplies. A World Bank Report (2010), ‘Deep Wells and Prudence’ claims that, by using an estimated 230 cubic kilometers of groundwater per year India has become the largest groundwater user world around. Not only had the largest groundwater user rather it is also one of the most water challenged countries in the world with more than half of India facing high to extremely high water stress, affecting nearly 600 million people. In particular, the high stress area blanketing the northwest, ‘India’s breadbasket’. A collaborative research by university of California, Irvine and NASA has found that the Indus Basin of northern India and Pakistan is among the hotspots where groundwater is being depleted most rapidly. Over the last few decades, there has been a tremendous overexploitation of India’s groundwater resources with particular concern in intensively cultivated and densely populated areas, where groundwater extraction is at an all-time high. This escalating demand for water was an outcome of the shift from water prudent crops to monocultures and multicropping and by the replacement of old varieties of wheat and rice with so called high yielding varieties (HYV). Such dramatic proliferation in water demand and consumption has led to ‘a total destabilisation’ of the water balance in the region.

2. Study Area



The study area under the lens is the northwestern India (Punjab, Haryana and Rajasthan), stretching from 23°30È N to 32°32È N latitude and 69°29È E to 78°17È E longitude. Spreading over an area of 436813 km², it accounts for 13.29 percent to the total geographical area of the country. Geologically it forms a part of the Indo-Gangetic plains lying between peninsular and extra peninsular region (The Himalayas) with rock formations of the Pleistocene and Recent Quaternary in origin. Being a part of extensive aggradational plains of north India, it possesses a flat, featureless and monotones topography as an outcome of alluvium deposited by three major river systems viz; The Indus, The Ganga and The Brahmaputra. Receiving an annual rainfall ranging from more than 100 cm in northeastern Punjab to less than 25 cm in western margins of Rajasthan northwestern India experience a variety of climates from tropical monsoonal (Cwg) to semi-arid steppe (Bshw) to hot desert (Bwhw) climates. According to the 2011 population census Punjab, Haryana and Rajasthan together hold 122 million residents accounting for 10 percent of national sum. The states of Punjab and Haryana are major contributors to national food supply owing to their favorable physical, climatic, social and political factors. Whereas the state of Rajasthan has the largest geographic area (10.41%) in the country to sustain about 6 per cent of country's population but various limiting factors such as; arid climate, deserted relief, scanty rainfall and deep aquifers the agricultural development is not as sound as in the other two states.

Results and Discussion

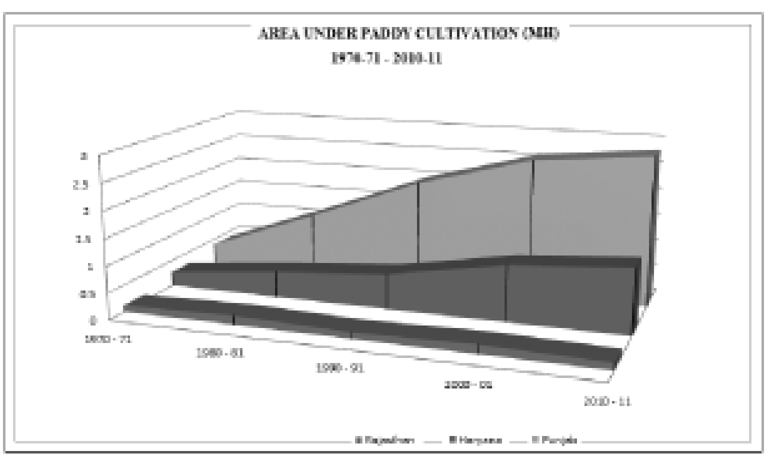
Groundwater Consumption in Northwest India

Of 4000 wells monitored all around the country 54 per cent shows a decreasing water level in the wells and 16 per cent with a decline more than 1 m/year (Shiao et al. 2015). Groundwater levels are falling as farmers, new urban residents and industries drain wells and aquifers. More than 60 per cent of irrigated agriculture and 85 per cent of its drinking water supplies in India is dependent on groundwater. The world Bank Report 'Deep Wells and Prudence' warns that 60 per cent of India's aquifers will end up critical in the next 20 years particularly in the Punjab-Haryana region, due to cheap and easy groundwater pumping and drilling technologies accompanied by decision distorting energy subsidies. The government subsidizes the farmer's electric pumps and places no limits on the volumes of groundwater they can extract, creating a widespread pattern of excessive water use and strained electrical grids.

Contrary to the national average of only 61 percent, the stage of groundwater development in Punjab, Haryana and Rajasthan is very high (average more than 140 percent). The northwest is experiencing disequilibrium in annual groundwater consumption (draft) and annual groundwater recharge, largely attributable to the increased popularity of paddy and wheat cultivation, acreage under which expanded phenomenally in the region since 1970s. Rice and wheat together; accounts for almost 75 per cent of the total food grains produced in the country with states of Punjab (98%) and Haryana (91%) having much greater share of rice and wheat in total food grains production. But the agricultural landscape is converse in case of Rajasthan where rice and wheat production accounts only for 40 per cent (rice 1.41% and wheat 38.31%) of total food grain production, much lower than the national share of the respective crops. Also the area under wheat and rice cultivation occupies only 17.30 percent share of the total area under food grains cultivation. Instead of wheat and rice the agricultural landscape is dominated by pulses (32%) and oilseeds (36%) cultivation. It is not only the usage of groundwater for irrigation rather the Physio-climatological conditions of the region such as arid landscape and scanty annual rainfall also contributes positively for bringing groundwater table low.

Fig. 2

Area diagram showing growth in area under paddy cultivation in northwestern India



The states of Punjab and Haryana producing 50 per cent of the national governments rice supply and 85 per cent of its wheat stocks are at the forefront in the country to experience drying aquifers in the near future owing to unsustainable anthropogenic interventions. The green revolution, which was mainly confined to cereals especially, wheat and rice, neglected the production of other crops like pulses, oilseeds, spices, etc. During last five decades, area under rice and wheat cultivation has expanded exceptionally in the northwest, especially in Punjab and Haryana (fig.2). Consequently the share of northwest as a whole in total rice production in the country has multiplied manifold from 3.3 percent in 1970-71 to 15.22 per cent in 2010-11. Wheat has also witnessed a phenomenal growth in productivity and production owing to favorable physiographical, climatological, technological, social and political factors.

Table 1

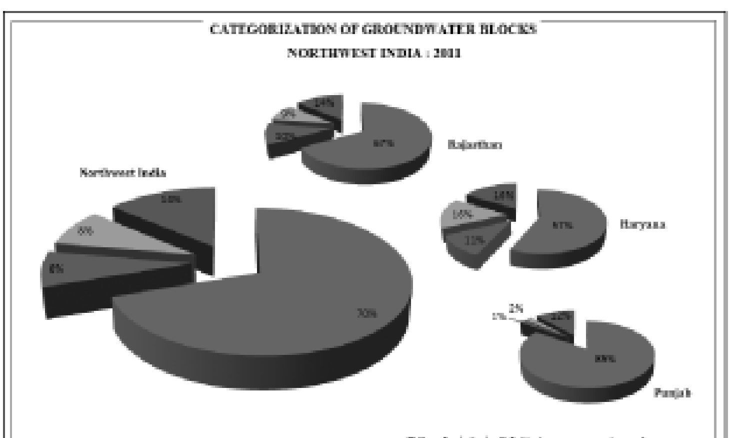
Groundwater Availability and Draft in North West India: 2011

State	Annual Replanisable Groundwater Availability (Recharge)	Net Annual Groundwater Availability	Irrigation Use	Domestic and Industrial Use	Total Draft	Excess Draft
Haryana	10.78	9.78	12.34	0.71	13.05	3.27
Punjab	22.53	20.32	34.17	0.71	34.88	14.56
Rajasthan	11.94	10.82	13.13	1.71	14.84	4.02
Total	**45.25**	**40.92**	**59.64**	**3.13**	**62.77**	**21.85**

Source: Central Groundwater Board

Fig. 3

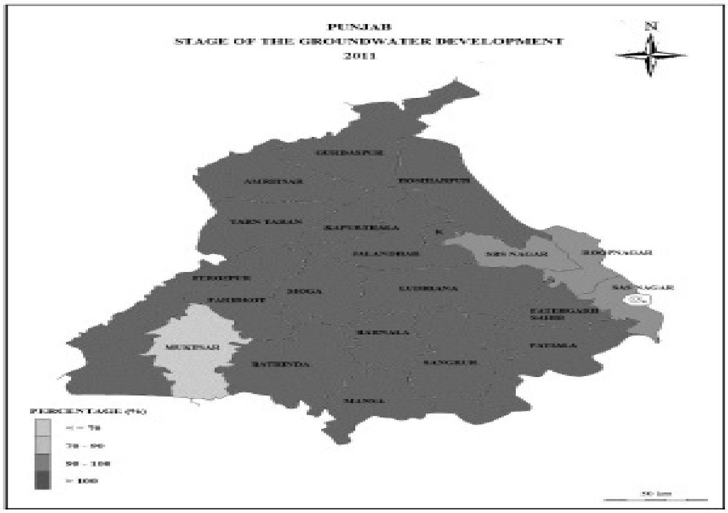
Categorization of Groundwater Blocks in Northwest India



Profuse pressure exerted by agricultural activities (irrigation) on groundwater in northwestern India could easily be assessed by the fact that irrigation alone consumes more than 95 percent of groundwater being extracted in the region. There are over 17 million groundwater extraction units in India, growing steeply even today. Government has provided huge

Fig. 4

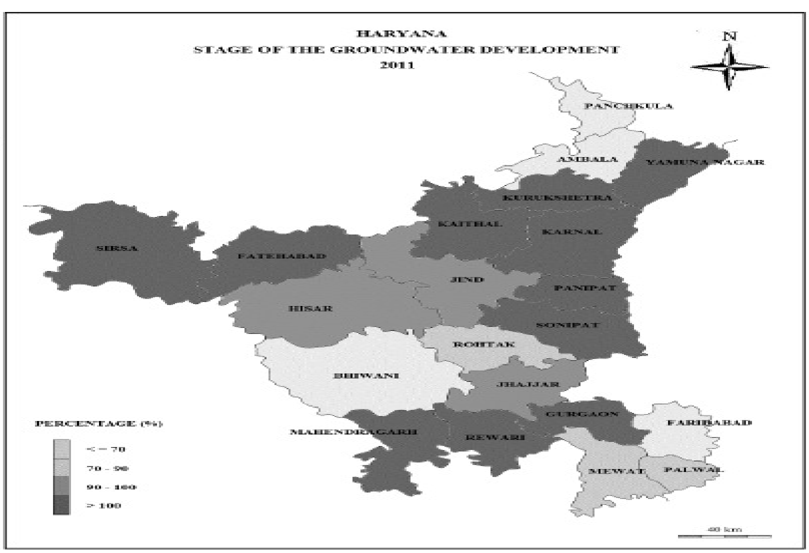
District-Wise Stage of Groundwater Development in Punjab (2011)



incentives for groundwater use in various forms; loans for wells, motors, electricity subsidies, incentivizing cropping pattern, industrial activities and residential uses. According to the report entitled 'Dynamic Groundwater Resources of India 2011', northwestern region holds

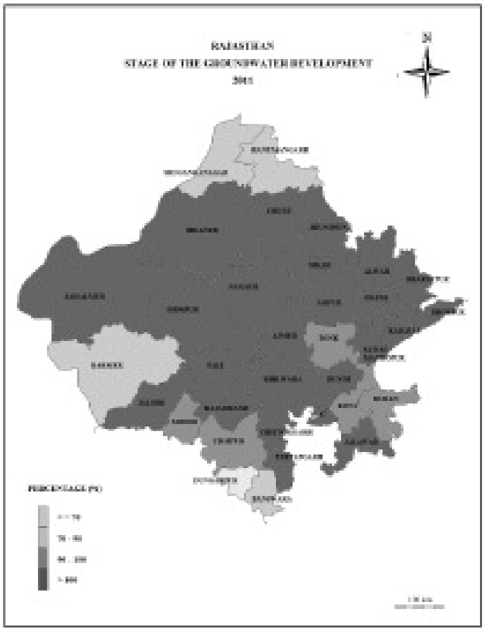
Figure: 5

District-Wise Stage of Groundwater Development in Haryana (2011)



around 10 percent of total net annual groundwater available but as far as irrigation is concerned, the share is 27 percent to the national total. In northwestern, Punjab is endowed with the richest aquifers with a net annual groundwater availability of 20.32 million cubic

Figure: 6.
District-Wise Stage of Groundwater Development in Punjab (2011)



meters accounting for almost 50 per cent of total groundwater resources in the region. Not only is the availability rather the consumption of groundwater is more than the sum of other two states. Punjab alone used 55 per cent of the groundwater drafted during 2011 followed by Rajasthan and Haryana with 24 and 21 per cent share respectively. Out of 463 groundwater blocks in the region70 percent are overexploited, 8 per cent are critical, 8 per cent semi critical and only 14 per cent are safe (fig.3). If segregated state wise Rajasthan holds the maximum number of overexploited blocks followed by Punjab and Haryana. But if per cent to its total water resources is considered Punjab leads with almost 85 per cent of its groundwater resources falling under the category of over exploited. It is not only the excess draft rather lesser recharge due to rainfall variability also contributes to groundwater paucity. Among the three northwestern states, Punjab is most severely affected followed by Haryana and Rajasthan. It is not the increasing population or developmental activities (urbanization, industrialization etc.) that are lowering the water table rather only irrigation directly exert the most drastic effect on groundwater.

Between 2005 and 2013, average groundwater levels dropped by 25 feet in parts of Haryana state and by 32-36 feet in parts of Rajasthan and Punjab states (USA Today/Desert Sun). Such rapid depletion threatens major farming regions and if unchecked will lead to more wells going dry. Withdrawing groundwater at rates that threaten to deplete aquifers in the northwestern region affects not just the livelihood of farmers and the regional economy but also the broader economy through the significant loss of food staples currently produced in the region. As the depth of the water table increases, future generations could face higher costs for water withdrawal that could force structural changes on the economy and lower the region's contribution to food security. (Nelson et al).

Conclusion

Groundwater has been an important water resource throughout the ages. Like any other natural resource, groundwater is also not unlimited. The spatial variability in groundwater availability is subjected to natural (local geology, physiography, rainfall, and forest cover) and human factors (crop combinations, population pressure and level of development). The world over, irrigation sector is the largest user of water in general and of groundwater in particular. Direct victims of excessive draft and overconsumption of water resources are the farmers themselves, who increasingly suffer from water shortages during weak rainy season or drought resulting in reduced harvests and loss of income. Taking into account the disequilibrium in net annual groundwater availability and draft this region could be presumed to witness acute shortage with Punjab as the epicenter. The way India will manage its groundwater resource in the future will clearly have very serious implications for the future growth and development of the agriculture sector in India. The drying aquifers of northwest will not only hamper the food availability to the people of this region rather being the largest contributor to the national pool, it will affect inversely to a large population. Hence sustain groundwater resources should be of utmost concern to sustain the food availability. Groundwater must be wisely managed and protected against undue exploitation and quality contamination for a sustainable groundwater supply and to maintain ecological or hydrological equilibrium.

References

Anuradha., (2015). *Groundwater crisis deepened in India. South Asian Network on Dams, Rivers and People* (SNDRP).

Anupama, J., Singh, R. P., Kumar, R.,(2008). Concerns of ground Water depletion and irrigation efficiency in Punjab agriculture: a micro-level study. *Agricultural Economics Research Review. 21,* 191-199.

Badoni, P., (2014). Groundwater - falling levels and contamination threaten India's water lifeline: urgent need for community-driven bottom-up management. SNDRP.

Chinnasamy, P., Ageramoorthy, G., 2016. India's groundwater storage trends influenced by tubewell intensification. Groundwater. 54.

Central Ground Water Board., 2016. Groundwater year book of rajasthan, Jaipur. Ministry of Water Resources, River Development & Ganga Rejuvenation, India.

Chinnasamy et al., 2015. Understanding groundwater storage changes and recharge in Rajasthan, India through remote sensing. Water. 7, 5547-5565.

Central Ground Water Board., 2015. Groundwater year book of Punjab and Chandigarh (UT). Ministry of Water Resources, River Development & Ganga Rejuvenation, India.

Central Ground Water Board., 2015. Groundwater year book of Haryana. Ministry of Water Resources, River Development & Ganga Rejuvenation, India.

Central Ground Water Board., 2014. Dynamic ground water resources of India. Ministry of Water Resources, River Development & Ganga Rejuvenation, India

Central Ground Water Board., 2013. Groundwater year book India, 2012- 2013.Ministry of Water Resources, India.

Gandhi, V. P., Namboodri, N. V., 2009. Groundwater irrigation in India: gains, costs and risks, Research and Publications, IIM, Ahmadabad.

James, Ian., 2015. How unchecked pumping is sucking aquifers dry in India. The Desert Sun.

Nelson et al., 2013. The shadow value of groundwater in Punjab, India: an analysis in an economy-wide context. Institute on the Environment, University of Minnesota.

Kumar, S., (2015) Status of ground water in punjab – A temporal analysis. *Discovery Agriculture. 3 (10),* 1-5.

Kaur, S., Vatta, K., (2015). Groundwater depletion in central Punjab: Pattern, Access and Adaptations. *Current Science. 108* (4).

Kumar, S., (2015). Overdraft-An anthropogenic hazard for Punjab. *Journal of art and science of geography. 1(1)*, 35-44.

Panda, K. D., Wahr, J., 2016. Spatiotemporal evolution of water storage changes in India from the updated GRACE derived gravity records. Water Resource Research.

Pander, Rita., 2014., Groundwater irrigation in Punjab: some issues and way forward. Paper no. 2014-140. National Institute of Public Finance and Policy, New Delhi.

Pradhan, G., 2014. Understanding interannual groundwater variability in north India using GRACE. M.Sc. dissertation, Indian Institute of Remote Sensing, ISRO.

Reddy, P. J. R., (2014). A textbook of hydrology. third edition. University Science Press, Delhi. 265.

Rodell, M., Velicogna, I., Jamiglietti, J.S., (2009). Satellite based estimates of groundwater depletion in India. Nature. 460, 999-102.

Shiao et al., (2015). 3 maps explain India's growing water risks. World Resource Institute.

Sharma, Hemanti., (2014). Evaluation of groundwater depletion scenario and its impacts in Northwest India by geodetic techniques & modeling approaches. M.Tech. dissertation (unpublished). Indian Institute of Remote Sensing, ISRO.

Sharma, K. D., (2011). Rain-Fed agriculture could meet the challenges of food security in India. *Current Science. 100 (11),* 1615-1616.

Shankar et al., 2011. India's groundwater challenge and the way forward. *Economic and Political Weekly, XLVI (2),* 37-45.

Singh, K., 2011. Groundwater depletion in Punjab: measurements and countering strategies. *Indian Journal of Agricultural Economics. 66 (4),* 573-589.

Shah et al., 2003. Sustaining Asia's groundwater boom: an overview of issues and evidence. *Natural Resurce Forum. 27*, 130-140.

The World Bank., 2010 Deep Wells and Prudence: towards pragmatic action for addressing groundwater overexploitation in India. 51676.

24

Climatic Cartography: A study on Topographical Map in higher secondary education in Beldanga Block, Murshidabad

Subhankar Samanta

Introduction

Topographical maps are very important for showing natural and cultural features of a place. The main component which is mainly shown in the map is relief. Topographical maps are not only use to interpretation of natural and cultural features of a place but also chance to interpret the place with the correct explanation. It can be explain the formation of physical features by the works of river, rainfall, temperature, locational extension etc. By the use of topographical maps we can explain many components on the earth's surface. It is time to culture our knowledge by more and more practical works. In our school system, practical works are done with the theoretical process. In the present time, project work must be prepared from class (IX) to (XII) in all subjects. But maximum students use to copy this work. So their knowledge limit to copy level in the project book. We have to give them a chance to inculcate their knowledge by the realistic knowledge in geographical practical works.

The main function of geography teaching is the relationship between man and environment. In topographical map, physical and cultural features are shown together. Students want to know the physical features not only in maps but also they want to see the real pictures i.e their surrounding at first. In this process their knowledge will grow from sensory stage to concrete and will be able to correlate the present physical features. And now the students automatically explain and analyze the other variable with the present situation. It is our unfortunate that in our education system for class (XII) teachers doesn't use topographical maps efficiently. This is because of the insufficient on quality maps in education system and markets and teachers educated without proper explanation and map use skills. Consequently school teachers face methodical problems and less than will power.

Objectives

In my paper it is analyzed interpretation of topographical map in class (XII) practical syllabus. It is determined the understanding level, previous knowledge and interest level of the students about the relationship between topographical map and climatic condition. It is also analyzed that how much climate effect on topographical maps. The main aim of this study is to explanation of topographical maps most interesting, brainstorming and conceptual base learning. For this purpose for clarifying current situation, I have done a questionnaire with some Higher secondary school teachers in Beldanga Block, Murshidabad.

Approaches and Methods

Firstly I have described a problem: By using topographical maps in practical of class XII, could student understand and explain climatic condition readily? Or not…With the interaction of the school teachers it is determined many deficiencies in term of concept of climatic condition base on topographical maps. When searching for answer to the problem, different situations may arise if the answer is negative, this should be considered. For this reason these situations may occur—

1. Students don't have enough knowledge about the relationship between climate and topographical map.
2. During the course, teacher does not give enough importance to the use of topographical map.
3. Identification of physical and cultural features is difficult for the students.
4. There are unavailable of climatic data in schools.
5. Students have no enough concepts in explaining topographical map.

To investigate and clarify these reasons, I have implemented a study with some teachers in Beldanga Block. In WBCHSE geography class XII syllabus, Map scale, Cartogram, Measuring Weather elements, Weather map, Temperature and Rainfall Graph and Field report are studied. In class XII geography practical syllabus, study and interpretation of topographical map is studied.

In our state education system students of class XI and XII are taught by PG level geography teachers. For this reason it is implemented questionnaire to these teachers. I have selected seven schools randomly. Twelve teachers were participating in this study. Questionnaire was performed face to face by the way of interviewing with teachers. The teachers are asked 20 questions and it is presented some options for each question. Questions are below:

1. Are students has clear concept on map scale?
2. Do students know the function of latitude and longitude on a topographical map?
3. Can the students measure the direction of the selected topographical map?
4. Can the students identify the topographical features from the topographical map?
5. How are they identifying the physical features? You can select more than one option.
6. Do the students explain exactly the cause of formation of identified relief?
7. Do the students mention the climate for the cause of topography formation?
8. If yes, which is the cause of topography formation according to the students? You can select more than one option.
9. Do the students think that there are any relation between climatic change and topography?
10. If yes, which relief is/are related with the climatic change? You can select more than one option.
11. Can the students have idea about the rainfall amount by observing natural vegetation on the topographical map?
12. Is there enough time for map use in the class?
13. Which subjects on topographical map are difficult for the students? You can select more than one option.
14. Do students show interest in identification and explanation of topography?
15. Are the explanations on topographical map in practical textbook sufficient for the better understanding for the students of class XII?

16. Do you think that climatic condition must be explained on the base of natural and cultural features on a topographical map?
17. If yes, how can be explained climatic condition of a place on topographical map? You can select more than one option.
18. Are there any available climatic data for explaining climatic condition on the selected topographical map?
19. Is the curriculum on topographical map reachable to the students of class XII?
20. If no, please mention the parts which need to omit and which need to add in the class XII curriculum.

Table no. 1

Questions	Answer/Option	No. of Teacher Choose this option	Percentage (%)
1st	Yes	11	91.66
	No	1	8.33
2nd	Yes	11	91.66
	No	1	8.33
3rd	Yes	12	100
	No	0	0
4th	frequently	10	83.33
	Occasionally	2	16.66
	Rarely	0	0
5th	By observing contour value	9	60
	By observing alignment of contour	2	13.33
	By cross profile	4	26.66
6th	frequently	5	41.66
	Occasionally	6	50
	Rarely	1	8.33
7th	Yes	8	66.66
	No	4	33.33
8th	Rainfall	6	46.15
	Temperature	6	46.15
	Wind	1	7.69
	Evaporation	0	0
9th	Yes	8	66.66
	No	4	33.33
10th	Plain	3	25
	Hill	5	41.66
	Plateau	4	33.33
11th	Strong	4	33.33
	Moderate	8	66.66
	Poor	0	0
12th	Yes	9	75
	No	3	25

13th	Identification of natural features	2	12.5
	Identification of cultural features	3	18.75
	Explanation of natural & cultural features	4	25
	Transact chart	7	43.75
14th	frequently	6	50
	Occasionally	4	33.33
	Rarely	2	16.66
15th	Yes	11	91.66
	No	1	8.33
16th	Yes	9	75
	No	3	25
17th	Use of climatic chart	5	35.71
	Use of Ombrothermic chart	1	7.14
	Use of Hythergraph	1	7.14
	Use of Weather Map	7	50
18th	Yes	3	25
	No	9	75
19th	Yes	10	83.33
	No	2	16.66

RESULT:

While teachers were answering questions some notes was taken related with teacher's option and attitudes. Some teachers showed great interest to my study, some others did not. Some teachers answered questions with care attention, others answered hurriedly.

In the first three questions more than 90% teachers said students have base level knowledge i.e knowledge like concept on map scale, latitude and longitude etc to enter the topic topographical map. They said to study topographical map, students have already learned latitude, longitude in secondary school and map scale, cartograms, field report in class XI. But below 10% teachers said the students of their school have not enough previous knowledge due to inattentive in the class and also forbidding. About 80% teachers told that students can identify maximum no of topographical features from topographical map. But about 17 % teachers have observed students occasionally identify them. It is most important that how to identify physical features. There are mainly three processes by which can be identified by a student. In the 5th question 60% teachers thinks that students are more comfortable to identify physical features by observing contour value, 27% teachers support the 3rd option "By cross profile" and remain 13% teachers think students identify by observing alignment of contour (Figure 1). Most teachers said that the second option is more useful for higher class students.

In the 6th question, are asked the question which is not directly related to the syllabus that the cause of formation of identified relief. So, maximum teachers (50%) answered occasionally and about 9% said students identify the cause hardly. Remain 40% teachers observed that student explain the cause of formation of relief as the teachers help student to understand the cause of the relief by explaining climate effect on physical features (Figure 2).

Figure 1: Identifying process of physical features

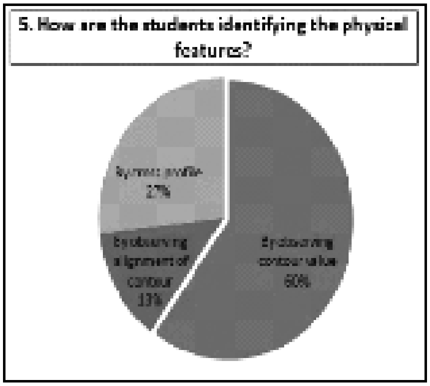
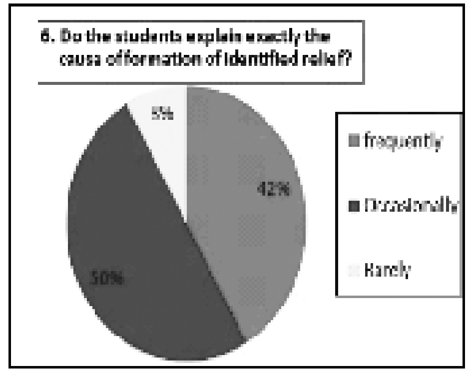


Figure 2: No. of student explain Cause of formation of identified relief



In the 7th question, among 42% teachers about 67% teachers said that student considers the climate which is cause for topography formation. And others 33% teachers said students think diastrophism, mass wasting and erosion by the river are responsible for the topography formation. In the next question among 67% teachers who said climate is the cause of topography formation, 92% teachers said students do responsible rainfall and temperature as component of climate for the change of topography. And about 8% teachers think students follow wind action.

In the 9th question, about 67% teachers showed their students can relate topography with the climatic change. They think when rainfall amount increase, the river erosion speed also increase. So the formation of deep valley in Upper River and floodplain in lower River is gradually increased. Floodplain is good for agriculture and also intensive rural settlement.

Figure3: Relation between climatic change and topography

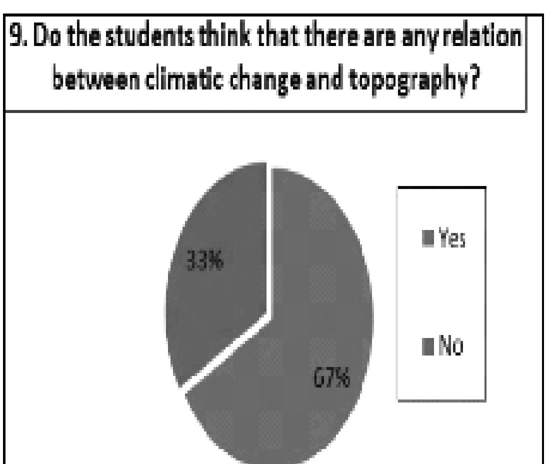
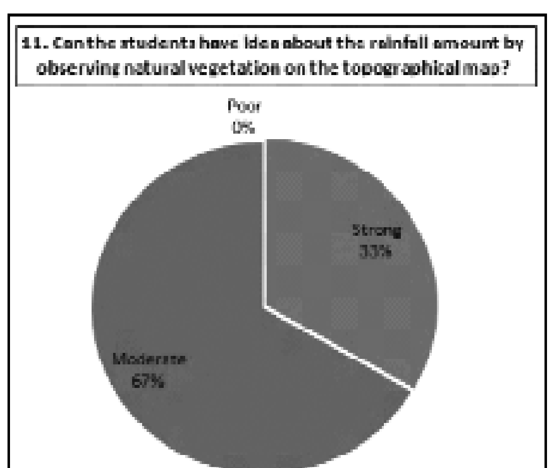


Figure 4: concept on rainfall amount observing natural vegetation



In the 12th question, 75% teachers get enough time for map use but 25% teachers said the excess number and different IQ students in the class are the problem of map use. 50% teachers said students show great interest in identification and explanation of topography map. It is seen in the 13th no question, most teachers (about 44%) observed it is most difficult to formation of transect chart due all features have to show in a single chart. Second most teachers (25%) said explanation of physical and cultural features are most difficult than other to the students. Although, teachers (about 92%) think explanation of topographical map in practical textbook sufficient for the better learning but they also think that those students need to more practical works on the base of direct knowledge and field trip.

Figure 5: Difficult parts in Topographical Map

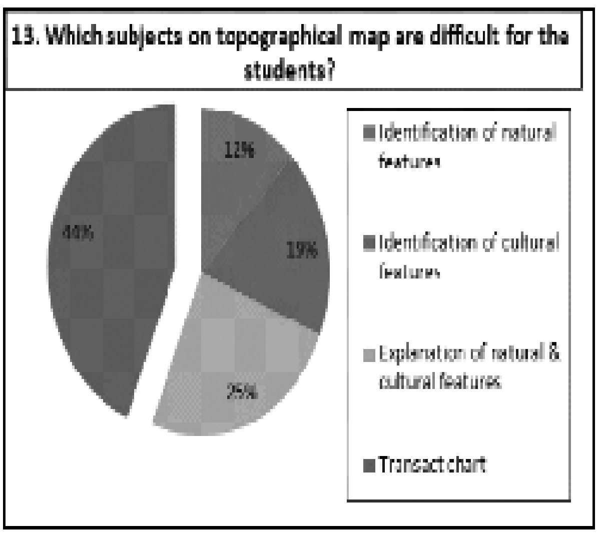
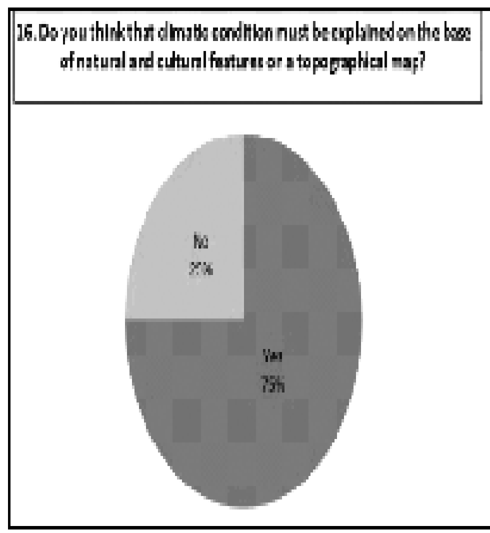


Figure 6: Percentage of teachers who want to explain climatic condition on the base of physical and cultural features on topographical map

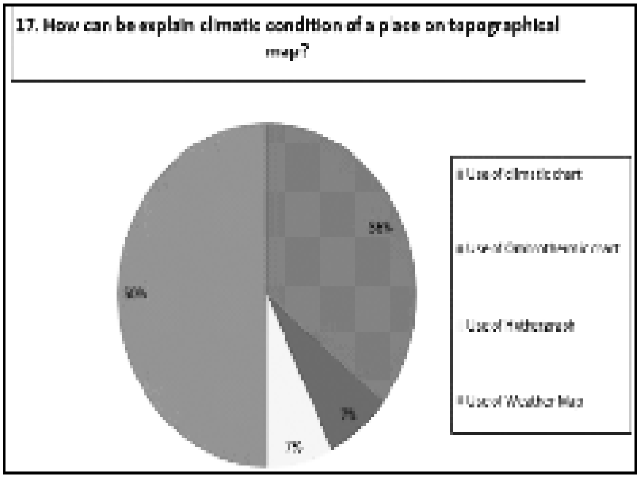


The most interesting and formally in contextual question is asked in 16th no question. 75% teachers think that by observing physical and cultural features, climatic condition like rainfall and temperature can be calculate on a topographical map on a particular place.

The average no. of teachers said there will be high rainfall area where evergreen natural vegetation are mostly found and high temperature and low rainfall area for vegetation less area, low rainfall and low temperature area for coniferous jungle etc. Like high compact rural settlement is sign of comfortable climatic condition for agriculture and human beings.

In Figure 7, among 75 % teachers, 50% teachers want to explain climatic condition of the particular place by use of weather map and 36% teachers want to use climatic chart. It is the problem that maximum teachers (75%) said that climatic data for explain climatic condition on the selected topographical map are not available. But 25% teachers said the climatic data will be available in nearest weather station with special permission.

Figure 7:
Use of different method for explain climatic condition on the topographical map



Ques.no. – 19, was about the satisfaction with class xii curriculum on topographical map. About 83% teachers think that is enough for the better learning of class xii students. According to them, there is strong definition, interpretation of deferent relief and cultural features, characteristics, index, pictures, diagrams and map etc. but remaining 17%teachers think that the syllabus on topographical map is vast. Here are many topics which are not totally reaching to the students.

Let's see the overall looks on to the previous knowledge, interest level of the students on to interpretation on topographical map. According to the maximum teacher (over 90%) are in one opinion that it is not difficult to understand and interpretation the topographical map for the students who have already gain previously the different parts of a map, relief, vegetation, river, and locational extension etc. students also showed interest as toposheet and the different sign of cultural features are something new to them.

And in the last, it is observed in the finding of the work. Main objective of this work was the concept of the students on climate which change topographical features i.e. concepts of the students on the relation between climate and topographical features and applicability and use of climate on topographical map.

- About 67% students have concept in the effect of climate to the topographical map and can have related topographical features with the climate.
- Students (67%) think that rainfall and temperature are responsible for formation of topographical features.
- They also think that topography is changing with the change of climate and hill, plateau are the main effect of climatic change.
- Finally 75% Teachers want to explain climatic condition of a place by observing physical and cultural features of that particular place on topographical maps. By this explanation process students can grow their concept and better learning on topography and also climate.

CONCLUSION AND FURTHER RESEARCH:

Attitude, skill and willpower can change many things which we feel difficult to teaching and learning. At the present time, school education curriculum has been changing with the new thoughts, practical base knowledge but school teaching has been changing with cramming and marks. In this situation it's time to change in evaluation system not only for the students but also for the teachers. In this study teachers have low interest and also answers were partially his own choice not for student choice. So it can be done for further research which will be based on student's direct interaction for better understanding value of the school education. Here are some suggestions for further works –

- Cultural features: a study on topographical map.
- Climate effect culture: a comparative study on topographical maps.
- Teaching and learning: a study on topographical map.
- Skill base practical or real base practical: a comparative study on topographical map.
- Evolution of school teaching: a study on cartography.

Reference:

Hazra, Yudhisthir. (2012), *Snatak Byaboharik Bhugol*.

Saha, Pijuskanti. & Basu, Partha. (2008), *Advance Practical Geography*.

Hazra, Yudhisthir. (2014), *Byaboharik, Bhugol*. (Xi, XII)

Mete, Jayanta. & Dasgupta, Jayarati.(2014) *Adhunik Bhugol Sikkhan Poddhoti.*

Pathak, Avijit. (2002*) Social Implications of Schooling: knowledge, Pedagogy and consciousness.*

Singer, Alan J. (2003) *Social studies for secondary schools: Teaching to learn, learning to teach.*

Bhattacharya, S. & Darji, D.R. (1996). *Teaching of social studies in Indian Schools.*

Omero, Benjamin. & Wakhunga, Nato. *Determining methods used in teaching geography in secondary schools in Rongo District, Kenya*.

Al-Shaikh ,Makram Murad. (2009), *Teaching Cartography using Maps, Critique Exercises: a proposed model for GIS Cartography course.*

Shaikh, Dr. Asam & Harichandan, Dr. S. *Method of Teaching Geography*.

Almeida, Regina Araujo de. (2009) *Cartographic Education For School Teachers And Children Current And Future Challenges*.

25

A Cartographic Analysis of Changing Nature of Canal Water Quality in the added areas of Southern Part of Kolkata

Tanushree Dutta

Introduction

Canals are manmade water channel for reducing drainage problem, draining out excess water, for irrigation even carrying waters to the dry areas etc. In Kolkata, the canals are very important in terms of removing water logging issues, carrying industrial wastes to river. Along with the growing population and urbanization the water quality changes and deteriorated.

Study Area

The study was carried out to evaluate the status of the ponds of the borough X to XV of KMC which comprises with 53 wards (81, 89, 91- 141). The samples were taken from various canals. The studies were conducted in both dry and wet season and also in 2012 and 2016 to analyse selected physico- chemical parameters of the pond. A few canals are passing through the area with their different utility and importance. But the samples were collected from Tolly's nullah, Churial khal, CPT canal and Dry weather flow canal.

Objectives of the study

- To describe the over all canal system in the study area.
- To determine the values of TSS, TDS, BOD, DO, pH, Nitrate, Phosphate, Fecal coliform etc of the sampling sites of the selected canal waters
- No narrate the water quality by calculating Water Quality Index.
- To study the seasonal changing scenario of canal water quality.
- To analyse the difference in quality of the canal water in different years.
- To find out the reasons behind such differences.

Methodology

The water samples were collected from six sites of various canals scattering over the study area to analyse the physico chemical parameters. The samples were collected twice in the selected ponds in the year 2012 and 2016. The samples were done in both dry and wet season to analyse the changing nature of the parameters. The waters were tested in the laboratory to get the value of individual parameters of sampling sites. The secondary data by pollution control board also have been collected to interpret the water quality. The pH, TDS and temperature were determined on field by relevant devices by the researcher directly.

Figure 1:
Location of sample sites on google map

Table 1
Sample Sites

Sample No	Canal	Latitude	Longitude	Remarks
1	Tolly's Nullah Near Bansdroni	22°28'26.04"N	88°21'36.40"E	Metro rail construction has done along the canal route.
2	Tolly's Nullah near Karunamoyee	22°29'12.69"N	88°20'24.27"E	
3	Tolly's Nullah near Garia	22°27'52.99"N	88°22'57.12"E	
4	Churial Canal	22°27'33.77"N	88°19'4.59"E	Slum is located in the banks of canal.
5	CPT Canal	22°30'38.97"N	88°18'45.14"E	
6	Dry Weather canal	22°32'1.84"N	88°24'5.17"E	Pump the waste water to Garden Reach

Source: Primary GPS survey

Selected parameters

- **TDS:** Total dissolved solid (TDS), also referred as total filterable residue, in natural waters consists mainly of carbonates, bicarbonates, chloride, sulfate, calcium, magnesium, sodium and potassium. Dissolved metals, dissolved organic matter and other substances also account for a small portion of the dissolved residue in water.(American Water Works Association, 2003)

  It is measured by TDS meter. The primary sources of TDS are residual runoff, domestic wastes deposited in the ponds by the local urbanites. The sum of all the chemical ions dissolved in the water is called total dissolved solids or TDS.
- **pH**: It is the measure of the relative amount of free hydrogen and hydroxyl ions in the water. It is a measure of how acidic or basic water is.
- **BOD:** Biochemical Oxygen Demand is an important water quality. It is a measure of the amount of oxygen needed (in milligram per litre or ppm) by bacteria and other micro organisms oxidize the organic matter present in the water sample over a periods of 5 days. (Palanna, 2009) . The higher the BOD value, the greater the amount of organic matter or "food" available for oxygen consuming bacteria.
- **Fecal coliform** test is used to determine whether water has been contaminated with fecal matter. The presence of fecal coliform indicates the possible presence of organisms that can cause illness. The test can be performed relatively quickly and easily. The EPA has set acceptable limits for fecal coliform in water based upon the use of the water. For example, drinking water cannot contain any fecal coliform but water for swimming may contain up to 400 fecal coliform colonies/ 100 ml.
- **DO:** Dissolved Oxygen (DO) is no of oxygen gas molecules present in the water. Aquatic creatures are not able to use direct oxygen from air, hence they depend on DO for respiration. The value of DO is related to temperature, time of day, season, depth, altitude etc. It is measured in mg/L. 0-2 mg/L DO indicates not enough oxygen to support life.
- **Temperature:** Temperature is a measure of how hot or cold something is; specifically, a measure of the average kinetic energy of the particles in an object, which is a type of energy associated with motion.
- **Nitrate:** Nitrogen is abundant on earth. Most plants cannot use it in this form. Plants use nitrate to built protein. Nitrate enters stream from natural sources like plant decomposition and animal wastes as well as human sources like fertilizer. Nitrate is measured in mg/L. Natural levels of nitrate are usually less than 1 mg/L. Concentrations over 10 mg/L will have an effect on the freshwater aquatic environment. 10 mg/L is also the maximum concentration allowed in human drinking water by the U.S. Public Health Service. For a sensitive fish such as salmon the recommended concentration is 0.06 mg/L(Behar et al, 1997)
- **Phosphate:** It is essential in small quantity for plant growth and metabolic reactions in animals and plants. Sources of phosphate include animal wastes, sewage, detergent, fertilizer, disturbed land, and road salts used in the winter. (Behar et al, 1997). High concentration of Phosphate poses a human health risk.
- **Turbidity:** The definition of Turbidity is the cloudiness or haziness of a fluid caused by suspended solids that are usually invisible to the naked eye. The measurement of Turbidity is an important test when trying to determine the quality of water.

Selected Canals within the Study Area

Tolly's Nullah: Tolly's Nullah is a very important water ways of Kolkata. It is the main drainage line of a substantial part of the city. It is 28.50 km in length and is an open cut between two natural drainage channel i.e. River Hooghly and river Bidyadhari. It has its entrance from the Hooghly near Old Khidderpore

Dock at Hestings and joins river Bidyadhari near Samukpota. The vast influence of this canal has been observed in the life of people living around the banks of this canal. Tolly's Nullah was excavated in the year 1775-76 for the purpose of providing an effective waterway connecting the eastern districts of undivided Bengal with Kolkata.

CPT Canal: This canal starts from DH Road in ward 132 of KMC and outfall to New Monikhali canal at Jinjira Bazar. It is at the border of KMC & Maheshtala Municipality. The Canal is within the land of Kolkata Port Trust (KoPT). Now the canal is maintained by KMC.

Churial Canal: Churial main Canal originates from KMC Ward No. 123 at Ramkrishna pally and outfalls into river Hooghly near Churial Bazar in Budge Budge Municipality Ward No. 4 through a five vented Sluice. It is the main drainage outlet of Borough XIII and XIV of KMC and a vast area of South 24 Parganas district including a part of Budge Budge municipality.

Dry Weather Canal: The DWF pumping system of Boroughs XIV and XV will pump the waste water to the Garden Reach STP which is proposed to be renovated by KEIP. The treated effluent will be discharged into the Monikhali canal.

$WQI = \sum_{i=1}^{n} QiWi$ **Water Quality Index :** The water quality data are recorded and transferred to a weighting curve chart, where a numerical value of Qi is obtained. The mathematical expression for NSF WQI is given by-

Where, Qi= sub-index for ith water quality parameter; Wi= weight associated with ith water quality parameter; n= number of water quality parameters.(*Tyagi.S et al(2013)*

For this NSFWQI method, the ratings of water quality have been defined by using following:

Table 4

National Sanitation Foundation Water Quality Index (NSFWQI)

WQI Value	Water Quality status
0-25	Very Bad Water Quality
26-50	Bad Water Quality
51-70	Medium Water Quality
71-90	Good Water Quality
91-100	Excellent Water Quality

Source: Tyagi.S et al(2013)

Table 3

Seasonal variation of characteristics of sample water, 2016

Parameters Canal	Sample1	Sample2 Tolly Nullah near Bansdroni	Sample 3 Tolly Nullah near Karunamoyee	Sample 4 Tolly Nullah near Garia	Sample 5 Churial Canal	Sample 6 CPT Canal	Dry Weather Weighting Factor
BOD	28	35	33	35	40	3	0.11
DO	Nil	nil	Nil	3.4	3.4	nil	0.17
Fecal Coliform	800000	350000	300000	3500000	2800000	1700000	0.16
Nitrates	36	56	45	56	45	43	0.10

pH	7.84	6.71	7.74	6.71	6.78	7.83	0.11
Temperature ^{0}C	25	29	30	28.5	27.6	28	0.10
TDS	365	848	863	839	860	154	0.07
Total Phosphate	0.03	0.02	0	0.03	2.54	0	0.10
Turbidity	18.1	16.2	20.1	16.2	18.5	16.4	0.08
WQI	**33**	**30**	**34**	**29**	**23**	**41**	

Source: Calculation has made by the researcher on basis of collected primary data.

Based on the data the calculated WQI of selected eight canal sites are not up to the mark. Every sample site of the canals has very poor quality. Except CPT canal the rest of the canals are under the group of bad Water quality class while CPT canal are under very bad quality group.

Table 5

Change in Canal Water

Parameters	Adi Ganga at Bansdroni (High Tide)		Adi Ganga at Karunamoyee (High Tide)		Adi Ganga at Shahid Khudiram (High Tide)	
	19.5.2014	10.5.2016	19.5.2014	10.5.2016	19.5.2014	10.5.2016
BOD m2g/l	20.75	17.29	22	8.65	24.25	9.13
COD mg/l	60.46	53	97.14	28	65.11	34
DO mg/l	Nil	Nil	Nil	Nil	Nil	Nil
Fecal Coliform MPN/100ml	1300000	3000000	2400000	3000000	5000000	2400000
pH	8.20	7.59	8.10	7.46	7.20	7.71
Temperature ^{0}C	32	32	30	33	31	32
Total Coliform MPN/100ml	2400000	5000000	3000000	9000000	8000000	5000000
Total Suspended Solids mg/l	26	22	54	18	20	22

Source: West Bengal pollution Control Board

Causes behind Water quality Deterioration

- As population size in the study area has grown manifolds over the time which consequently has put much pressure on the available water. Eventually the water quality has deteriorated in consequence of misutilization and overconsumption of available water sources by this expanding population for their daily requirements. The items discharged by the slum dwellers in the water by the side of the canal or at the shallow bottom of the canal, making the water highly rich in base or acidic properties.
- Even some medium and small scale industries discharge their effluents in the canal water, turning it vulnerable to contamination.
- Even at the city fringes of my study area, it is found that livestock are also bathed in the canal water.

- This unhindered mass accumulation of plastic items on or below the water surface blocks the runways to enter into deep area of the water bodies where aquatic lives exist. As a result it disturbs the natural balance and ecosystem and also level of oxygen in water goes down exceedingly, thus making it difficult for aquatic life to survive this risky condition.
- Apart from the plastic items other non-biodegradable as well as water insoluble items are disposed of in a large quantity in a water bodies, which over the time putrefy into rotten objects and mixes up with water.
- Also the other harmful elements mixes with water bodies from which are not immerse into water according to Hindu mythology and thus placed beneath the trees beside the canals.
- Though municipal corporation and other affiliated civic bodies in absence of corporation bodies, have embarked upon a new initiatives of making city clean like cities in western countries but lack of awareness and deeply entrenched old habits in the people have seen that the daily garbage are disposed of in their surroundings.
- Also the harmful chemical present into detergents used by the households combines with water to make it completely unusable and stinking and frothy because people belonging to lower class income group wash their dirty linens by the side of water bodies from which the detergent in liquid form flow into water bodies and thus converting it into a water den for the household living around it.
- Religious extremism plays spoil shot in terms of intimidating people to offer used puja materials into water bodies as they are driven by this obsession hat these are the sacred materials should not be discarded into vast or garbage collecting van, instead it should be sacrificed in the water for salvation, deliverance from sin and other forthcoming bad omen.
- Due to the lack of roadside wastage bins the mobile people prefer to throw the garbage in the nearer ponds and canals. The lack of consciousness of people is the main problem in the environment.
- The construction of roads, metro, buildings is also the major source of pollution. The canals are getting contaminated by the washed out construction materials with the rain water. Besides, the waste waters from the drains are also passing to the depressed pond areas through water logging in the rainy season.

Major Findings

- The data collected from primary survey reveals that the each of the samples is characterised by pollutants.
- The BOD is comparatively higher in CPT canal followed by Churial canal hence prove the pollution level.
- The DO is almost nil except in Churial and CPT canal. So the Tolly Nullah or Dry Weather flow canal is not ideal for survival of the aquatic creatures.
- Fecal Coliform is amost present in each of the sample sites in huge quantity.
- The pH value ranges within 6.71 to 7.8 which is under permissible of WBPCB.
- The presence of phosphate is negligible in each sample areas while the presence of nitrate is remarkable.
- The turbidity is comparatively higher in Adi Ganga or Tolly's nullah as there is possibility of siltation.
- The computed values of WQI reveals that the water of CPT canal is in 'Very Bad' condition while the rest of the water samples are under 'Bad' category.

Conclusion

The above study concludes that the maximum of the selected canal sites are polluted as the WQI values are indicating the results range within bad to very bad quality. The urban runoff and dumping of domestic wastes are affecting the quality of water. Many of the ponds are totally or partly eutrophicated. The fish, frogs are affected for this pollution. A proper management step is needed to control the degradation of the water quality.

References

Print Media

Behar.S, Montpelier. VT (1997), *Testing the Waters: Chemical and Physical Vital Signs of a River,* River Watch Network.

Best. G.A et al (1997), *International River Water Quality,* E& FN Spon, UK

Chatterjee A.(2014), *An overview on different Basins related to various khals in an around Tolly's Nullah*

Frumkin H. et al (2004), *Urban Sprawl and Public Health*, Island Press.

Laws. A.E (2000), *Aquatic Pollution : An Introductory text*, John Wiley & Sons, Inc, USA.

Palanna O.G (2009), *Engineering Chemistry,* Tata McGraw Hill Education Private Limited, New Delhi. P 281

Parameters of Water Quality (2001), Environmental Protection Agency, Wexford, Ireland

Tyagi. S, Sharma. B, Singh. P, Dobhal R (2013), Water Quality Assessment in Terms of Water Quality Index, *American Journal of Water Resource, Science and Education Publighing, pp* 34-38.

Water Quality (2003), American Water Works Association, pp 140-141

Electronic Media

- http://www.businessdictionary.com/definition/dissolved-oxygen-DO.html
- http://www.keiip.in/sewarageNdrainage.php
- http://pubs.sciepub.com/ajwr/1/3/3/
- http://www.water-research.net/index.php/water-treatment/water monitoring/monitoring-the-quality-of-surfacewaters

AN APPROACH TO THE UNDERSTANDING OF SEDIMENTARY ENVIRONMENT AND FACIES IN THE EASTERN NAYAR BASIN: GARHWAL HIMALAYAS

U. K. MANDAL

Introduction

Analyses of sedimentary facies and environment play a significant role in geological and geomorphological studies. It has a wide range of applicability especially in mining and quarrying activities, extraction of mineral resources and also in terrain evaluation. It helps in identification of the potential zones of petroleum, natural gas, coal and locating the metallic ore in sediments whose geometries are facies controlled. In addition to this knowledge of sedimentary environment helps in describing the terrain stability and the genesis of the area. A *sedimentary environment* is a part of the earth's surface which is physically, chemically, and biologically distinct from the adjacent terrain. The sedimentary environment includes the flora, fauna, geology, geomorphology, climate and weather; and in case of sub aqueous the depth of the environment, temperature, salinity, current system of water. While, a *sedimentary facies* is a mass of rock which can be distinguished from that of others by its geometry, lithology, sedimentary structure, palaeo current pattern and fossils (Selley R.C.,1985,pp-1,2.). All these variables are linked in a dynamic equilibrium and change in one variable cause changes in all the others giving rise to a characteristic facies/formation and environment.

The present research article is an attempt to the identification of the sedimentary environment/ facies in the Eastern Nayar basin. Environmental analysis of sedimentary deposits is mostly carried out under the five defining factors of a facies mentioned above. The study has been carried out through the petrographic studies of rock specimens, analysis of litho-stratigraphic successions, geology, geomorphology and the sedimentary structure. The thin section prepared for various rock specimens have been studied with the help of Leitz Polarized Microscope under the normal incident day light. Properties of individual grains such as colour, birefringence, refractive indices, optic sign etc., have been studied under the plain polarized light and cross nichols to distinguish and identify individual minerals. Textural relationship between the framework elements and matrices has also been studied. Granulometric study of a few rock specimens has also been carried out for identification of the relationship between the grain size distribution and the environment of deposition. The grain size of sediment is an important indicator of the energy level of a depositional environment. The coarser the grain size the higher the energy level of a depositing current and the better the sorting the more prolonged the action (Selley R.C., 1985, p-11.). Similarly, sedimentary structure that is essentially an internally generated property of the environment is also an important indicator of the sedimentary facies and environment. Presence of the pre depositional, syn-depositional and post depositional features in the sedimentary rocks are the important indicators of the environment. Sedimentary environments are broadly classified into three types:

i) Erosional sedimentary environment,

ii) Non-Depositional sedimentary environment and

iii) Depositional sedimentary environment.

The Eastern Nayar basin at its present morphological set up belongs to the erosional sedimentary environment of a dissected mountain chain and is characterized by the occurrences of different facies or formations as described below.

Study area:

The study area is located between $29^0 45' 16''$ N to $30^0 07' 09''$ N latitude and $78^0 39' 49''$ E to $79^0 12' 18''$ E Longitude. It forms a part of the Lesser Garhwal Himalayas. Administratively it occupies a small portion of the Pouri and Almora districts in the state of Uttaranchal (part of erstwhile U.P), India; and covers an area of about 1002 Km^2. The area is characterized by marked relief variation. The absolute relief ranges from a minimum of 565m to a maximum of 3098m. About 45.91per cent of the basin area lies in the 1400m to 1800m altitudinal zone. The Eastern Nayar forms a 5^{th} order drainage system and has a total length of 92 Km from source to mouth along the course of which a number of tributary streams have joined to form a complex drainage net. The morphology of the basin has been largely determined by its geologic and tectonic history, and the imprints of such geological history points to the sedimentary environment in this area.

Sedimentary Facies and Environment:

The Eastern Nayar basin is characterized by nine distinct geological formations/facies. These are High Grade, Low Grade, Damta, Chandpur, Lower Deoban, Sandra, Blaini, Krol and Tal. These formations indicate the results of deposition in different periods ranging from Pre-Cambrian to Cretaceous under varying geological condition and processes.

The High Grade Formation:

This is the oldest formation found in this area. It belongs to the early Pre-Cambrian period. The source area of the Eastern Nayar river i.e. the north-eastern part of the basin, is covered by this formation. Another outcrop is also identified in the south-western part of the basin near Lansdowne. The high grade in the north-eastern part is separated from the adjoining facies by the inner sedimentary masses and the Almora- Dudatoli thrust while in the south-west the Lansdowne thrust demarcates the boundary between the high grade and the Low grade. This formation mostly comprises granite and gneiss. Quartz, biotite, muscovite and plagioclase are the main mineral content in this formation. The rocks can thus be classified as Quartz-Muscovite-Biotite gneiss and Quartz -Biotite-Muscovite gneiss depending on the proportion of mineral content. Average thickness of this formation ranges from 6000 ft. to 8000 ft.

Table: 1

Tentative Age of the Geological Formations/Facies and Tectonics of the Eastern Nayar basin (After Rupke and Sharma, 1974)

Geological Formations	Era	Period	Age in million years	Tectonic Events
Recent terraces	Tertiary	Pleistocene-Recent	1	Depositional and erosional uplift
Tal	Mesozoic	Jurassic/Cretaceous	150	Uplift restricted in the western part of the basin with local unconformities
Krol	Paleozoic	Permocarboniferous /Middle to upper Triassic	190	Regression of Krols
Blaini	Paleozoic	Carboniferous	280-320	Formation of fore deep
Sandra	Paleozoic	Silurian/Devonian	360	Basic igneous intrusion
Lower Deoban	Paleozoic	Pre-Cambrian/ Cambrian/ Ordovician	435	Basic igneous intrusion along major fracture lines
Chandpur	Paleozoic	Pre-Cambrian	500	Basic igneous intrusion along major fracture lines
Damta	Paleozoic	Pre-Cambrian	750	Turbidities
High Grade	Paleozoic	Pre-Cambrian	750	Turbidities
Low Grade	Paleozoic	Pre-Cambrian	750	Turbidities

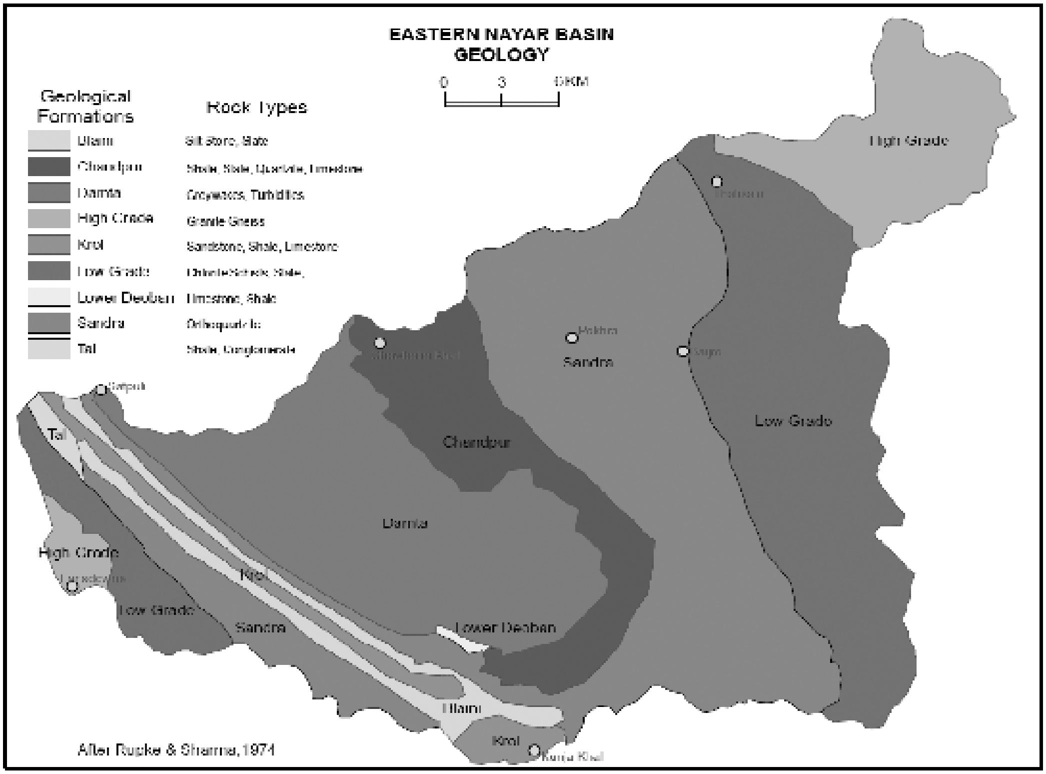
The Low Grade Formation:

The low grade formation is noted in the eastern and south-western part of the basin at 1800m to 2200m altitudinal zones. It forms a part of the Lansdowne synclinorium in the west and Almora-Dudatoli syncline in the east. The rock types in this formation belong to the Pre-Cambrian period and have a thickness of about 9000 ft. This is overlain by the Krol/ Nagthat formation. This formation is separated from the adjoining Sandra formation by the Almora-Dudatoli thrust in the east and by the fault line along the Medi gad in the west. The important rock types in this formation are quartzite, chlorite, schist, slate, and phylonite.

The Damta Formation:

The oldest sedimentary deposit found in this area is damta formation. It belongs to the late Pre-Cambrian period and covers a considerable portion of the Eastern Nayar valley tract. This sedimentary facies is well exposed near Satpuli (at the mouth of the basin) and extends up to the confluence of Khatal gad in the west. It comprises turbidities, greywackes and slumped beds, reddish brown to greenish gray coloured shales and intervening basic intrusions.

Figure: 1



The Chandpur Formation:

The Chandpur formation belongs to the Junsar series of Cambrian to Ordovician period. The Chandpur formation is made up of shale, slate, quartzite and limestone. The color of the exposed surface is generally black. This formation extends from Ekshewar in the north to Kunjakhal in the south and covers the central part of the basin. Another long narrow strip also extends from Satpuli to Kunjakhal parallel to the western border of the damta facies. The Chandpur formation in the study-area is highly affected by tectonic lineaments and is separated by fault line and fracture planes from the adjoining facies.

The Lower Deoban Formation:

A very small pocket of Lower deoban formation is noted near the mouth of walsa gad in the western part of the basin. This also belongs to the Ordovician period, but is quite asymmetrical to the general sequence of junsar series. It lies in between Chandpur and the Sandra group of formation.

The Sandra Formation:

The Sandra formation is to some extent identical in nature to that of Nagthat formation that belongs to the Junsar series. This formation is not well defined in the study-area; still the associated rock types of sandstone, meta ortho-quartzite, green clay, slate and phyllite have given this sedimentary mass a distinguishing facies characteristics. The granulometric study and population analysis of the meta ortho-quartzite of this formation depict that the sediments were deposited under tidal inlet and beach environment during Silurian/Devonian period. A large part of the study-area, particularly in the central and south-central part, is covered by this formation.

The Blaini Formation:

A long narrow strip of blaini bed is noted in the Eastern Nayar basin that extends from north-west to south-east. It lies over the Sandra formation and belongs to the Carboniferous period. The boulder beds and the limestone are the constituent rock type of this unit. The boulder beds are dark gray to greenish in appearance while the limestone is noted as pink argillaceous to purple calcareous shales and slates. These two rock types are intervening with one another by tectonic movement.

The Krol Formation:

The Krol formation lies over the Blaini boulder bed. It belongs to the Permocarboniferous to upper and middle Triassic period. Occurrences of Krol formation is noted in the in the south-western part of the basin in a long narrow strip from Satpuli to Ghungti danda at an elevation of 2110m. Middlicott (1864) first described the krol sequence. This formation is composed of limestone shale and sandstone.

The Tal Formation:

The term ‘Tal series’ was proposed by Medlicott (1864). The Tal formation, an important lithostratigraphic unit in the Mesozoic succession of the lesser Himalayan region is well known for its paucity of fossils. It lies between the krol and the recent sediments of Eocene period. After the deposition of the calcareous krol a striking change in deposition took place in Cretaceous period. The younger beds consist exclusively of detrital quartzite. These sediments have been called tals (Middlemiss 1887). The Tal formation is found in the extreme north-western part of the basin. A narrow strip of Tal formation runs parallel to the Eastern Nayar river. It is composed of shale and conglomerate of Cretaceous/Jurassic period (Auden, 1934). It is also noted that dolomitic boulders are embedded in this formation due to the faulting that took place during the development of Krol sequences.

Sedimentary structure:

Sedimentary structure of a facies is an important indicator of depositional environment. It provides evidences of whether an environment is aqueous, glacial or sub-aerial. In the Eastern Nayar basin post-depositional structures including vertical as well as lateral reorientation of beddings and stratigraphic sequence are predominant. Analysis of structural section shows the stratigraphic succession of the facies in the basin. The sedimentary structure in the basin area is highly affected by the tectonic activity during post-depositional period. In general, it is observed that the eastern and north-eastern part of the basin is less affected by tectonics, whereas the central part is characterized by the presence of numerous tectonic lineaments of highly complicated nature. It is noted that the high grade granite rock is thrusted over the low grade formation in the Lansdowne area. The thickness of this granite mass varies from 3000 ft. to 8000 ft. The basement of these High grade and Low grade is noted as Sandra orthoquartzite. This Sandra orthoquartzite belongs to the Silurian/Devonian period, which is younger than that of the overlying high grade and low grade formation developed during Pre-Cambrian period. Such inversion in the sequence of stratigraphic succession is due to the Lansdowne thrust. About 10 Km north of Lansdowne a deep gorges has been formed by the Nayar fault. It runs along the course of the Eastern Nayar and Medi gad. In this fault zone, the Krol sandstone, shale and limestone are exposed and the Krol, Infra krol, Nagthat and Damta formations lie sequentially from the top. The thickness of these formations varies from 2000 to 14000 ft. thus on the basis of these structural lineaments, stratigraphy and associated topographic configuration the eastern Nayar basin can be divided into four important tecto-structural units. These are:

i) The Lansdowne synclinorium, Allocthon
ii) The Rethwadhab Autochthon
iii) The Nayar high and related Autochthon
iv) The Almora-Dudatoli synclinorium, Allocthon

The Lansdowne synclinorium, Allocthon:

A very small portion in the western part of the basin is covered by this unit. The Nayar fault demarcates the eastern and northern boundary of this unit. In the south it extends upto the Main Boundary Fault (MBF). Structurally it includes the Tal quartzite, Chandpur shales and High grade metamorphic rocks that are exposed in this area. The eastern and southern trips are cut off by a near strike fault along the Medi gad. The Lansdowne proper is made up of Highgrade metamorphic gneiss, which is underlain by the Lowgrade chlorite schist and quartzite. Most of the axes of this synclinorium are plunging towards north and lay in general bedding plane along Lansdowne-Gumkhal road in the western boundary of the basin.

The Rethwadhab Autochthon:

A narrow strip in between Medi gad strike fault and Nayar fault comprising the south western part of the basin constitute the Rethwadhab Autochthon. This unit has a number of concentric folds and faults. The dominant rock types in this unit are krol limestone, shale, tal conglomerate and chandpur shales and quartzite dipping towards south-west. Blaini boulder beds are also noted in this area.

The Nayar high and related Autochthon:

These unit forms the foundation between the Nayar fault and the low grade thrust at the base of the Almora-Dudatoli synclinorium. It covers the central and northern part of the basin. The major facies noted in these units are Sandra, Damta and Chandpur comprising turbidities, mudstone, shale, quartzite and limestone rock types. This series corps out in an anticlinal break-through passing parallel to the Nayar fault. The eastern limb of this structural unit is uplifted along the Nayar fault that has resulted the dip of Damta beds towards north-east. The authocthonus unit run along the Nayar axis and extends upto Kali gad region. A number of cross faults have also been noted in this region which is characterized by Damta turbidities.

The Almora-Dudatoli synclinorium, Allocthon:

This unit forms one of the main thrust sheets in the Garhwal Himalayas. It is mainly made up of High grade and Low grade metamorphic rocks. The thrust plane runs from north to south. It forms a clear-cut boundary between the Almora-Dudatoli synclinorium and the Nayar high units. The basal layers of the metamorphic sheets are having the dip of 25° to 50° towards east. The contact between the metamorphics of the thrust sheet and the underlying authocthonous masses are almost parallel to the foliation of the supra and infra thrust fault sequence. It is noted that the High grade metamorphic rock of the Purvi Nayar, Singwar gad and Thalisain nadi are gneissic in character and there is no sharp contrast with the low grade rocks. The base of the allocththonous series is a bedding plane contact in which the top most bed of allochthon is of varying lithology and age ranging from Kopra equivalent to Infra-krol/Krol and Nagthat formation (Rupke & Sharma, 1974 p.185).

Petrographic study of important rock types and identification of deposition environment:

The above mentioned analysis shows that the Eastern Nayar basin is composed of different rock types belonging to Pre-Cambrian to Pleistocene times. quartz-biotite-muscovite gneiss, quartz-muscovite-biotite gneiss, quartzite, chlorite-schist, slate, phylonite, turbidites, greywackes, shale, limestone, sandstone, ortho-quartzite, phyllite, green clay, slate, boulder beds and fault berccia heave formed different lithostratigraphic units and facies in the study-area. The petrographic study of rock specimens reveals that the rocks are mostly meta-sedimentary in nature and the area including the rock members have undergone minor changes in stress effect. The details of petrographic study are as follows:

Slate: The slates are found characterized by fine grained and greenish in colour. Incipient lamellar banding with angular striation indicates pressure effect on the rock. Mica and carbonate alongwith quartz occur in profuse quantity are the major rock forming minerals. Development of incipient schistosity and small scale folding of the schistosity plane are noted in this rock.

Fault Breccia*:* This is composed of recrystallized carbonate minerals as fracture filling material within a highly crushed volcanic rock. It may be the result of sheer effect. The volcanic rock is basalt and it constitutes the maximum portion of the rock material. The basaltic rock fragments are mainly polygonal and is either equant or lath shaped. The space in between the basaltic fragments is filled with carbonate, which afterwards recrystallized into marble. A few void space exhibit vug-fill structure. The carbonate crystals are found under the microscopic study, which has grown perpendicular to the boundary of the basaltic fragments. It points to the emplacement of the carbonate in fluid state and crystallization. Thereafter when the stress effect reduced, these corroborate well to the nearness of the rock to a fault plane.

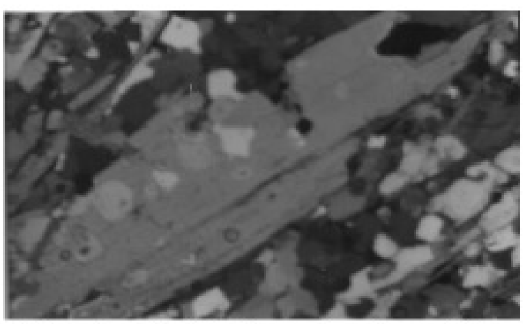
Quartz-Chlorite Schist: The specimen is a greenish coloured metamorphic schistose rock intruded by quartz-vines across the schistosity plane. On microscopic examination, the rock is found to be composed of quartz, biotite and chlorite having moderately coarse grain size. Most of the quartz grains are elongated and particularly ellipsoidal indicating high degree of compaction by which quartz grains have broken down into smaller size. Quartz grains exhibit undulatory extinction pattern which is again indicative of stress effect. Chlorite is the less dominant mineral after quartz while biotite is less in quantity. Both chlorite and biotite exhibit a wavy pattern of development within the quartz grains. The long axis of the quartz grains is uindirectionally oriented pointing to the stress effect.

Calcrete: This rock is a coarse to very coarse grained carbonate rock and highly porous in character. Th is strongly effervasive with dilute HCL. The external irregular shape indicates the rock as calcrete that has subaerialy exposed and partially eroded by surface processes. Microscopically, the rock is found to be composed of segregated large calcite crystal fragments embedded within the entire groundmass. Hence, it is likely to be a sedimentary rock, which was sub-aerially exposed and eroded by the action of surface water.

Well developed gneissocity formed by muscovite and quartzo feldspathic horizons. (Under Crossed Nicols. 40x)

Quartz-Chlorite-Schist, Pressure effect is evident from the undulose extinction Pattern of quartz grains. (Under Crossed Nicols, 40x)

Quartz-Biotite-Muscovite Gneiss: This rock is mainly associated with the high grade and low grade formations. The major rock forming minerals are quartz, biotite, and muscovite with a minor amount of plagioclase of medium to coarse grain. Biotite and muscovite are associated together and have framed several banding pattern within the rock. The interspace between two bands is occupied by sailic quartzo-feldspathic mineral. Thus, alternate bands of mica and sailic minerals are obvious that has developed a gneissic pattern. Puckering of lineation are framed in the quartzo-feldspathic banding.



Inclusion of quartz within a large mica grain - an evidence of post depositional diagenesis. (Under Crossed Nicols 40x)

Recrystalized breccated rock with highly angular basalt fragment surface indicate pressure shadow zone (Under Crossed Nicols 40x)

Quartz -Muscovite-Biotite Gneiss: The mineralogical character of this rock specimen is almost similar to that of quartz-biotite-muscovite gneiss; though in this specimen muscovite with quartz inclusion is more frequent than biotite.

Meta-Orthoquartzite*:* this rock is widespread in this area. Five different specimens were collected from different locations. It may be mentioned in this connection that the general appearance of these rock specimens seem to be different but their petrographic study reveals that these are all medium to coarse grained meta-sedimentary quartzo-feldspathic rocks. These are off white and violet in colour. Quartz and feldspar constitute the major portion of the rock and occur as framework element. Out of these two minerals quartz constitutes almost 90% -95% of the total mass. Hence the name of meta-orthoquartzite may be assigned to this rock type. Another important mineral forming the groundmass or acts as binding material of coarse fragment are the matrix of finely crystalline carbonate and silica.

This is a grain-supported rock where the boundary of the large size grains is fused due to pressure effect. The contact between adjacent quartz grains is marked by fused/serrated boundaries. Carbonate matrix recrystallized to form anhedral, polygonal shaped small crystals. Plagioclase feldspars are also affected along cleavage planes. Recrystallization of carbonate cement and fused boundary relationship of framework element point to a high degree of compaction i.e., pressure effect of metamorphism. This is also evident by the overgrowth development around the quartz grains. Thus, low grade metamorphism is envisaged.

Granulometric Studies of Rock Specimens:

Thin section analysis for granulometric study of the sediments involves only the quartzite/ meta-orthoquartzite members of samples collected from different locations in the study-area. The analysis reveals that sample Nos. 6 and 8 resemble samples 4 and 7 respectively (refer the table below). The present analysis gives the details of these samples.

Though, many sedimentologists have questioned the relationship between size distribution and environment of deposition, attempt to relate the size distribution of sandstone to its environment of deposition have successfully been made by Griffith (1967), Friedman (1961,67), Peltijohn, Palter and Siever (1972), Visher (1969) and others.

In the present investigation, 5 mm x 5 mm area was marked on each slide for keeping a fixed unit area of investigation. The reading was taken in linear fashion and traverses were controlled by mechanical stage. Micrometer ocular readings were confused in xÙ scale (Phi-scale) unit of Krumbein (1934) following the logarithmic transformation of Udden Wentworth's grade scale (1922). The distribution pattern of population were plotted on an arithmetic probably graph. This has been done after tabulating the cumulative frequency percentages of each size population. The graphic measures derived from each curve include Median (MD), Graphic Mean (M_z), Graphic Standard Deviation (S_d) and Graphic Skewness (S_{kg}) following Folk and Ward (1957).

The log probability grain size distribution curves were also analyzed for sub-population (following Visher, 1969) to correlate with the mode of transportation, rolling, saltation and suspension. These studies reflect the characterization of each population vis-à-vis the environment of deposition. The median value and mean grain size in I scale range from 0.95 to 1.65 and 0.98 to 1.63 respectively for sample no 12 and 4. These grains are moderately well sorted. Skewness varies from fine to coarse skewed. The sub-population analysis if Visher, considering Coarse Truncation (C.T.) and Fine Truncation (F.T.) of probability distribution curve and other properties clearly indicate tidal inlet to beach environment. The prominent rolling population along with dominance of suspension population is evident from the analysis and this is the characteristics of tidal inlet to beach environment Reineck and Singh, 1986).

Provenance:

In all the rock samples, low to moderate stress is evident from the recrystallization effect and the grain fabric of the meta-orthoquartzite and slate horizons. The low grade metamorphism is also evident from the well daveloped schistosity pattern and occasional gneissic banding in the fine clastic dominated and coarse clastic dominated rocks respectively. Thus, the original grain distribution and interrelationship between grains are obscure.

A distinct feature noted in the petrographic analysis is the bimodality of the framework elements. Some small size quartz grains whose hardness is about 6, are well rounded (nearly spherical in three dimensions) while the large size quartz grains and few plagioclase grains (hardness about 3.50) are highly angular. The bimodality of framework elements, point to the dual source for the contribution of the rock forming minerals in the area. The contribution of the framework elements from some pre-existing quartzo-feldspathic sedimentary terrain is also evident from the high sphericity and roundness of some of the quartz fragments in association with other strained quartz grains which are irregular in shape

Thus, it may be concluded that the petrographic analysis of various rock samples collected from the area under investigation reveals the area including the rock members have undergone minor changes in stress condition i.e., the pressure with almost no change in temperature. This is interpreted from the presence of chlorite, biotite etc., low temperature/pressure minerals in the thin sections of the rocks. The structured pattern also indicates a framework of low magnitude directed pressure which resulted in the generation of schistosity (preferred orientation of minerals) in the limbs of the folded blocks. On the other hand the core of the fold exhibits a gneissic structure that has resulted from greater pressure effect in comparison to the limbs of the fold. So, the rock members encountered are all low grade metamorphic rocks, where pressure effect is evident from the schistosity and gneissosity.

It also reveals that the rock bodies are metasedimentary in nature i.e., the parent rocks were of sedimentary origin. For example the orthoquartzite gave rise to meta- orthoquartzite, greywackes gave rise to the chlorite schist and shale or silt stone are the source of slate.

Thus, the study reveals a shallow water and beach environment of deposition in the study area. The intermittent effect of tidal inlet within a beach is evident from the various meta-greywackes and slate horizon.

References:

Auden, J.B. (1934): The geology of the Krol Belt, Rec*., G.S.I., 67(40),* 357-454.

Banerjee, D.M. (1974): Stratigraphy and Depositional Characteristics of Tethyan sediments in Kuti-Kalapani area, Kumayon, India, *Himalayan Geol. 4,* 296-322.

Choudhuri, R.S. (1971): Environments of deposition of the Siwaliks (abst.) *Pr. Ind.Sci. Congr. Ass. 58th Sess., Part 3*, 270-271.

Jha, V.C. (1996): *Himalayan Geomorphology, Study of Himalayan Ramganga basin*, Rawat Pub. New Delhi, 224.

Jha, V.C. and U.K.Mandal. (1997): Drainage basin in environmental management, A case study of Eastern Nayar basin, U.P.Himalayas, (ed) *Geography and Environment* by P. Nag, V.K.Kumra and J.Singh, Concept Pub. New Delhi, Vol.2, pp 204-225.

Jha, V.C. and U.K.Mandal. (1999):Geoengineering mapping of Saintoli gad Basin, Garhwal Himalaya, (ed) *Geomorphology and Remote sensing*, by V.C.Jha, ACB Pub, Calcutta, pp 369-377.

Selley, R.C. (1976): *An introduction to sedimentology*, Academic Press Inc. (London) Ltd.

Selley, R.C. (1976): *Ancient Sedimentary Environments*, Chapman and Hall, London.

27

Climate Change and Sustainable Development: The Legal-Political Dynamics

Viswajit Giri

Introduction

Climate Change is a change in global or regional climate patterns, particularly, a change apparent from the mid to late 20th century onwards. It is a change in the statistical weather patterns. The change is measured in a long-run period, for an extended period of time, such as a decade to millions of years. Albeit, climate change is an effect of both natural and anthropogenic factors, however, according to reports of various International Research Institutions and Think-tanks, it is anthropogenic acts which have aggravated the potentiality of climate change more than natural factors for the last hundred years. The World Meteorological Organisation identifies three principal factors of human induced climate change, i.e. emission of Green House Gases, aerosols, and environmental damage, particularly, deforestation. The double-whammy is that it is human acts which have caused climate change, and it is human beings who have to pay for this chaos. Climate change is essentially an environmental problem. As an environmental problem, climate change can be attributed to the result of the dynamic inter-play of socio-economic, institutional and technological activities. Climate change may be driven by many factors including economic growth, population growth, urbanization, intensification of agriculture, rising energy use, transportation, and industrialization. However, two major anthropogenic factors that have aggravated the potential intensity and gravity of climate change are over population and economic growth.

Population growth is undeniably a cause of environmental degradation. Following arguments of Garret James Hardin, population growth leads to environmental damage in the sense that with burgeoning population, consumption increases, and increased consumption requires higher production. Higher production requires higher utilization of resources, including natural resources, and thus, starts environmental degradation. This process is like *Discover-Exploit-Ruin-Move on*. This process is a linear infinity. This process functions in an infinite way. All this leads to *The Tragedy of the Commons* (1968).

The Malthusian Theory of Population growth is another instance. Thomas Robert Malthus was the first economist to propose a systematic theory of population growth. In his famous book *Essay on the Principle of Population* (1798), Malthus proposed the principle that human population would grow exponentially or geometrically, i.e. doubling with each cycle while food production would grow arithmetically only, i.e. by the repeated addition of a uniform increment in each uniform interval of time. Thus when food production was likely to increase in a series of twenty-five year intervals in the arithmetic progression 1, 2,3,4,5,6,7,8 and so on, population was likely to increase in the geometric progression, 2, 4, 8,16,32,64,128, 256 and so forth. This scenario of arithmetic food growth with geometric population growth would lead to a future where humans would have left no resources to survive on. To avoid such a catastrophe, Malthus, and later Hardin urged control on population growth, albeit, their modes of prescriptions (for control on population growth) were different in nature.

Economic growth is supported by four core objectives, i.e. increased production for the consumption of burgeoning population, poverty reduction, employment generation and achieving better standard of living. Industrialization, infrastructural development, trade, business and commerce have been the driving forces of economic growth. Whether economic growth has succeeded in achieving its objectives is a different issue. Nevertheless, unbridled and imbalanced economic growth has led to massive environmental damage in the developing nations of Asia, Africa, and Latin America.

Table 1

Causes and Effects of Climate Change at a Glance

Human Induced Factors of Climate Change	Effects of Climate Change
Emission of Green House Gases	➢ ***Increase in Temperature***
➢ ***Water Vapour (H2O)***	➢ ***Frost Free Season***
➢ ***Carbon Dioxide (CO2)***	➢ ***Changes in Precipitation Patterns***
➢ ***Methane (CH4)***	➢ ***Droughts and Heat Waves***
➢ ***Nitrous Oxide (N2O)***	➢ ***Hurricanes***
➢ ***Ozone (O3)***	➢ ***Ice-Melting in the Arctic***
➢ ***Chlorofluorocarbon (CFC)***	➢ ***Increase in Sea Level***
➢ ***Hydro-Chlorofluorocarbon (HCFC)***	➢ ***Effects on Biodiversity, Ecosystem and Local Environment***
Environmental Damage	
➢ ***Deforestation***	➢ ***Effects on Food Grain Production***
➢ ***AerosolsManufacturing and Use of Weapons***	➢ ***Effects on Plants and Animals***
➢ ***Weapons of Mass Destruction***	➢ ***Effects on Human Health***
➢ ***CBRN Weapons***	➢ ***Effects on Livelihoods***

Keeping this scenario in view, this Paper is going to discuss the legal-political dynamics of climate change, environment protection, and sustainable development, with particular reference to India. This Paper is divided into two sections. The first part highlights the political and ideological issues embedded with environment protection. The second part draws attention to the pros and cons of Indian environmental jurisprudence, and accordingly, suggests measures.

Section One

Environment and Development: The Socio-Political Debates

It is remarkable that Socio-Political thoughts on environment, development and climate change has accelerated more than the environment movement itself during the last hundred years. Scholars in the fields of Politics, Social Studies and particularly Economics, see the environment movement as an ideological war between groups, furthering away from the core issues at times. According to these scholars, the environment movement and all that is related to environment is difference between ideologies: capitalism, communism, and socialism, free market economy, the industry, the peasantry, the rich, the poor, and the rural and urban problems, and so on. It would be wise here to look into the ideological differences that exist in various thoughts regarding environment and development. The discussions highlight the socio-political and ideological differences that exist among scholars regarding environment and development. One notable feature of the discussions is that the differences lie in extremes. For instance, consider the views of Capitalism and Communism on environment. While supporters of freed trade capitalism consider nature and environment as a mere thing or property to be used by man, Communism on the other hand, very powerfully refutes this theory and advocates for preservation and conservation of nature and equitable distribution of resources. Similarly, when Techno-centrism supports for use of science and technology for environment protection, Eco-Centrism calls for more humanistic, ethical and moral values for the same.

Box 1

Capitalism and the Environment

- Capitalism Causes Social Inequality in matters of Resource Distribution. This Principle Applies to Natural Resources. Capitalism takes away all Natural Resources Making the Poor its Prime Victim.
- Capitalism Creates Wastes. Unequal & Uneven Distribution of Resources Increases the Rich-Poor Divide. As a Result, Excess of Resources with the Rich Get Wasted. It is not used for Productive Purposes. This Principle Applies to Natural Resources as well.
- Capitalism is Anti-social. The Primary Motive of Capitalism is Profit by hook or by crook. This Principle is completely Anti-Social, and Goes against Altruism. Nature and Natural Resources are mere means of Production for Capitalism. To Earn Profit from Nature, Capitalism can Go to any Extent Possible.
- Capitalism is Dangerous. For Production, Capitalism Uses Technology which can Bring Potential Danger to Nature and Humanity.
- Capitalism is Undemocratic. Under Capitalist System, albeit, the Government is formed through Popular Election, however, the Government is Run, Controlled, and Managed by few Powerful Business Tycoons and Industrialists. The Elected Government, in a Capitalist System, can at best be called as Democratic in Form but Capitalist in Spirit.
- Capitalism Creates Pollution. With Heavy Industrialization in Capitalism, Comes Pollution which is a Danger to Humanity.
- Capitalism Creates Conflicts. With Unequal and Uneven Resources Distribution, there Happens to Arise Conflicts in Society. This Conflict Aggravates further when there is Question of Natural Resource Distribution.
- Capitalism is a Parasite. Like the Parasite Makes its Growth on the Host, Capitalism Makes its Growth on Labour. It Exploits Labour, and when its Objective is fulfilled, it kills that Labour.
- Capitalism is based on the Foundation of Consumerism. It Creates Consumerism in the Society Making the Poor its Consumers and Looting them.
- Capitalism Resorts to Covert Methods for Geopolitical Expansion & Economic Exploitation Regardless of Humanitarian and Environmental Consequences.
- The Golden-Egg Story best Applies to Capitalism in Matters of Resource Exploitation.
  The Paradox of Wealth: Capitalism and Ecological Destruction.

Box 2

Communism and the Environment

- Communism Brings Forced Collectivization. It Forcefully Takes away Resources and Makes those People Share Holder who have not Put their Labour for the Production of those Resources
- Communism Obliterates Individual Freedom of Using Resources and Abridges Individual Right to Property.
- Communism is very weak at Economic Calculation. It Miscalculates Labour-Wage Equilibrium.
- Communism's Opposition to Injustice is Violent, Militant and Aggressive in Nature. This can cause Mayhem in the Society.
- It is not Capitalism; rather, it is Communism which is the real Danger to Environment. Capitalism Uses Science and Technology for Environment Protection. Communism Uses Resources with Monopoly.
- There is no Actual Class-Struggle as Argued by Marx. The Problem is Monopolistic and Whimsical Public Policy Measures of the State.
- The Labour Theory of Value on which the Economic Paradigm of Communism is founded is essentially wrong. We cannot assert that a Car should Cost more than a TV because more Labour is needed to produce it. This is Oversimplification of the Market.

Table 2

The Peasantry-Industry Tussle

Peasantry	Industry
Massive Capitalization and Unbridled Industrialization Destroy Traditional Livelihoods and Peasantry.	Industrialization is Key to Development. It Generates Revenue, Employment and Foreign Currency that are the Driving Forces of an Economy. We cannot Put a Full-Stop to Industrialization.
Albeit, India is a Newly Industrialized Country, Agriculture still Predominates Indian Economy. Its Contribution towards Rural Employment and Food-Grain Production is Immeasurable. Industry Damages Agriculture by Land Grabbing, Displacement, and Abuse of Natural Resources.	Industry does not Automatically and Forcefully Grab Land or Displace People. It is Faulty Public Policies due to which People Suffer.
Massive Industrialization is against the Principle of Sustainable Development as it Destroys all Resources with no Concern for Future Use.	Industry does not Destroy Resources. It Uses Resources for higher Production for National Consumption.
There Happens to Exist a Symbiotic Relationship between the Peasantry and the Environment. Peasantry is the best Protector of the Environment and Natural Resources.	Poverty Causes Environmental Degradation. Peasantry, Tribes and the Poor Cause Environment Damage.

Industry Causes Collateral Damage and Direct-Action-Damage to Environment and to Humanity.	Industry has ample Technologies to Minimize Damages.
Industry Causes Pollution and other Social Costs.	Don't Worry We can Save the Environment and Compensate Social Costs through Polluter-Pays-Principle.
Science and Technology have their Own Limitations. They cannot Handle all kinds of Environmental Problems.	We are capable of Dealing with Losses to Mankind.

Table 3
The Eco-Centrism versus Techno-Centrism Debate

Eco-Centrism	Techno-Centrism
The human race is a part of the nature. Its status is as equal to all other species living in the world.	Man is considered as separate from and superior to all other living beings, and the natural world.
The human race has no right to exploit nature and the natural resources for its greed. Alike all other species, the human race is a part of nature, and thus, it has to bow before nature.	There is a belief that man being superior to all other living beings possesses a right to manage the natural world in the cause of development, i.e. the material well-being of the human race.
Labour is the father and nature is the mother of wealth. The human race should respect labour as he does to his father and love nature as he does to his mother.	There is firm belief on science and technology not only to progress, but also to resolve any kinds of ecological problems that arise in the process of development.
The human race should not be proud of science and technology which he thinks to be the permanent solution to all evils. Science and technology can provide only short-term solutions. In the long-run, they can fail. Science and technology can create more problems in the long-run than they can solve in the short-run. Thus, it's not science and technology that can save the natural world. Rather, it is nature itself which can sustain itself.	The Polluter-Pays Principle is an important characteristic of Techno-Centrism. Compensation against collateral damage is another legal-economic principle of Techno-Centrism. Criminal Liability for wrong doings and economic compensation for damage are the two major principles of Techno-Centrism.
Deep Ecology is the founding principle of Eco-Centrism.	Green Ecology is the founding principle of Techno-Centrism.

Environmental Movement: The Rural-Urban Fringe

While the rural poor of the Indian society fight for environment defence as a basis of their livelihood issue, the elites, particularly the urban elites respond to environmental movement in an entirely different way. In contrast to the rural poor, the urban intelligentsia argue for environment protection to maintain and sustain a healthy city life, such as clean and pollution free air and water, bigger greenery, noise-free environment that is limited to city problems only.

Often there appears to be a centre-periphery disparity in the city or within an urban agglomeration. As a general rule, massive urban activities such as heavy industrialization, business infrastructure or trade & commerce are found to happen in the periphery or sometimes in the suburban areas of the city. Usually the centre or the core of the city is left for public purposes; say for, residential purposes, schools, colleges or universities, offices, health institutions, public transport and communications, or recreational purposes. Technically therefore environmental problems arising in the periphery of the city lie beyond the boundaries of the urban authorities, or if within large cities, in relatively new and weak municipalities. Although environmental problems arise in the periphery of the city and directly affect the core of the city, it is no wonder that the city administration cannot take any immediate measures to counteract such problems as the area where these problems originate lie outside the administrative or legal jurisdiction of the urban authorities.

Accordingly, government responses to environmental problems in terms of institutional, legislative and policy measures tend to be inhibited by the way they come cross spatial and sectoral boundaries and differences. Urban authorities are limited to urban environmental problems that arise as a result of urban activities only and inclined to ignore the rural impacts of urban activities, and the vice versa.

Although, there happens to remain differences in rural and urban environmental problems, however, there seem to be some common grounds in both. Problems such as, air pollution, water pollution, environment pollution, forest degradation, damage to ecosystems, are common both in urban and rural areas; and the most common factor for these problems is anthropogenic interferences. For instance, land acquisition in an urban or suburban area for development project not only displaces people living within the vicinity but also deforests the area and damages the ecosystem, ecology and natural environment. Same is the case in rural area. When a development project is proposed in a rural area, the first issue that arises is land acquisition and displacement of people, and subsequently, resistance to displacement. Even if land is acquired, there arises further resistance from local people for livelihood issues. This issue is possibly the most important one which differentiates the rural environmental movement from that of the urban movement. The rest are very common in both movements (differing in degree only and homogenous in nature). The Rural-Urban Fringe in environmental issues on grounds of livelihood security has, at times, been criticised as Urban Intelligentsia Snobbery. Whatever the criticisms are or wherever the criticisms go do not matter. What really matters is that unbridled and irresponsive anthropogenic acts have caused much damage to environment, and thereby, making the entire human race the victim. No matter we live in a village, town, city, or urban agglomeration, Antarctica or Africa, we are affected in a way or the other. True, the affects can vary with time, situations, and circumstances; however, it cannot be denied that we are victims of our own acts. In short, we are the convicts, and we are the victims.

Box 3

Major Urban Environmental Problems

- ❖ Air Pollution
- ❖ Water Pollution
- ❖ Noise Pollution
- ❖ Chemical Pollution
- ❖ Sanitation Problems
- ❖ Illegal Waste Dumping
- ❖ Waste Management Problems
- ❖ Increase in City Temperature
- ❖ Decrease in Urban Green Space
- ❖ Acidification of City Environment
- ❖ Local Ecosystem Degradation in the City
- ❖ Growing Traffic and its Effects on Local Environment
- ❖ Effects of the above Problems on the Economy of the City
- ❖ Genetic Engineering and its Effects on Environment and Public Health
- ❖ Heavy Industrialization and its Effects on Environment and Public Health

Note: Box 3 and Box 4 contain information that is based on common-sense observation obtained from scientific academia. This is not a water-tight compartment. Variations or exceptions may occur.

Box 4

Major Rural Environmental Problems

- ❖ Water Pollution due to Animal Wastes and Agrochemicals, such as, Inorganic and Synthetic Fertilizers, Pesticides, and Hormones
- ❖ Land Degradation and Deforestation due to Shifting Cultivation, such as, Slash-and-Burn Agriculture (Fire-Fallow Cultivation)
- ❖ Population Pressure and its Impacts on Rural Land, Environment, and Ecosystems.
- ❖ Soil Erosion due to Overgrazing by Cattle, Deforestation and Denudation of Land, and Cultivation along River Banks.
- ❖ Rural Livelihoods Issues

Section Two

Environment and Development: The Legal Issues

Sustainable Development

Sustainable development has been defined in many ways. But the most frequently quoted definition is from Our Common Future, also known as the Brundtland Report, 1987:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

Sustainable Development is the policy. It is the means to achieve the above objectives. It is a means to an end. In Public Policy Theory, there is an aphorism that policies are like Vine (climbing plants or scandent) that cannot grow themselves, but require another plant on which they can make their growth. Public policies, until and unless, channelized through proper processes, techniques and framework, are worthless. Similarly, sustainable development policy, until and unless, put into a proper framework, cannot be expected to achieve desired objectives. Thus there comes the task of putting sustainable development policy into legal framework. That is undertaking sustainable development within a particular legal framework.

Legal Framework for Development

The World Bank documents on Sub-Saharan Africa in 1989 mentioned four key dimensions of good governance: (1) Public Sector Management (2) Accountability (3) Transparency and Information, and, (4) Legal Framework for Development. We have developed techniques such as, administrative reforms, electronic information & communication technology for effective public sector management. To ensure accountability, there are accountability legislations, institutions such as boards and commissions, and to maintain transparency, we have parliamentary legislations such as, the Right to Information Act.

However, the most controversial and debatable issue remains to be legal framework for development (LFD). The most relevant questions regarding LFD are: What is LFD? Who has to decide or who has the right to decide what LFD is? How to decide what LFD is? What are the measuring criteria of LFD? Should the LFD be value-laden or value-free? Should the LFD be based on a particular ideology or ideologies? If so, what or which ideology? Is it the Constitutional ideology? Is it political ideology? And what if there appear conflicts between legal-constitutional principles and popular mandate? Unfortunately, neither the World Bank nor any other International Agencies or Institutions answer these questions. And this is possibly the most important factor that there arises an environment-development debate, particularly, in the developing nations of Asia, Africa, and Latin America. We have failed or we are unable to develop LFD. We have development paradigm. We have development policies. We have development objectives. But we lack appropriate development framework while it comes to environment and development.

Table 5

The Environment-Development Linkage

What is to be Sustained?	For How Long? Now/In Future/Forever	What is to be Developed?
NATURE Earth Biodiversity Ecosystems Plants & Animals		PEOPLE Human Development
LIFE SUPPORT Ecosystem Services Natural Resources Environment COMMUNITY Cultures Groups Places	Linked By Only/Mostly/But/And/ Or	ECONOMY Wealth Productive Sectors Consumption SOCEITY Institutions Social Capital States Regions

The Indian Environmental Jurisprudence: Looking from Below

Environmental defence framework in India is based on two broad legal principles of Eminent Domain and Criminal Liability. While the principle of eminent domain institutes the supremacy of the State over natural resources including land and other immovable property, the principle of criminal liability applies to non compliance of pollution control laws. The combination of these two principles have resulted in a conflicting model of environmental legal system failing to address the real problems of people and stumbling over providing a solution. The fact is that India follows a traditional regulatory framework of environment protection that seeks to achieve short-term improvements and fails to foresee long-term consequences. Sustainable development which seeks to meet the needs of the present without compromising the future would be a fiasco, if it is based on this model of environment defence.

Courts as legal institutions are designed to adjudicate legal disputes between parties and carry out administration of justice in civil, criminal, and administrative matters. Courts need necessary legislations to resolve disputes. Courts cannot resolve disputes in a particular matter, if necessary legislations are not present there relating to that matter. This is what has happened to the Indian environmental legal framework. In environmental dispute resolution domain, India has two primary legal institutions: the National Environmental Tribunal and the National Green Tribunal. While the National Environmental Tribunal provides for strict liability for damages arising out of any accident occurring handling any hazardous substances, the National Green Tribunal is established for the effective and expeditious disposal of cases relating to environmental protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property. Although these institutions have been assigned responsibility to resolve disputes regarding ordinary environmental issues, however, they have not been authorised to look into matters relating to nature and natural resources protection. The fact is that there are no such legislations which can empower or authorise these institutions to interpret Rights of Nature. These institutions are limited only to the domains of liability, compensation, and damage control which are merely a set of banal mechanisms of traditional environmental regulatory system.

Depending on science and technology can provide short-term solutions. In the long-run, science and technology may fail. Science and technology can create more problems in the long-run than they can solve in the short-run. In case of India, this picture is even more pathetic. Research and development in science and technology in India is not so advanced that it is capable of dealing with major environmental disasters. Are the science and technology experts of India capable of dealing with another Bhopal Gas Tragedy or another Chernobyl Incident or another Fukushima Daiichi Nuclear Disaster? We are not even capable of dealing with small-scale natural calamities, such as, flood, cyclone, and drought and prone. How can we expect ourselves to handle fatal disasters like Nuclear Disaster, Industrial Disaster and Chemical Disaster? It is not suggested that we should keep a distance from science and technology. What is merely suggested is that we should stick to the principle of an ounce of prevention is worth a pound of cure. We should prevent problems instead of finding solutions after creating problems.

This is the picture of Indian environment defence on the basis of which one should fathom the pain and gain of Indian development. In short, it can be concluded that: (a) the Indian development paradigm lacks a proper and legitimate development framework (b) as a result, the vulnerable and marginalised groups, predominantly, the peasantry, the poor, the landless, the unemployed, and the tribal groups, have become victims to development. Keeping this picture in view, it is advisable that we should shift our environment protection policy from cure to prevention, from damage control to damage prevention, and from compensation to compatible.

Box 6

Indian Environmental Legislations at a Glance

Pollution Control Legislations

- The Water (Prevention and Control of Pollution) Act, 1974
- The Water (Prevention and Control of Pollution) CESS Act, 1977
- The Water (Prevention and Control of Pollution) CESS (Amendment) Act, 2003
- The Air (Prevention and Control of Pollution) Act, 1981
- The Environment Protection Act, 1986
- The Mines Act, 1952Legislations Relating to Forest and Wildlife
- The Indian Forest Act, 1927
- The Forest Conservation Act, 1980
- The Wildlife Protection Act, 1972Legislations Relating to Liability
- The Public Liability Insurance Act, 1991Legislations Relating to Environmental Tribunals
- The National Environment Tribunal Act, 1995
- The National Environment Appellate Authority Act, 1997
- The National Green Tribunal Act, 2010Legislations Relating to Biodiversity
- The Biological Diversity Act, 2002Legislations Relating to Protection of Nature and Nature Based Livelihoods
- The Protection of Plant Varieties and Farmers' Rights Act, 2001
- The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006

Rights of Nature as the Foundation for Sustainable Development

Rights of Nature is a legal-politico notion that advocates legal standing for the Natural Environment. This notion argues that similar to other legal entities (such as companies, corporations, co-operatives, municipalities, natural persons, political parties, sovereigns states, institutions of religious affairs, institutions of state affairs, health and educational institutions, trade unions, and ships or vessels) nature and natural objects, such as an ecosystem, land, forests, marine/wild resources, biodiversity, are legal entities as well, and thereby, they are entitled to enjoy such legal rights and immunities as has been provided and guaranteed to the former. This right recognizes that nature in all its life forms does possess certain basic and minimum rights such as, right to exist, persist, maintain and regenerate its vital cycles.

The Global Alliance for the Rights of Nature defines Rights of Nature in the following words: Rights of Nature is the recognition and honoring that Nature has rights. It is the recognition that our ecosystems – including trees, oceans, animals, mountains–have rights just as human beings have rights. Rights of Nature is about balancing what is good for human beings against what is good for other species, what is good for the planet as a world. It is the holistic recognition that all life, all ecosystems on our planet are deeply intertwined. Rather than treating nature as property under the law, rights of nature acknowledges that nature in all its life forms has the right to exist, persist, maintain and regenerate its vital cycles.

This approach is a major break away from Traditional Environmental Regulatory System (TERS) in three broad ways. First, in TERS, nature is considered as a mere property, and hence, possessionship, ownership, use and management of this property is controlled and maintained through ordinary property rights legislations. In such a system, nature does not have any legal rights but its users have. The users make decision how to use, manage and control it as they do with other property. However, in the later form, nature becomes a legal entity and possesses all such legal rights as is held by other legal entities. Nature itself becomes the defendant. It can fight for its own rights whenever there is a condition of breach of its right due to encroachment by any other party. Second, the basic principle on which TERS stands is that nature is a mere servant or service provider to humanity and man is its master. It thus establishes a master-and-servant relationship between the two. Accordingly, it confers all rights on the master to use, manage and control the servant according to the master's impulse. Rights of Nature strongly discards this relationship. It postulates that man and nature are two separate and full-fledged legal entities interacting with each other for their respective benefits, interests and necessities. They are complementary to each other and nobody subdues the other. Here the relationship is rather symbiotic. And lastly, in TERS, adjudication of disputes is primarily conducted on the basis of property rights legislations. Rights of Nature refutes this notion and calls for adjudication based on individual rights.

Rights of Nature in Legal History

The Origin of Rights of Nature as an academic and intellectual legal-politico discourse can be traced back to the publication of the essay Should Tress have Standing?-Toward Legal Rights for Natural Objects in 1972. In this famous work, Christopher D. Stone, a Professor of Law, University of Southern California for the first time presented an argument for conferring legal personality and rights on nature and natural objects. In the essay, as Stone has explained, as a right-holder, nature or a natural object should have a legally recognised worth and dignity in its own right, and not merely to serve as a means to benefit us. The natural object, to achieve or get legal right-holder status, has to satisfy three basic criteria: First, the thing can institute legal actions at its behest; second, in determining the granting of legal relief, the court must take injury into account; and, third, relief must run to the benefit of it.

In 1989, another seminal work appeared in the American legal academia. Professor Roderick Frazier Nash published The Rights of Nature: A History of Environmental Ethics. Charting the history of philosophical and religious beliefs regarding nature, Nash, in the book, focused his attention primarily on changing attitudes toward nature in the American society. Drawing heavy influence from history, he explained how the right-less, such as slaves, women, others-have struggled to expand the domain of legal rights to include themselves. Nash's principal argument was that there had appeared an uncontrolled cult of anthropocentric and techno-centric notion of ecology protection which was running towards its doom. This attitude was not only dangerous, but logically and philosophically wrong also. Nash's study therefore concerned the attitude of the Americans towards the idea of wilderness. Nash stated that if wilderness would be to survive, management of the wilderness was necessary, i.e. human behaviour towards nature had to be controlled. Attributing anthropocentric attitude as the cause of all evils, Nash argued that an eco-centric view was an ideal notion to establish a natural relationship between man and nature.

In 2001, Thomas Berry, an American cultural historian and eco-theologian published The Origin, Differentiation and Role of Rights in which he described how all members of the earth community possess certain basic and intrinsic rights. Re-conceptualizing the concept of rights, Berry argued rights meant giving every being its due and no entity could abridge or encroach another's rights. Superiority of one living being over the other is essentially wrong and against the law of nature. There happens to be a symbiotic relationship between human beings and other living beings. Human rights are not superior to the rights of other living beings. Nor do human rights cancel out the rights of other modes of being to exist in their natural capacity. Wild Law: A Manifesto for Earth Justice (2003) by Cormac Cullinan a South African environmental attorney succeeded Berry's work and opened up a new front on rights of nature. Together Berry and Cullinan aided spiritual and moral elements to the discussions initiated by Stone and Nash. However, in the American legal academia, Christopher Stone is considered to be the founding father or the biological father of the concept of Rights of Nature as he was the first who provided and discussed such a concept candidly and vividly.

Rights of Nature in Practice

The Sierra Club is a landmark environmental law case in the Federal legal history which, for the first time, not only recognised legal standing for 'inanimate natural objects' to sue in courts, but also paved the way for future judicial standings. The suit arose when the United States Forest Service permitted development of Mineral King (a subalpine glacial valley) located in the southern part of the Sequoia National Park in the State of California. The key question in the case was whether the permitted development of Mineral King would cause sufficient injury to Sierra Club (the petitioner) or any of its member/members to give them standing to sue to put a ban on the permit. The Federal Supreme Court held that the Sierra Club, in its corporate capacity lacked standing to sue to block the permit.[1]

In the words of the Court:

A person has standing to seek judicial review under the Administrative Procedure Act only if he can show that he himself has suffered or will suffer injury, whether economic or otherwise. In this case, where petitioner asserted no individualized harm to itself of its members, it lacked standing to maintain the action.

As Sierra Club had failed to state in its complaint that any of its members had ever visited Mineral King although several members had used it for recreational purposes, and even owned property in nearby area, it lost the case. The Federal Supreme Court struck down the objection of the petitioner on three major grounds: First, the Petitioner could not establish a 'cause-and-effect' relationship with the defendant. The Court did not find any acts done by the defendant that would bring any injuries to the petitioner. Second, as the first relationship could not be established, there was also no 'petitioner-defendant' relationship. And thirdly it was due to third party concern. In the Case, Sierra Club was considered to be third party. The First Party being Rogers Clark Ballard Morton and the Second Party being the Mineral King. The First Party being a corporation held legal standing. The Second Party, i.e. Mineral King, being a mere natural object lacked legal standing. Thus the Third Party's objection on behalf of the Second Party could not stand valid. Therefore the Court in a 4:1 majority, including C.J. Burger, delivered its judgment in favour of Morton.[2]

However, what is worth noting in this case is the view of the dissenting jury. In his dissenting opinion in this landmark case, Justice William O. Douglas asserted that natural resources ought to have standing to sue for their own protection. In his words:

The critical question of "standing" would be simplified and also put neatly in focus if we fashioned a federal rule that allowed environmental issues to be litigated before federal agencies or federal courts in the name of the inanimate object about to be despoiled, defaced, or invaded by roads and bulldozers and where injury is the subject of public outrage. Contemporary public concern for protecting nature's ecological equilibrium should lead to the conferral of standing upon environmental objects to sue for their own preservation. This suit would therefore be more properly labelled as Mineral King v. Morton.

He continued:

Inanimate objects are sometimes parties in litigation. A ship has a legal personality, a fiction found useful for maritime purpose. The corporation sole-a creature of ecclesiastical law-is an acceptable adversary and large fortunes ride on its cases.....So it should be as respects valleys, alpine meadows, rivers, lakes estuaries, beaches, ridges, groves of tress, swampland, or even air that feels the destructive pressures of modern technology and modern life. The river, for example, is the living symbol of all life it sustains or nourishes-fish, aquatic insects, water ouzels, otter, fisher, deer, elk, bear, and all other animals, including man, who are dependent on it or who enjoy it for its sight, its sound, or its life. The river as plaintiff speaks for the ecological unit of life that is part of it.

Although Sierra Club lost the case, practically, there was a moral victory. The dissenting jury's views based on the moral idea of conferring legal standing on Natural Objects not only actively challenged an established doctrine in the domain of TERS, but also opened ways for future judicial decisions. This was probably the first instance in the history of Federal Environmental Law in which a jury walked out of convention and did attempt to elaborate his justifications, not on the basis of text, history or precedent, but on the basis of ethical and philosophical insights. Albeit, no legislations were passed either at the State or at the Federal level regarding providing legal standing to nature or natural objects since the pronouncement of this decision[3], nevertheless, in later environmental cases, many State Supreme Courts and the Federal Supreme Court have followed the Sierra Club as a strong precedent in their respective judicial decisions.

Rights of Nature: Legal Operational Aspects

The fact is that each time there is a movement to confer rights onto some new entity, the proposal is bound to sound odd or frightening or laughable. This is partly because until the Rightless thing receives its rights, we cannot see it as anything but a 'thing' for the use of 'us'- those who are holding rights at the Time.[4] This is also because there is a phobia of loss or encroachment of existing rights of the present right holders. The present right holders will tend to resist the new proposal as they may see conferring new rights on the new entity might encroach or abridge the rights, liberty and interests that they have been enjoyed for a long time. Furthermore, if the degree of rights conferred on the new entity supersedes or exceeds that of the present right holders, the situation is going to be volatile and provocative notwithstanding the fact that there exists a noble objective of greater human interest behind the conferring of such rights on the new entity. This is due to the fact that man, as Thomas Hobbes has aptly observed, is an altogether 'selfish' and 'self-seeking' animal. His inclination towards his own self-interest remains all time high throughout history. Napoleon Bonaparte was not inaccurate when he said that a man would fight harder for his interests than for his rights.

It has long been observed in the history of human civilization that whenever there emerges a new doctrine or idea, simultaneously there also appears resistance to such a thing. Man hesitates to accept a new thing all of a sudden. Probably this is a tendency of human nature or probably the cobwebs of old ideas hold so strong in man's mind that he cannot simply accept new ideas.

Rights of Nature as a new concept is no exception to it. Contemporary objections and criticisms to Rights of Nature fall under the following heads:

• **Rights of Nature runs counter to the principle of Sustainable Development.**

The truth is however the opposite. Conferring legal standing on nature and natural objects would foster sustainable development, at least in five ways: (1) nature and natural objects with legal standing can fight for their own existence, survival and protection form second party encroachment. Courts will have to consider nature and natural objects as party to judicial decisions, and thus, they can maintain their own sustainability (2) those who depend on nature and ecosystem services[5] for their livelihoods can approach the court whenever there occurs a possibility of loss of their livelihoods due to anthropogenic interference in nature, (3) developing a legal framework for undertaking development has caused considerable debates especially in the developing nations. In such cases, the principle of Rights of Nature can be used as a foundation stone on which development framework can be built, (4) Rights of Nature does not mean we cannot cut a tree or we cannot use nature and natural resources in toto. Rather, it is a legal constraint on reckless and unbridled encroachment in nature. It will function as a measuring-rod which will measure the gravity of danger on the one hand and the degree of necessity on the other. Unlike traditional environmental economics which studies environment and environmental policies only in terms of profit and loss, this principle would take into account the sociocultural value systems in environmental policy goals and (5) the principle of Rights of Nature is more democratic, people-centric, participatory and egalitarian in nature than any other environmental policies, and these characteristics are potential solutions to conflicting claims arising in environmental policy domain.

• **Rights of Nature is an additional layer of regulation. It overlaps current legal system.**

Firstly, Rights of Nature is not a regulation concept. It is a prevention concept. Today, legal systems around the world and in India in particular, treat nature as a mere property to be used by man and thus making it right-less. Treated as property, environmental laws only regulate the use of this property, and one way or another, legalise environmental harm. Under this system, ecosystems and species are facing extinction. So is the condition of those who depend on nature, for their livelihoods. On the other hand, laws recognising the rights of nature empower people, communities and individuals to reject governmental actions and State activities that permit destructive development to transpire by enabling people to assert the rights of those ecosystems that would otherwise be destroyed. Secondly, Rights of Nature as a legal concept is not going to overlap the present environmental legal system. The present system is based on a regulatory framework having no legal rights for nature and natural objects. Rights of Nature on the other develops a preventive & protective framework-a totally different model from the former. The concept will not overlap the former. Rather, it might sort out the problems and complications arising out of the former and call for greater opportunities for environment protection.

• **There would be conflicts between Rights of Nature and Human Rights.**

Where there are multiplicities of ides there will be conflicts. Conflicts are not fighting or warfare but are only differences of ideas, of opinions, of interests. Conflicts are not wasteful outbreak of incompatibilities but are normal processes by which differences in ideas, opinions, and interests register themselves for the enrichment of all concerned. Conflict resolution process should be constructive and not destructive as advocated by Mary Parker Follet the great American management thinker. Follet identifies three ways of resolving conflict: domination, compromise and integration. Domination is a victory of one party over the other by hook or by crook, i.e. through 'violence' to use the exact terminology. This is the easiest way of resolving conflict. It has but its own disadvantages. Firstly, victory achieved through violence or domination is temporary in nature; secondly, it might be adversely counterproductive and rebelling in nature. Compromise is generally the way people settle their disputes. However, in compromise, each side has to lose or give up something to settle the conflict so that the activity which has been interrupted by conflict can go on. Although compromise is a widely accepted method of conflict resolution, people rarely resort to this method as this involves giving up something. Integration is the third method of conflict resolution. Here two desires are integrated and a separate solution is devised. Neither side needs to sacrifice its desires. In this process a new synthesis is developed from the thesis and the anti-thesis by integrating the two.[6] In a civilised society integration is predominantly followed as the ideal model of conflict resolution in every sphere of life. Same would be the case when there would be conflict between rights of nature and human rights. The same resolution process would be followed when different human rights conflict or when the Fundamental Rights and DPSPs conflict or when conflicts would rise between Rights of Nature and Human Rights. A court would weigh the harms to the interests, and then decide how to make a balance. Each entity would get its own rights, interests and benefits and no one could encroach or abridge the other. There will be a 'win-win' game. Nobody has to lose.

Rights of Nature: From Sierra Club to South America

With a population of roughly 420 million and an area of nearly 7 million square miles, South America is home to 12 Sovereign States and 3 dependent territories. Demographically and socioculturally the region is one of the most diverse territories of the world. Indigenous tribal groups constitute a major portion of its population. The population of the region displays a wide variety of as many as 600 indigenous peoples. According to World Bank figures, approximately 13% of the entire South American population and approximately 40% of rural population is indigenous. There are still some un-contacted tribes residing in the Great Amazonian Rainforest. The biodiversity and environment of the region comprises different ecosystems, forests, plains, valleys, flora and fauna, and a variety of animals and is one of the richest and most bio-diverse regions on planet earth. According to the Millennium Ecosystem Assessment Reports, South American ecosystems are the richest ecosystems on this earth and they provide largest ecosystem services both in terms of magnitude and quality. Out of the total indigenous groups in the region, more than 400 groups are directly or indirectly dependent on the ecosystem services for their daily lives and livelihoods.[7]

On the contrary, the neoliberal development models in lines with the Washington Consensus did not bring much prosperity in the region especially for the indigenous populations who constitute about 40% of the continent's population. The region's economy based on exportation of the continent's raw materials, principally oil, was also causing irreversible damages to the region's environment and ecosystems. Further the global economic crisis of 2008 revealed the vulnerabilities of an extractive and export-oriented economy, and led to a period of economic instability and political turmoil in the region. The situation obviously called for a new more inclusive government and a development model based on post-oil, post-neoliberal and human-centred principles. In 2002, the election of Hugo Chavez in Venezuela, in late 2006, the election of Rafael Correa to Ecuador and Evo Morales to Bolivia showed the emergence of a new political era in the region, based on the principles of democratic socialism that emphasized more on fundamental necessities than fundamental rights, particularly, the necessities of the indigenous, tribal and backward groups of the region.

Presidential candidate Rafael Correa of Ecuador first proposed calling for a Constitutional Assembly in his 2006 election campaign. On the 15th of April 2007, more than 80% Ecuadorians voted for a new Constitutional Assembly. The primary objective of the Assembly was to create a (new) Constitution based on indigenous and traditional Andean principles of Buen Vivir[8]. The Assembly with the advice of the Pachamama Alliance[9] enlisted the help of the Community Environmental Legal Defence Fund to draft languages for the new provisions of the Constitution detailing Rights of Nature. On the 10th of April 2009, with 91 votes out of 130, the Constitutional Assembly approved and adopted Article 10 (Recognition of Rights of Nature as Constitutional Rights) for inclusion in the new Constitution. On the 7th of June 2009, Articles 71 to 74 were included in the Constitution compiling Rights of Nature. With this enactment, Ecuador became the first and the only nation on planet earth to identify and provide legal-constitutional standing for nature and natural objects.[10]

Rights of Nature: From South America to India

According to estimates of the National Commission for Enterprises in the Unorganised Sector (NCEUS), roughly 93% of the total working population of India are absorbed in the unorganised sector (informal economy). Keeping this figure as 100%, it has been calculated that more than 82% are employed in the rural informal sector. And it is a well-known fact that barring primary agricultural and allied activities, the entire rural economy of India depends on nature, natural resources, and ecosystem services. On the contrary, noted Human Development scholars such as Amartya Sen, Jean Dreze, Kaushik Basu, Prashant Patnaik, Pravat Patnaik and Mahbub-ul-Haq claim that despite its immense economic growth since the adoption of the New Economic Policy in 1991, India's development paradigm has currently failed to address the core issues of poverty, vulnerability, livelihood security, and environment protection on the one hand, and has aggravated environmental conflicts over competing claims on natural resources primarily between two sharp opposite groups, viz. the peasantry and the industry, between the market and the citizens, and between the government and the people. Development process in India has caused much socio-political tensions, and the poor, the tribal people, and the vulnerable groups have been victims of development who should be the primary target groups of development. Land acquisition, displacement, loss of tribal livelihoods, large scale migration, increased labour Informalization and environment degradation are some of the core issues that the present model of development has resulted in. Keeping this picture in view, it would be wise and advisable to prescribe Rights of Nature as the legal foundation for economic development and environment protection in the Indian Environment Jurisprudence. Building a movement towards incorporating Rights of Nature in the Indian Environmental Jurisprudence is quite feasible. We can unify around what we are for-a future where nature would have legal rights to exist, flourish, and regenerate its natural capacities and where there prevails justice for impacted communities and crimes against nature would be dealt with strictly.

Conclusion

The last four or five decades have been the longest and the darkest part of India's so-called Environmental Movement Politics. How does one weigh Human Life? How does one weigh development? One billion men against the policy of development and in the middle poverty that we have ignored, abandoned or marginalized…..a devastating menace to the Indian society……. and that the Indians have paid for that neglect in blood…….is equally real and equally tragic. We are at war with poverty, vulnerability and insecurity. And fighting a war means casualties. No matter the war is a battlefield war or a war in the societal field, there will be causalities. At the battlefield, when we fight with our enemy, we have to lose our forces as much as our enemy regardless of we win the war or lose. Similarly, when we fight poverty in the society with the weapon of economic development, we have to sacrifice rather. We have to lose rather. This is the dilemma but this is the truth. Eliminating the catch-22 situation should be the primary objective of every development policy. Albeit India has adopted the sustainability notion as one of her core development policies, however, the country has not been able to develop an appropriate legal framework for the same. Providing legal rights to nature and natural objects in India may not be a magic spell or a radical panacea which would cure all evils all of a sudden, it would however, prepare a road map or foundation for environment protection & sustainable development.

Bibliography

Alier, Martinez (2002). The Environmentalism of the Poor. Cheltenham: Edward Elgar.

Bailey, George (1960). Tribe, Caste and Nation: A Study of Political Activity and Political Change in Highland Orissa. Manchester: Manchester University Press.

Bandyopadhyay, Sekhar (2009). From Plassey to Partition. New Delhi: Orient Black Swan.

Basham, Arthur Llewellyn (2004). The Wonder that was India. New Delhi: Picador.

Bipan Chandra (2004). The Rise and Growth of Economic Nationalism in India. Anamika Publisher: New Delhi.

Boesche, Roger (2002). The First Great Political Realist: Kautilya and his Arthashastra. Maryland: Lexington Books.

Chacko, Pariyaram (ed.) (2005). Tribal Communities and Social Change. New Delhi: Sage Publications.

Chakrabarti, Anjan and Stephen Cullenberg (2003). Transition and Development in India. New York: Routledge.

Chang, Ha-Joon (2011). 23 Things They Don't Tell You About Capitalism. New Delhi: Penguin.

Cullinan, Cormac (2003). Wild Law: A Manifesto for Earth Justice. Dartington: Green Books.

Datt, Ruddar and K.P.M Sundharam (2005). Indian Economy. New Delhi: Sultan & Chand.

Debroy, Bibek and P.D. Kaushik (eds.) (2005). Reforming the Labour Market. New Delhi: Academic Foundation.

Dror, Yehezkel. (1971). Venture in Policy Sciences: Concepts and Applications. New York: American Elsevier Publishing Company.

Dube, Indrajit (2007). Environmental Jurisprudence-Polluter's Liability. New Delhi: Lexis Nexis

Follet, Mary Parker (1924). Creative Experience. London: Longmans Green.

Gadgil, Madhav and Ramchandra Guha (1995). Ecology and Equity: The Use and Abuse of Nature in Contemporary India. New Delhi: Routledge

Ghurye, G.S. (1980). The Scheduled Tribes of India. New Jersey: Transaction Publishers.

Giri, Viswajit (2013). Reinventing the Concept of Social Security for Workers Employed in the Traditional Industries in the Ecologically Fragile Regions: A Case Study of the Sabai Grass Workers of Mayurbhanj District of Orissa. PhD Thesis Submitted to Jawaharlal Nehru University, New Delhi. Unpublished.

Gupta, Meenakshi (2007). Labour Welfare and Social Security in Unorganised Sector. New Delhi: Deep & Deep Publications

Haq, Mahbub-Ul (1976). The Poverty Curtain: Choices for the Third World. Columbia: Columbia University Press

Haq, Mahbub-Ul (1996). Reflections on Human Development. Oxford: Oxford University Press

Hardin, Garret James (1993). Living Within Limits: Ecology, Economics and Population Taboos. Oxford: Oxford University Press

Heyes, Anthony (2001). The Law and Economics of the Environment. Northampton: Edward Elgar Publishing.

Hunter, W.W. (1877). A Statistical Account of Bengal. London: Trubern and Co.

Karmakar, K.G. (2002). The Silenced Drums: A Review of Tribal Economic Development. New Delhi: Northern Book Centre.

Kaufman, B.E. (2004). The Global Evolution of Industrial Relations. New Delhi: Academic Foundation.

Kolstad, Charles D. (2012). Environmental Economics. New Delhi: Oxford University Press.

Kumar, S. and M. Sarngadharan. (ed.) (2007). Traditional Industries of India in the Globalized World. New Delhi: New Century Publications.

Kundu, Amitabh and Alakh Sharma (ed.) (2001). Informal Sector in India: Perspectives and Policies. New Delhi: Institute for Human Development.

Lane, Jan-Erick (2005). Public Administration and Public Management: The Principal Agent Perspective. New Delhi: Rutledge.

Laski, Harold Joseph (2010). A Grammar of Politics. New Delhi: Anamika Publishers and Distributors.

Leelakrishnan, P. (1999). Environmental Law in India. New Delhi: Butterworths.

Mazumdar, D.N. and T.N. Madan (1980). An Introduction to Social Anthropology. New Delhi: Mayur Paperbacks.

Mishra, Baidyanath (et al) (ed.) (20002). Agro Industries and Economic Development: A Vision for the 21st Century. New Delhi: Deep & Deep Publications.

Nash, Roderick Frazier (1989). The Rights of Nature: A History of Environmental Ethics. Wisconsin: University of Wisconsin Press.

Nassem, Mohammed (2011). Environmental Law in India. London: Kluwer Law International

Osborne, David and Ted Gabbler (1993). Reinventing Government: How the Entrepreneurial Spirit is Transforming the Public Sector. New York: Plume.

Panda, N.K. (2006). Policies, Programmes and Strategies for Tribal Development. New Delhi: Kalpaz Publications.

Pandey, J.N (2003). The Constitutional Law of India. Allahabad: Central Law Agency.

Patnaik, Nihar Ranjan (ed.) (1997). Economic History of Orissa. New Delhi: Indus Publishing Company.

Paty, Chittaranjan Kumar (ed.) (2007). Forest Government and Tribe. New Delhi: Concept Publishing Company.

Penner, J.E. (1997). The Idea of Property in Law. Oxford: Clarendon Press.

Pierre, John and B. Guy Peters (2000). Governance, Politics and the State. New York: St. Martin's Press.

Prasad, Archana (2004), Environmentalism and the Left: Contemporary Debates and Future Agendas in the Tribal Areas. New Delhi: Left Word.

Prasad, D. Ravindra (et al.) (ed.) (2007). Administrative Thinkers. New Delhi: Sterling Publishers Private Limited.

Rajgopalan, S. and Meenu Bhaatnagar (ed.) (2008). Social Security for the Unorganized Sector. Hyderabad: Icfai University Press.

Rangarajan, L.N (ed.) (1992). Kautilya: The Arthashastra. New Delhi: Penguin Books.

Rangrajan, Mahesh (ed.) (2007). Environmental Issues in India. New Delhi: Pearson.

Rawls, John (1971). A Theory of Justice. Boston: Belknap.

Ray, Binayak (1999). India: Sustainable Development and Good Governance. Delhi: Atlantic Publishers and Distributors.

Riggs, F.W. (1961). The Ecology of Public Administration. Bombay: Asia Publishing House.

Riggs, F.W. and A.D. Barnett (ed.) (1970). Frontiers of Development Administration. Dueham: Duke University Press.

Risley, H.H (1892). The Tribes and Castes of Bengal. Calcutta: The Bengal Secretariat Press.

Roberts, Jane (2004). Environmental Policy. London: Routledge.

Rout, Shyama Prasad, (1999). Land Alienation and Tribal People's Rights: a Case Study of Mayurbhanj District in Orissa. PhD Research Proposal submitted to Jawaharlal Nehru University, New Delhi. Unpublished.

Roy, Tirthankar (1999. Traditional Industry in the Economy of Colonial India. Canbridge: Cambridge University Press.

Russell, Bertrand (1917). Political Ideals. Liverpool: C. Tinling & Co. Limited.

Sen, Amartya (1997). On Economic Inequality. Oxford: Oxford University Press.

Sen, Amartya (2000). Development as Freedom. New York: Anchor Publisher.

Sen, Amartya (2009). The Idea of Justice. Boston: Harvard University Press.

Sen, Amartya (2011). Peace and Democratic Society. Cambridge: Open Book Publisher.

Singh, Amita (ed.) (2001). Administrative Reforms. New Delhi: Oxford.

Singh, Katar and Vishwa Ballabh (eds.) (1996). Cooperative Management of Natural Resources. New Delhi: Sage Publications.

Singh, M.P. (2008). Constitution of India. Lucknow: Eastern Book Company.

Trautmann, Thomas R. (2012). Arthashastra: The Science of Wealth. New Delhi: Penguin Books India Private Limited

Vayunandan, E. and Dolly Mathew (eds.) (2003). Good Governance: Initiatives in India. New Delhi: Prentice Hall of India.

Vijayarani, K.R. (2011). Small Scale Industries in India: Problems and Policy Initiatives. New Delhi: New Century Publications.

Weaver, Samuel Pool (1946). Constitutional Law and its Administration. Chicago: Callaghan and Company.

Articles

Ahmed, Farooq (et al) (2010), "Ethnomedicinal Uses of Grasses in Salt Region of Northern Pakistan". Journal of Medicinal Plant Research. Vol. 4(5), March

Ambec, Stefan (et al) (2011), "The Porter Hypothesis at 20". Resources for the Future Working Discussion Paper. No. 202-328-5000.

Ambec, Stefan and Philippe Barla (2002), "A Theoretical Foundation of the Porter Hypothesis". Economic Letters. Vol. 75

Bandyopadhyay, Jayanta and Tapas Roy (2012), "Political Challenge of an Intensifying Conflict over Land". Economic and Political Weekly. Vol. XLVIIM, No. 7

Basu, Manisha (et al) (2006), "Exploiting Fly Ash as Soil Ameliorant to Improve Productivity of Sabai Grass (Eulaliopsis binata (Retz.) C.E. Hubb) under Acid Lateritic Soil in India". Asian Journal of Plant Sciences. Vol. 5, Issue 6

Basu, Manisha (et al) (2006), "Growth and Yield of Sabai Grass (Eulaliopsis binata) Under Two Cropping Patterns with Horticultural Crops in Lateritic Follow Lands of India". Agro Thesis. Vol. 4, No. 1

Basu, Manisha (et al) (2006), "Performance of Sabai Grass (Eulaliopsis binata (Retz.) C.E. Hubb) under different Levels of Organic and Inorganic Fertilizers in Acid Soil". The American- Eurasian Journal of Agricultural and Environmental Science. IDOSI Publications: Cairo. Vol. 01, No. 02

Basu, Manisha (et al) (2007), "Effect of Cutting Management on Growth and Yield of Sabai Grass (Eulaliopsis binata): Intercropped with Horticultural Plants under Acid Lateritic Soils if India". Journal of Plant Sciences. Vol. 2, No. 1

Boyce, Bret (2007), "Property as a Natural Right and as a Conventional Right in Constitutional Law". Loyola of Los Angeles International and Comparative Law Review. Vol. 29

Chang, Ha-Joon (1998), "The Role of Institutions in Asian Development". Asian Development Review. Vol. 6, No. 2

Chang, Ha-Joon (2007), "Rethinking Public Policy in Agriculture: Lessons from History, Distant and Recent". Journal of Peasant Studies. Vol. 36

Chang, Ha-Joon (2011), "Reply to the Comments on Institutions and Economic Development: Theory, Policy and History". Journal of Institutional Economics.

Cotter, Bridget (2010), "Property as a Human Need: A Moral Basis for Private Property Ownership in the Work of Hannah Arendt and Simone Weil". Paper Presented to the Political Studies Association Annual Conference, University of Westminster.

Crowe, Beryl. L (1969), "The Tragedy of the Commons Revisited". Science. Vol. 166, No. 1969

Damu, T (2003), "Helping 'Ecosystem People' Protect Wilderness and Their Own Welfare". USDA Forest Service Proceedings. RMRS-P-27

Datt, Radar (2003), "National Commission on Labour and Review of Labour Laws". The Indian Journal of Labour Economics. Vol.46, No.1

Ghos, S, K. Sarkar and S. Bhowmik (2004), "Collective Bargaining in Tea Plantation in West Bengal". The Indian Journal of Labour Economics. Vol. 47, No. 4

Ghos, Santanu, Mohan Kumar Gupta and Atanu Karmakar (2007), “Conditions of Work and Status of Social Security: The Case of Workers in Display Board Works”. The Indian Journal of Labour Economics. Vol.50, No.4

Giri, D.V and P.C. Das (2007), “Plight of Beedi Workers and the Blame Game in Orissa”. The Indian Journal of Labour Economics. Vol.50, No.4

Giri, Viswajit (2008), “Women in the Unorganised Sector: Case Studies in Cuttack and Bhubaneswar”. M.Phil Dissertation Submitted to Jawaharlal Nehru University. Unpublished.

Giri, Viswajit (2013), “Reinventing the Concept of Social Security for Workers Employed in the Traditional Industries in the Ecologically Fragile Regions: A Case Study of the Sabai Grass Workers of Mayurbhanj District of Orissa”. PhD Thesis Submitted to Jawaharlal Nehru University. Unpublished.

Hardin, Garret James (1968), “The Tragedy of the Commons”. Science. Vol. 162, No. 3859

Hathy, Priti Ranjan (et al) (2010), “Marketing of Sabai Grass in Socio-Economic Development of Tribals in Mayurbhanj District, Orissa (India)”. International Journal of Business and Management, Vol. 5, No. 2, February

Jia-Ling, Yao (et al) (2004), “Embryological Evidence of Apomixis in Eulaliopsis binata”. Acta Botanica Sinica. Vol. 46, No. 1

Kabra, K.N. (2003), “The Unorganized Sector in India: Some Issues Bearing on the Search for Alternatives”. Social Scientist. Vol. 31, No. 11-12, Nov-Dec.

Kar, Jyotirmayee (2008), “Improving Economic Position of Women through Microfinance: Case of a Backward Area, Mayurbhanj-Orissa, India”. Indus Journal of Management and Social Sciences. Vol. 2, No. 1. Spring.

Kooros, Syrous. K. and Laura M. Badeaux (2007), “Economic Development Planning Models: A Comparative Assessment”. International Research Journal of Finance and Economics. Issue 7

Kriechel, Ben and Thomas Ziesemer (2003), “The Environmental Porter Hypothesis as a Technology Adoption Problem”. Maastricht Economic Research Institute on Innovation and Technology Working Paper Series. No. 2003-010.

Kumar, Namita (2004), “Unorganized Trading Sector in India: Employment and Productivity”. The Indian Journal of Labour Economics. Vol.47, No.4

Kumar, Sanjay and N.K. Sharma (2003), “Informal Sector: An Indian Perspective”. The Indian Journal of Labour Economics. Vol.46, No.1

Madhavi, P. (2006), “Organizing the Invisible and the Informal: A Case Study of Unions in the Beedi Industry in Telengana Region of Andhra Pradesh”. The Indian Journal of Labour Economics. Vol. 49, No. 4

Manandhar, Narvan. P. (1998), “Ethnobotanical Census on Herbal Medicine of Banke District, Nepal”. Contributions to Nepalese Studies. Vol. 25, No. 1, January

Maslow, Abraham (1943). “A Theory of Human Motivation”. Psychological Review. Vol. 50

Mathur, A. and R.P. Mamgain (2002), “Technical Skills, Education and Economic Development in India”. The Indian Journal of Labour Economics. Vol. 45, No.4

Mehta, P.S. (2002), “The Indian Mining Sector: Effects on the Environment and FDI Inflows”. Draft paper presented in the ‘Conference on Foreign Direct Investment and the Environment: Lessons to be Learnt from the Mining Sector’, 7-8. February.

Metcalf, T.R. (1994), “Ideologies of the Raj” in “The New Cambridge History of India”, Vol.3.4, Cambridge University Press: Cambridge.

Mohapatra , Anand Shankar (et al) (2012), “Accessibility of Credit Facilities to the Tribal Entrepreneurs of Mayurbhanj District in Orissa, India”. International Journal of Research of Research in Management, Vol. 1, Issue 2

Mohapatra , Anand Shankar (et al) (2012), “Constraints Faced by Tribal Entrepreneurs in Dairy Farming Enterprise”. International Journal of Physical and Social Sciences, Vol. 2, Issue 7

Mohapatra, Anand Shankar and Upendra Nath Shu (2012), “A Study of Socio-Economic and Entrepreneurial Characteristics of Tribals of Mayurbhanj District in Sabai Grass Enterprise”. International Journal of Management, IT and Engineering, Vol. 2, Issue 5

Mohr, Robert, D (2002), “Technical Change, External Economics, and the Porter Hypothesis”. Journal of Environmental Economics and Management. Vol. 43

O’Riordan. T (1990), “Major Projects and the Environment”, Geographical Journal.156 (2)

Ostrom, Elinor (1999), “Revisiting the Commons: Local Lessons, Global Challenges”. Science. Vol. 248. 9 April.

Pande, P.C. (et al) (2007), “Ethnoveterinary Plant of Uttaranchal-A Review”. Indian Journal of Traditional Knowledge. Vol. 6, No. 3, July

Papola, T.S. (2007). “Debate on Labour Market Reforms in India: A Case of Misplaced Focus”. The Indian Journal of Labour Economics. Vol.50, No.2

Pattanaik, Sarmistha (2006), “Commercialization of Shrimp Trade, Environment and Rural Poverty: A Socio-Ecological Exploration in Costal Orissa”. Institute of Economic Growth Working Paper Series. No. E/274/2006

Porter, Michael and Claas van der Linde (1995), “Green and Competitive: Ending the Stalemate”. Harvard Business Review.

Porter, Michael and Claas van der Linde (1995), “Toward a New Conception of the Environment-Competitiveness Relationship”. Journal of Economic Perspectives. Vol. 9,No. 4, Fall.

Roy, Rabindra (2005), “Environmental Audit of Quarry: Issues of Forest Resource”. The Nepal Journal of Forestry. Vol. XII, No. 3

Roychoudhury, Supriya (2005), “Labour Activism and Women in the Unorganized Sector” Economic and Political Weekly. Vol. XL No. 23-24 May, 28-June 4

Roychoudhury, Supriya (2007), “Informality in Globalized Forms of Production” The Indian Journal of Labour Economics. Vol.50, No.4

Sahoo, Laxman Kumar (2001). “Socio-Economic Profile of Tribal Populations in Mayurbhanj and Keonjhar Districts”. Orissa Review, May

Sahu, S.C. (et al) (2010), “Ethnobotany of Eulaliopsis binata (Retz.) Hubbard-Poacea, in Odisha, Eastern India: Cultivation, Practice, Economics and Prospects”. Journal of Advances in Developmental Research, Vol. 1, No. 2, December

Saini, D.S (2007). “Securing Working Class Rights for Informal Sector Workers in India: A Case Study of Self Employed Women’s Association”. The Indian Journal of Labour Economics. Vol.50, No.4

Sarvanan, Velayutham (2003), “Colonial Commercial Forest Policy and Tribal Private Forests in Madras Presidency: 1792-1881”. Indian Economic and Social History Review. Vol. 40, No. 4

Satpathy, Asit Ranjan (2011), “Poverty and Socio Economic Development of Tribal’s Communities in Mayurbhanj District of Odisha”. The Journal of Krishna Research and Educational Consortium, Vol. 1, Issue 3

Sengupta, Arjun, K.P. Kannan and Ravi Srivastav (2007), “Growth Pole: A Case for Special Economic Zone for Clusters of Small and Macro Enterprises”. The Indian Journal of Labour Economics. Vol.50, No.2

Sharma, R.K. and Vinoj Abraham (2004), “Labour Productivity in the Indian Unorganized Service Sector: Measurement Issues, Patterns and Determinants”. The Indian Journal of Labour Economics. Vol.47, No.4

Shyamsundar, K.R (2007), “Contract Workers: The Need for Community of Interest Perspective”. The Indian Journal of Labour Economics. Vol.50, No.4

Siddiqui, K.M. (et al) (1999), “Forest Ecosystem Climate Change Impact Assessment and Adaptation Strategies for Pakistan”. Climate Research. Vol. 12, August

Singh, Jaivir (2004), “(Un) Constituting Property: The Deconstruction of Right to Property in India”. CSLG Working Paper Series. CSLG/WP/04-05

Somayaji, Sakarama (2008), “Man-Made Disasters: Displacement, Resettlement and Rehabilitation in Orissa-Reflections from the field”, in Social Change. Vol. 38, No. 04. December.

Stone, Christopher, D. (1972) “Should Trees have Standing? -Toward Legal Rights for Natural Objects”. Southern California Law Review, Vol. 45, Pp. 450-501

Sundar, Shyam (2007a), “Trade Unions and Civil Society: Issues and Strategies”. The Indian Journal of Industrial Relations. Vol. 42, No. 4

Suryanrayanan, S.S (1998), “Information Base for the Informal Sector”. The Indian Journal of Labour Economics. Vol.41, No.3

Thakur, C.P. and C.S. Venkatrata Ratnam, (2007), “Conditions of Work in the Unorganized Sector in India”. The Indian Journal of Labour Economics. Vol.50, No.4

Tripathy, B.K. (et al.) (2013), “Effect of Crusher Dust on Floristic Composition and Biological Spectrum in Tropical Grassland of Odisha, India”. Journal of Ecology and the Natural Environment. Vol. 5(6).

Turner, Graham (2008), “A Comparison of the Limits to Growth with Thirty Years of Reality”.

Unni, Jeemol and Ming Lu (2007), “Informal Development in India and China”. The Indian Journal of Labour Economics. Vol.50, No.3

Uprety, Yadav (et al) (2011), “Plant Biodiversity and Ethnobotany inside the Projected Impact Area of the Upper Seti Hydropower Project, Western Nepal”. Environment, Development and Sustainability. Vol. 13

Verma, Anil and Morley Gunderson, (2001), “Laboring for Advantage: Worker Stakes in a Globalizing Economy”. The Indian Journal of Labour Economics. Vol.44, No.3

Wagner, Marcus (2003), “The Porter Hypothesis Revisited: A Literature Review of Theoretical Models and Empirical Tests”. Paper Presented at the Centre for Sustainability Management, University of Luneburg.

Wilson, Woodrow (1887), “The Study of Administration”. Political Science Quarterly. Vol. 2, No. 2, June.

Xepapadeas, Anastasios and Aart de Zeeuw (1999), “Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital”. Journal of Environmental Economics and Management. Vol. 37

(Footnotes)

1. For more details, see, Sierra Club v. Morton, 405, U.S. 727 (1972)
2. Although J. Brennan and J. Blackmun dissented from the majority, however, they did not take part in the consideration or decision of the Case. J. William O. Douglas was the sole judge who candidly dissented from the majority and delivered his own dissenting views.
3. It is only in 2006 when Tamaqua Borough of Schuylkill County in the Commonwealth of Pennsylvania became the first community in the USA to recognise Rights of Nature as legally enforceable in courts. Since, more than 35 communities in Pennsylvania have followed law suits recognising legal Rights of Nature. The city of Pittsburgh in Allegheny County in Pennsylvania with a population of roughly 350,000 has also given legal recognition to such rights.
4. Stone, Christopher, D. (1972) “Should Trees have Standing? -Toward Legal Rights for Natural Objects”. Southern California Law Review, Vol. 45, P.455
5. For more details about Ecosystem & Ecosystem Services, see Appendix 1.
6. For more details about Conflict Management Theory (Constructive Conflict), see the two renowned works of Marry Parker Follet: Creative Experience (1924) and Dynamic Administration (1940).
7. For more details, see the Millennium Ecosystem Assessment Reports of the UNEP.
8. Details about Buen Vivir have been given in Appendix 2.
9. Details about Pachamama have been given in Appendix 4.
10. Details about Rights of Nature in the Ecuadorian Constitution have been given in Appendix 3.
11. http://www.gwclim.org/presentations/plenary/kundzewicz.pdf.
12. Monitoring data on Himalayan glaciers present a confusing picture. They indicate recession of some glaciers in recent years, but the trend is not consistent across the entire mountain chain (Singh and Arora 2007).

Impact of Climate Change on Arid Agro-ecosystem in Western Rajasthan: Review and Observations

Balak Ram and J.S.Chauhan

Introduction

Climate is a natural phenomenon. It keeps changing since the origin of universe. It was the development of favourable climatic conditions that early man took a sedentary life and origin of agriculture taken place. Climate is one of the greatest challenges of 21st century. The impact of any change in climate may have negative as well as positive (short term and long term) impact on environment, natural resources, animate & inanimate life and worldwide activities. The impact can also be direct or indirect as well as local or regional. It is mankind who can modify and manage the impact of such changes as per his present and future needs. Increase in temperatures and wind regime can lead to drought and soil erosion and lead to degradation of water, vegetation and agricultural resources and adverse affect on human and animal life. Excess and abrupt of rainfall may cause flood, water erosion and damage to infrastructures and loss to agricultural crops as well as human and livestock population. Hot arid region is a fragile ecosystem and can be affected with any climate change. The neglectful and exploitive use of natural resources has set the train of global climate change in motion. It is anticipated that the impact of climate change will cut across all boundaries. Crops, cropping systems, crop rotations and biota will undergo transformation. To maintain the balance in the system, there is a need for new knowledge, alternative policies and institutional changes. The marginalized people in dry areas are likely to be most seriously hit by the shifts in moisture and temperature regimes as a result of the global climate change. To help them and cope with the challenges, there is a need to how the impact and risks related to climate change can be reduced and managed and for that a new paradigm in agricultural research and technology transfer that makes full use of modern science and technology in conjunction with traditional knowledge is need of the time. This necessitates more investment by international agencies and national governments for supporting the relevant integrated research and sustainable development efforts, with full participation of the target communities. With this scenario an attempt has been made to review the climatic upheaval taken place in arid western Rajasthan. Long term climatic data from 1901 to 2015 are analyzed to assess short term and long term trend and find out their impacts at local, district and regional level. Frequency and intensity of droughts from thirteenth century to 2009 is studied to assess the impact. Major droughts, flood and dust storms occurred in western Rajasthan and their impact are discussed. Adaptation strategies and measures are suggested to manage such natural hazards and minimize their adverse impact.

Location And Environment

Hot arid zone in India occupy about 31.7 m ha areas of which 61.9% is concentrated in 12 western districts of Rajasthan with a total geographical area of 208,751 km^2. The region extends from 24° 37¢ 00^2 to 30° 10¢ 48^2 north latitudes and between 69° 29¢ 00^2 to 76° 05¢ 33^2 east longitudes. This hot arid region is characterized by low and high erratic rainfall, high evaporation loss and extremes of diurnal and seasonal temperatures. The average annual rainfall varies from 456 mm in south east to less than 100 mm in western most part of Jaisalmer district. Dominant landforms of the region are sandy plains with varying degree of hummocks and sand dunes. These are encountered with hills and outcrops (of mainly granite, rhyolite, sandstone and limestone), saline depressions and buried channels. Light textured sandy soils cover major part of this region. Desert soils are lower in fertility status, water holding capacity, very low in organic matter and high in pH values. The soils have high infiltration rate. Vegetation is quite sparse with limited number of xerophytic plants and thorny bushes. The drainage, except the ephemeral *Luni* river system, is mostly internal. Ground water is deep, scares and over exploited. Ground water in 45% area is saline to very saline and in 40% moderately brackish. As per 2011 census the region has 27.12 million human populations. The density of population varies from 17 in Jaisalmer to 361 in Jhunjhunun district (Anon.2012). Rural poor ratio varies from 3.3% in Jaisalmer to 35.4% in Bikaner district. Similarly the percent of BPL families varies from 4.44% in Jhunjhunun district to 31.14% in Bikaner district. The region supports 30.18 million livestock population as per livestock census 2012.

Method And Materials

Palaeoclimate of 'Thar' desert considered is essential to assess the onset of climatic conditions in this region. Early work of eminent climatologist and meteorologist (Dutt 1901, Banerjee 1952, Pramanik and Hariharan 1952 and Sikka 1997) has been reviewed to know the situation of various climatic parameters. Historical climatic data generated at CAZRI from 1901 to 2015 as well as statistics from state department and IMD are analysed to bring out trend of each climatic parameter. Impact of drought, flood and sand storms on natural, human and animal resources as well as physical environment are discussed both in negative and positive manner. Recent works of eminent experts on the impact of climate change (Sikka 2004, CAZRI 2005, Narain et al 2006, TERI 2010, Adel and Magdy 2012, Ranuzzi and Srivastava 2012, Punia and Rao 2013, Saxena et al 2014, Kaushik and Sharma 2015 and Singh and Kumar 2015) as well as recent government policies are reviewed to gather present picture on this issue. Population data is also considered in light of future growth. The findings are supported with maps and charts. Adaptation strategies to minimise the adverse impact of climate change and management options are highlighted to deal with such natural hazards.

Results And Discussion

Climatic parameters: Studies on various parameters of the climate of Rajputana desert was attempted by Banerji (1952), Pramanik and Hariharan (1952), Pramanik and Jagannathan (1954) and Rao (1958). Jagannathan (1964) presented climatic environment and drought and aridity by Subramanium (1964), Later on at CAZRI, Jodhpur, Krishnan (1968a) delineated different climatic zones and further distribution of arid areas in India (Krishnan, 1968b). Ramakrishna and Sastri (1980) undertaken studies on incident of droughts; Ramakrishna, Agnihotri and Rao (1992) on climatic resources of Thar desert; Rao et al (1994) on determination of crop growing period; Rao (1996) on climatic changes in IGNP region; Rao et al (1997) on evapotranspiration, water and energy requirements and utilization; Sikka (1997) on desert climate and its dynamics and Rao and Singh (1998) on climatic features and crop production.

Arid western Rajasthan has been divided into five agro-climatic zones by NARP (Fig.1). Arid western plain constitutes 21.5% area, irrigated north western plain 9.7%, hyper arid partially irrigated plain 36.3%, transitional plain of inland drainage 17.5% and transitional plain of Luni 15.0% respectively. Salient features of each climatic zone are given in table 1. Ramamani (2009) has analyzed agro-ecological zone wise impact of climate change.

***Rainfall*:** The mean annual rainfall over the region varies from 600 mm in south eastern part of Pali district to less than 150 mm in north western part of Jaisalmer district. District wise various rainfall parameters are given in table 2. More than 85% of total annual rainfall is received during south west monsoon from July to Sep. The rainly season varies from 50 to 80 days. About 7-10% of annual rainfall is received during winter season. The length of crop growing period varies from 7 to 14 weeks. The coefficient of variation of annual rainfall varies from 37% to more than 59%. The high inter-annual variability of rainfall is the major single factor influencing crop and pasture yield (Rao and Singh, 1998). Commencement of sowing rain is another important feature for crop production. The normal period of occurrence of sowing rains (> 25 mm per week) over the area is 1st to 15th July. However as per climatic data sowing rain can be delayed by first week of August in western part and 3rd week of July in eastern part of the region. Such late or early commencement of sowing rain leads to larger variability of crop production. The seasonal rainfall of 2009 and 2010 and deviation in seasonal rainfall during 2014 is given in table 3.

The average number of rainy days from rainfall data from 2000 to 2012 comes to 17 in Barmer, 11 in Jaisalmer and 19 in Jalor districts. During 2013 the seasonal rainfall recorded deficit over the normal rainfall in Jaisalmer, Nagaur and Pali districts by 1.0, 8.0 and 15.0% respectively. Jodhpur district received normal rainfall. Other 8 districts on the other hand got excess rainfall being 31% in Barmer, 29% in Jalor and 28% in Hanumangarh districts (Singh and Mahima, 2014). Tehsil wise distribution of average rainfall from 2000 to 2005 is shown in figure 3. During 2014 monsoon period abnormal rainfall (60% & above) occurred in Jaisalmer, Barmer and Jalor districts; excess rainfall (20% to 59%) in Ganganagar, Jodhpur, Nagaur and Bikaner districts; and normal rainfall (19% to -19%) in Pali, Churu, Jhunjhunun and Sikar districts (Fig. 2, Anon. 2015). Actual rainfall in year in 2014-15 was 457.8 mm which was 53% above normal rainfall. Of this 384.0 mm occurred in monsoon, 2.2 mm during winter, 70.5 mm in pre monsoon and 1.2 mm in post monsoon period. Characteristics of 2014 monsoon rainfall are given in table 5. District wise rainfall variability from 1980-81 to 2009-10 is shown in table 4. Decrease in number of rainy days and increase in the intensity of rainfall on a given rainy day causes flood (Kumar, 2009). During 1901-1997, there were 25 instances of heavy rainfall in arid region. Severe floods in the region occurred 7 times in a period of 97 years during 1907, 1908, 1944, 1973, 1979 and 1990. In 1967, 1976, 1983 1990 and 2006 also floods were occurred.

Temperature: 'Thar' desert is subjected to extreme temperatures between -5.7°C to 50.0°C. The mean maximum temperature during winter varies from 24.0°C in the east to 26.5° C in the west. During summer the mean maximum temperature vary from 36.1° C and 42.9° C in the east to 38.8° C to 45.5° C in the western most part. The distribution of mean maximum and minimum temperatures is shown in fig. 4. Occasionally temperature above 46°C are recorded when a heat wave passes across the region. The mean minimum temperatures during winter vary from 9°C in the east to 11°C in the west. January is the coldest month with an average temperature of 6.5° C to 9.5° C. The minimum temperatures on individual days occasionally reach to less than -3 ° C. Mean minimum and maximum temperatures during 2015 remain 7.0 and 45.0°C in Barmer, 2.4 and 46.2 in Bikaner, 3.2 and 46.3 in Ganganagar, 2.0 and 46.5 in Jaisalmer and 6.0 and 44.8 °C in Jodhpur districts respectively as per IMD report.

Wind regime: Wind direction over the region remains predominantly south-west from April to October and generally north-east during intermittent months. The average wind speed varies from 3 kmph to 8 kmph. During peak summer month the average wind speed vary from 14.6 kmph to 18.5 kmph. The average wind speed during hot weather and monsoon season vary from 9 kmph to 13 kmph. The dust storm frequency in Ganaganagar comes to 17 days, Bikaner 15 days, Jodhpur 6 days and Jaisalmer 2-3 days. Annual number of thunder storm (dry and wet) is about 10 over western Rajasthan (Ramakrishna and Rao, 1992).

Relative humidity: Low relative humidity (< 30%) prevails during March and April months. Mean day time relative humidity during August varies from 60 to 80%. Evaporation is low during winter months of December and January with an average rate of 5 mm per day. It sharply increases from middle of March and reaches 15-16 mm per day by May. During monsoon period evaporation is Low (6-8 mm per day).The annual estimated potential evapotranspiration (PET) values ranges from 1600 mm in the eastern part to 1800 mm in the western part. A 1°C increase in normal temperature will enhance the evaporation from minimum of 35 mm in Ganganagar to maximum of 96 mm in Jaisalmer. Increase in evaporation will have direct bearing on total water demand for irrigation. Thus an increase of 1°C temperature will cause an additional annual water demand of 1570.9 mcm for entire western Rajasthan (Saxena *et al.* 2014). On an average the region experience 3 to 8 dust storm per year. Whenever the rainfall during monsoon season was very low, there was sharp increase in dust storm activity in the subsequent year and vice-versa (Ramakrishna *et al.,* 1987). During rainy season morning RH values can be as high as 60-70%. PE during May and June vary from 21 to 31 cm.

Climate Change Scenario:

Climate change will affect people and environment in many ways like agriculture, health, energy, water supplies, plant animal ecosystem, forest, coastal area and resources. Climate change has a serious impact on the availability of various resources on the earth especially water which sustain life on this planet. Change in biosphere, biodiversity and natural resources are adversely affecting human health and quality of life. The effects of climate change poses many threats, one of the important consequence is bringing about change in the quality and quantity of water resources and crop productivity (Kumar and Gautam, 2014).

The arid regions of Rajasthan are the worst sufferer of climatic changes according to Central Arid Zone Research Institute (CAZRI), Jodhpur. Eleven districts in this zone have seen a rise in surface heating, reduction in rainfall, change in crop pattern and low milk productivity of livestock. The inference emerged after CAZRI analyzed climatic data of this region from 1913 to 2013. Unusual heating of the surface has been happening since the mid 80s. Annual temperature was increased by 2-3 ° C, and it is estimated in the few decades the figures will be around five degrees celsius. It will drastically affect food, fodder, water and livelihood of people

Arid region has a climate history of 3000 years. Roy (2015) has carried out trend detection in temperature and rainfall over Rajasthan and found that delayed onset of monsoon increase in post monsoon rainfall. Rising temperature in most part of the year can worsen the situation of availability of water. Even Barmer, Bikaner and Jaisalmer districts experience minor rise in rainfall. Climatic changes were studied by Rao (1996) in IGNP region and found that increase in annual rainfall was apparent during 1961-1993. Decrease in air temperatures were observed in this region at a rate of 0.039°C year[1] at Ganganangar, 0.023°C year[1] at Bikaner and 0.009°C year[1] at Jaisalmer. Increase in the frequency and intensity of heavy rainfall events at the expanse of low rainfall events, substantial decline in monsoon depression and increase in low pressure system. IPCC-AR 4 March opined that there will be no significant change in monsoon rainfall until about 2015.

Singh and Kumar (2015) found that during last 30 years the average rainfall has declined by 50 mm in arid Rajasthan. It was 400 mm in 1973 which came down to 350 mm. The region covering part of western Bikaner, north Jaisalmer, central Barmer and western Jalor have shown decrease in arid conditions. The climate over western Rajasthan is showing definite sign of change with decrease in rainfall and increase in temperature and aridity. The arid climate belt has shifted eastward intensifying the process of land degradation and causing desertification (Singh and Kumar, 2015). Punia et al.(2013) observed that the ari temperatures by the end of 21st century are likely to increase by +3.3^0 C at Bikaner, +3.4^0 C at Jaisalmer, +2.9^0 C at Jodhpur and + 2.5^0 C at Pali. Simultaneously annual rainfall is likely to increase by +100 mm at Bikaner, +124 mm at Jaisalmer, +24 mm at Pali and – 40 mm at Jodhpur.

Changes in temperature, precipitation and CO_2 are expected to have significant impact on crop growth. India has experienced 23 large scale droughts from 1891 to 2001 and the frequency of drought is increasing. As such per capita availability of fresh water is bound to be reduced due to growth of population. This will lead to fast withdrawal of water and this in turn reduces the recharging time of water table. Change in climate will thus affect the soil moisture, GW recharge, frequency of flood or drought and finally GW level. Consequences of climate change are the declining quality and quantity of water resources and crop production.

Wind speed during summer (May and June) remains 25-30 kmph. Trend of more rainfall, lower temperature and lowest humidity are indication of dust storm in IGNP Command area (Ramakrishna and Rao,1992). Lal *et al.* (1996) viewed that rainfall should decrease by about 5% and temperature by 1^{0}C. Thus there is hardly cause for concern with regard to climate change due to green house global warming over Rajasthan desert (Sikka, 1997). Dust storm frequency in Ganganagar district is 17 days, Bikaner 15 days, Jodhpur 6 days and Jaisalmer 2-3 days. Annual number of thunderstorm is about 10 over western Rajasthan. Frequency of severe droughts intensifies the frequency of dust storms. In worst rainfall year in Jaisalmer district in 2009 five severe dust storms were recorded with 73.6 mm rainfall while in 2010 with rainfall 370 mm only one dust storm was occurred.

Drought in Arid Rajasthan

Drought in Rajasthan has a long history. Major droughts in Rajasthan between middle of 14th century and the middle of 18th century occurred in 1362-63, 1648-49, 1659-60 and in 1747-48 (Sikka, 2004). There is historical record of major droughts between 1309 and 1313, 1570, 1660-61, 1698, 1747, 1756, 1783, 1792, 1796, 1804,1812-13, 1838-39,1848-49, 1850-51, 1853-54, 1868-70, 1877-78, 1891-92, 1896-97 and 1898-1900 (CAZRI, 2005). In 1899-1900 famine 23.4% population of Marwar, 29.7% of Bikaner and 36.6% of Jaisalmer states were declined and 199600 people along with 661906 cattle from Marwar were migrated (Dutt, 1901)

From 1956-57 to 2010-11 there had been 49 drought years out of 55 years in Rajasthan. Out of them 22 droughts affected 76-100 % districts; 13 droughts 51-75% districts; and 7 droughts each affected 1-25% districts respectively as per record of Disaster Management and Relief Department, Govt. of Rajasthan. The droughts of 1979-80, 1987-88, 1991-92, 2000-01, 2002-03 and 2009-10 were so widespread that more than 30000 villages were affected. Table 6 shows the drought years in western Rajasthan.

CAZRI has recorded droughts of varying intensities from 1901 and 2005. The droughts of 1918, 1987 and 2002 were worst. Often the drought persists continuously for 3 to 6 years at different intensities, as has been experienced during the period 1903-05, 1957-60, 1966-71, 1984-87 and 1998-2000, causing multiple effects on crop and fodder production, groundwater and availability of drinking water in the region (Narain et al. 2006). Arid western Rajasthan experienced droughts in 52 to 62 % of the years during1901 to 2005 in one place or the other. There were 34 mild droughts, 20 moderate droughts and 6 severe droughts in the region. The distribution of droughts of different intensities is given in table 7. Jaisalmer, Barmer, Jodhpur and Pali districts have probability of drought occurrence once in 2-3 years; Jalor, Bikaner, Nagaur, Sikar Ganganagar and Hanumangarh districts 3-4 years; and Churu and Jhunjhunun districts 4-5 years (Fig 5). Drought vulnerability indicate that on an average the annual rainfall is less than 200 mm once in five years in Ganganagar, eastern part of Bikaner and Jodhpur and western part of Nagaur and Jalor district while in Jaisalmer and western parts of Bikaner and Barmer average rain is expected to be less than 100 mm.

Impact of Climate Change:

The erratic and scanty rainfall leading to high water deficit, soil salinity leading to frequent physiological droughts, acute drought at the time of grain formation and nutrient imbalance, especially for N, P Zn and Fe. Such protracted drought during crop growing season influences agricultural production. Rainfall drives water availability and determines sowing time for rainfed crops. Temperature drives crop growth duration and influence milk production in animal (Rao, 2012). Soil loss due to wind erosion magnify geometrically (283 to 2837 t/ha) when the sandy loam heavily tilled or disc ploughed in dry season with wind speed more than 20-30 kmph during April to June. During dust storm wind speed often reaches 60-110 kmph. Mean annul temperature during 1905-2007 show an increasing trend of 0.51^{0}C/100 year while an accelerated warming is of 0.21^{0}C/10 years after 1970.

Rajasthan State Action Plan on Climate Change (SAPCC) observed that changes in climate variables crucial for agricultural growth such as temperature and precipitation increased incidence of drought and intensification of water-scarce condition can adversely impact agricultural production and productivity owing to change in hydrological cycle. Change in precipitation pattern can also increase the likelihood of short term crop failures and decline in production (TERI, 2010). Studies on impact of drought on agricultural production reveal that production of pearl millet in western Rajasthan has declined by 52% during 1998 drought, 74% during 1999 drought, 38 % during 2000 drought and 86% during drought of 2002 as compared to the production during 1997 good monsoon year. Highest loss was observed in Pali and Barmer districts. Similarly the production of kharif pulses has declined by 65% during the drought of 1998; 86% during drought of 1999, 53% during the drought of 2000 and 89% during 2002 drought. Highest % of reduction in production was observed in Barmer, Churu and Pali districts. Similarly during 2009-10 the yield of rainfed crops like bajra was just 137.79 kg/ha, jowar 21.43, moong 49.15, moth 31.61, sesame 30.66 and guar 66.63 kg/ha respectively. Production of pearl millet (bajra) is reduced by 10-30% during mild drought, 35-60% during moderate drought and 75-90% during severe drought (Rao *et al.* 2012)

Ramakrishna and Rao (1991) observed that impact of increased vegetation on the rainfall in Ganganagar region seems to be positive. There is a significant rise in decadal value of average annual rainfall. The frequency of dust storm has reduced from 17 to 10 in this region which can be attributed to the increased vegetation as a result of irrigation. During good rainfall years grass cover increases and protecting soil from erosion. Wet soil also reduces soil - erodibility (TERI, 2010).The area under rainfed agriculture increased by 332% from 110 ha to 146246 ha between 1980 and 2006 in Jaisalmer district. This expansion has been at the expanse of grassland. Kumar and Gautam (2014) studied impact of climate change on agricultural productivity and observed that India may experience more seasonal variation in temperatures with more warming in winter than summer. Climate models predict a gradual rise in carbon dioxide.

Sarkar et al. (2014) studied the socio-economic impact of climate change in arid Rajasthan and found that farmers of this region are agreed that temperature is increasing. The frequency and intensity of heat waves increasing by which soil becoming hard and rough. Winter season is now delayed by one month as a result the yield of rabi season crops is affected. Monsoon rainfall is coming late which affect timely showing of kharif crops. The frequency and duration of droughts as well as heat wave frequency and intensity has increased. Less fog is reported during winter and hence low soil moisture in the fields. Frequency of sand storms and shifting of sand dunes became less. Moreover, land degradation and desertification is increasing.

Impact of major drought, flood and sand storms in Arid Rajasthan:

Severe Drought of 2002: During 2002 severe drought the average monsoon rainfall of Rajasthan state was 220.4 mm which as lowest in recorded period of 136 years. Rainfall departure from normal in western Rajasthan was in the range of - 64% in Churu to -85% in Bikaner district. All districts of Rajasthan were under the grip of drought. About 44.8 million human and 45.2 million livestock population were affected. Out of 2341 irrigation tanks in the state, only 16 were filled. Groundwater table was declined by 3.5 to 6.0 metres. Kharif crops in 11.7 million ha were damaged. About 7.8 million families depending on agriculture and animal husbandry were severely affected (CAZRI, 2005).

Luni Flood of July 1979: Continuous torrential rain for 70 to 80 hours from 15th to 19th July, 1979 caused widespread flood havoc in Luni basin covering Jodhpur, Nagaur, Pali, Jalor and Barmer districts. Total rainfall of 700 to 850 mm that a number of stations have got just in five days, had surpassed all previous records. Kosana and Borunda received respectively 507 and 415 mm rainfall in a single day (17th July). The peak discharge in Luni at Samdari and Gandhav was an order of 10520 and 13920 cu. m. with flood volume of 28.27×10^8 and 24.09×10^8 cu. m. respectively (CAZRI, 1982). The flood brought widespread and heavy damage to human and livestock life, houses, buildings and infrastructures, crops , irrigation wells, road and rail transport etc. In all 939 villages and a number of important town were seriously hit. 25000 people were marooned. 337 people were died and 119 declared missing. In all 99688 heads of livestock were perished. 63464 houses were completely destroyed or seriously damaged. In the districts of Pali, Barmer and Jalor standing crops over an area of 67481, 4800 and 14905 ha land respectively were completely damaged. 71 irrigation tanks were also damaged. Loss to industrial units and mining area was another concern. Total estimated loss was Rs. 11625 lakh. Widespread piling of coarse land over the fertile irrigated land and lateral spread of sand along the rivers and increase in channel and bank cutting were other impact of this flood. Long term impact was the emergence of bilayti babool (*Prosopis juliflora)* throughout the Luni basin.

***Heavy rainfall in Barmer district, 1990**:* The heavy wet spell during July and August, 1990 caused serious damages in Siwana, Pachpadra and Guda Malani tehsils of Barmer district. Sheet and gully erosion of irrigated fields; deposition of coarse sand on cultivated fields; widening and shifting of streams; damage to houses, standing kharif crops and irrigation wells and inundation of land were major impact of unprecedented heavy downpour. 216 villages were affected by July rain and 159 villages by August rain. 6279 houses were completely damaged and 6949 houses were partially damaged.

Flood havoc in Barmer and Jaisalmer district 2006: Barmer was deluged on 30th September 2006 with 723 mm rainfall in seven days. Kawas and a dozen surrounding villages were marooned with 2.0 to 4.5 metres deep water surrounded by dunes. Being internal drainage region, the flood water could not be drain out. Road, rail and other infrastructures were damaged. Crop worth Rs. 1000 crore were damaged and flood claimed lives of 140 people and 50,000 livestock. The Thar desert - which basks in sunshine for a yearly average of 320 days - has suddenly been transformed into a trough of death and destruction. An uninterrupted weeklong downpour in August caused flash floods, the worst in at least a century. The unprecedented event not only caused extensive damage to life and property, it also rendered homeless over a million people in Jaisalmer and Barmer districts. The floods have created at least three large lakes in Kawas, Malwa and Uttarlai - all in Barmer district, and each covering 7-8 sq km (Ranuzzi and Srivastava, 2012). More than 20 new water bodies in the Barmer-Jodhpur region came up. Several water channels or natural drains have also shown up after the flooding. According to Nityanand Singh of the Indian Institute of Tropical Meteorology, Pune, rainfall has been increasing in the Rajasthan desert since 1973, though marginally. What has also made a difference is the decreasing rain spells with great intensity of showers. Singh recalls that there were heavy floods in Jodhpur in 1979 and 1981. He says that given the trend of weather patterns, there could be floods in Rajasthan every third or fourth year. According to Kar (2011) the flood had some positive impact besides damages. Available of huge volume of potable water increased soil moisture and enrichment of soil, reducing salinity, improving biomass and increasing vegetation cover on sand dunes. The vegetation greenness index has increased and impounded water and conserved moisture were utilized to grow rabi crops.

***Severe dust storm and sand movement in Barmer and Jaisalmer districts 1985**:* Due to constant dust storms during summer of 1985 about 5-30 cm soils were eroded and sand dunes were advanced by 2 to 5 metres, houses were buried under sand and sand was deposited on roads and railway track. A large number of sheep and goats were died. Major affected areas were Sheo tehsil of Barmer, Phalsund area of Jaisalmer, and Shergarh, Chirai and Chawa area of Jodhpur districts.

Adaptation strategies for reduction of climate change impact:

Adaptation strategies are inevitable as both climate change and extreme climates and monsoon are expected to be more profound in future. The climate change causes two major groups of impact i.e. (1) Biophysical impact and (2) Socio-economic impact. Adaptation is a process that requires action from many decision making authorities/organization. Farmers from centuries are continually adjusted cultivation and breeding practices for varying climatic conditions. Adaptation to climate change calls for a new paradigm that manages risks related to climate change by recognizing the prospects for departure from historical conditions, trends, and variation. The adaptation planning model devised by U.S. National Academies (2010) is shown in fig. 6.

The essential steps are to prioritise adaptation strategies for highest vulnerable areas; develop robust mobilization mechanism which encourage climate proofing of development programme; ensure the flow of financial and technical support; strengthening of existing capacities and local authorities, civil society's organizations and private sector, capacity building & capacity development (IASC, 2009). Effective disaster risk reduction; reduction of green house gas emission, educate people how to adjust their behaviour and choice in response to climate change and avoiding the risk are equally important. Special package for adaption should be developed for rainfed areas based on minimising risk (Ranuzzi and Srivastava, 2012.)

Water resources development; agriculture and food security, infrastructure development; disaster risk management, rural livelihood, livestock system and agro-biodiversity are key sectors for efficient and sustainable management. CAZRI has developed improved water management practices to enhance water use efficiency and productivity without affecting the soil health (Saxena et al, 2014). These includes increasing water available to crop plants, crop planning based on rainfall and soil moisture availability, increasing water in relation to other losses like weeding, plant spacing and application of fertilizer/manure; management of limited irrigation water, pressurized irrigation, restricting evaporation loss and rainwater management. Other practices are water supply and irrigation system, seasonal changes in sowing data, other inputs, fertilizer, tillage methods, grain drying, field operations and suitable new crop varieties.

Enhancing the resilience of communities to cope with climate change would require running awareness campaigns, lesser dependency on government, facilitating access to risk-reducing technologies and practices to enhance the capacity of local communities to cope with climate change, encouraging agricultural biodiversity and diversification of production systems and livelihood sources (Adel and Madkour, 2012).

In order to combat drought there should be short term, medium term and long term strategies. Short term strategies include contingency crop planning; water, food and feed supply; animal health care and managing animal migration, need based employment and soft term credit facilities. Medium term measures are development of a workable drought monitoring and early warning system with good network of meteorological stations; development of market facilities for animal products and grazing resources. Development of drought resistant and low water requiring crop varieties, productive and adaptable animal breeds, creation of large surface water storage and utilization facilities and ground water augmentation are some long term needs (Narain and Kar, 2005). Thus the transformation in economic, social and technological and political decisions and action can enable climate resilient pathway (IPCC, 2014). So for safeguard it is in our interest not to first pollute then to cleanup; or first to be inefficient, then to save energy.

CONCLUSION

Arid Rajasthan is more sensitive to climate change impact, particularly on natural resources and environment and human and animal life. Low, high erratic and ill distributed rainfall, high evaporation loss and extremes of diurnal and seasonal temperatures are major characteristics of arid climate. Occurrences of drought once in 2-3 years interval, untimely onset of monsoon rain, midterm dry spell and high deficiency in seasonal rainfall are other constraints. From centuries drought/famine of varied intensities has remained an integral climatic phenomenon in western Rajasthan. Prior to 1901, 27 droughts have recorded history. From 1901 to 2005, there were 30 drought years Flood and wind storms are other natural disasters and consequences of climatic disturbances. The Luni flood of 1979, Barmer-Jaisalmer flood of 2006 and severe dust storm of 1987 are examples of major destruction and losses and adverse impact on natural resources. In spite we get suffered every time and have not came up with long term and effective solution. More dependency on government is another setback. Degradation of ground water resources, reduction in flow and volume of rain water into the rivers/streams, abandonment of large scale irrigated double cropped land as well traditional water harvesting/conservation structures, reduction in winter season, increased frequency of late onset of monsoon/sowing period, declining yields of rainfed crops are other visual impact. Fear of uncertainty and livelihood insecurity is prevailing amongst peasants. However a couple of positive impacts like stability of duny terrain, increased moisture contents and increase in vegetation cover and biomass production are also observed in IGNP command area. Fast degradation of ground water, grazing and other natural resources and reducing interest on rainfed farming are major issues. Technologies are there but there is great need of long term workable planning; its execution schedule, strong supportive law; political and administrative will and preparedness; public support and inter-departmental coordination. Key sectors for efficient and sustainable management are agriculture, water resources, food security and rural livelihood and extreme weather events.

References

Anon. 2010. Adapting to the impact of future climate change. National Academies Press, Washington.

Anon.2012. Administrative Atlas - Rajasthan, 2011. Dte. of Census Operations, Rajasthan, Jaipur, p.697.

Anon. 2015. Monsoon, 2015. Chief Engineer, Water Resources, Govt. of Rajasthan, Jaipur, p.121.

Banerjee, S.K. 1952. Weather factors in the creation and maintenance of the Rajputana desert. Proc. Sym. on Rajputana Desert. National Instt. of Sciences of India, New Delhi, pp.151-166.

Adel EL-Beltegy and Madkour Magdy, 2012. Impact of climate change on arid lands agriculture. *Agriculture and food security,* 2012, 1:3.

CAZRI, 1982. July1979-Flash Flood in the Luni; A case study, CAZRI, Jodhpur, p.36.

CAZRI, 2005. Drought in western Rajasthan: Impact, coping mechanism and management strategies (Eds. Pratap Narain and Amal Kar), CAZRI, Jodhpur, p.104.

Dutt, R. 1901. *Indian famines: Their causes and prevention*. P.S. King & Son, London, p.28

IMD, 2015. Annual climate summary, 2015. IMD, Pune

Impact of climate change in arid region in India. Centre for Education and Documentation, 2010.

IPCC, 2014. Climate Change 2014: Impacts, Adaptation and Vulnerabilities. Summary for policy makers. Contribution of Working Group II to the fifth assessment report of IPCC. Columbia University Press, USA, p.32.

Jagannathan, P. 1964. Climatic environment and its fluctuation in Rajasthan. Proc. on problems of Indian arid zone. Min. of Education, Govt. of India, pp.368-379.

Kar, A. 2011. Flood havoc in Thar desert: Is nature to blame. In: Water crisis in the Indian Subcontinent (eds. Jahid Hussain and L. Cajee), Bookwell, Delhi, pp.3-17.

Kaushik, G. and Sharma, K.C. 2015. Climate change and rural livelihoods adoption and vulnerability in Rajasthan. *Global Nest Journal* 17 (1)41-49.

Krishnan, A. 1968a. Delineation of different climatic zones in Rajasthan and their variability. *Indian Journal of Geog.* 3(1):35-40.

Krishnan, A. 1968b. Distribution of arid areas in India. Proc. XXI Int. Geog. Congress, Sym. on arid zone, Jodhpur, pp.11-19.

Krishnan, A. 1977. Climate In: Desert eco-system and its management (Ed. H.S. Mann), CAZRI, Jodhpur, pp.8-25.

Kumar, R. and Gautam, H.R. 2014. Climate change and its impact on agricultural productivity in India. *Journal of Climatology & Weather Forecasting* 2:109

Lal, M., Srinivasan, G. and Cubasch, U.1996. *Current* Science 1996, 71,746-752.

Narain, P., Rathore, L.S., Singh, R.S. and Rao, A.S.2006. Drought assessment and management in arid Rajasthan. CAZRI, Jodhpur, p.64.

Pramanik, S.K. and Hariharan, P.S. 1952. Climate of Rajputana desert. Proc. Sym. on Rajputana Desert. National Instt. of Sciences of India, New Delhi, pp.167-178.

Punia, S. and Rao, A.S. 2013. Climate change and its impact on Thar desert ecosystem. *Journal of Agricultural Physics*, Vol.13 No.1, pp.71-79 (2013).
Ramakrishna, Y.S. and Shastri, A.S.R.A.S. (1980) Studies on the incidence of droughts over western Rajasthan. *Nat. Geog. Journal of India,* 26: pp. 44-49.
Ramakrishna, Y.S. and Rao, A.S. (1991). Climatic features of the Indira Gandhi Canal Region. In : *Prospects of Indira Gandhi Canal Project* (Eds. I.P. Abrol and J. Venkateswarlu), ICAR, New Delhi, pp. 1-10.
Ramakrishna, Y.S., Agnihotri, C.L. and Rao, A.S. (1992). Climatic resources of the 'Thar' desert and adjoining arid area of India. In: *Perspectives on the 'Thar' and the Karakum* (Eds. Amal kar, R.K.Abhichjandani, K. Anantharam and Joshi, D.C.), DST new Delhi, pp.10-20.
Ramakrishna, Y.S. (1997). Climatic features of Indian arid Zone. In: *Desertification control in the arid ecosystem of India for sustainable development* (Ed. Surendra Singh and Amal Kar) Agro botanical publishers (India), pp.27-35.
Rama Mani, (2009). *Impact of climate change in India; An agro-ecological zone level analysis.* India Water Portal.
Ranuzzi, A. And Srivastava, R. 2012. Impact of climate change in agriculture and food security. ICRIER Policy Series No.16 may 2012, P.26
Rao, A.S. 1996. Climatic change s in the irrigated tract of Indira Gandhi canal region of arid western Rajasthan, India. *Annals of Arid Zone* 35(2), 111-116.
Rao, A.S. Singh, R.S., Joshi, N.L. and Ramakrishna, Y.S. 1997a. Evapotranspiration requirements of some arid zone crops. Proc. Sym. Recent advancements for management of arid ecosystem
Rao, A.S. and Singh, R.S. 1998. Climate features and crop production. In: Fifty years of arid zone research in India (Eds. A.S.Faroda and Manjit Singh), CAZRI, Jodhpur, pp.17-38.
Rao, A.S., Poonia, S. and Chaudhary, S. 2012. Climate change impact and drought scenario in arid Rajasthan. *Ann .Pl. Soil Res*. 14(1):25-28 (2012)
Rao, V.U.M., 2012. Impact of climate change on agriculture. CRIDA, Hyderabad, PPP.
Roy, A.D. 2015. Trend detection in temperatures and rainfall over Rajasthan during the last century. *Asian Journal of Research in Social Sciences and Humanities,* Vol.5 No.2, 2015, pp.12-26.
Poonia, S. and Rao, A.S. 2013. Climate change and its impact on Thar desert ecosystem. *Journal of Agricultural Physics* Vol.13 No.1 pp.71-79.
Sarkar, S., Padaria, R.N., Vijayaragavan, K., Burman, R.R., Pathak, H., Kumar, P. and Jha, G.K. (2014). Assessing the socio-economic impacts of climate change in arid ecosystem of India. *Range Mgmt. & Agroforestry* 35(2):249-255, 2014
Saxena, A., Goyal, R.K., Singh, R.K. and Roy, M.M. (2014). Water management for climate resilience in arid region. CAZRI, Jodhpur, p.52
Sikka, D.R. 1997. Desert climate and its dynamics. *Current Science* Vol.72, No.1, 10Jan. 1997, pp.35-46.
Sikka, D.R. (2004). Monsoon droughts: A natural hazard in India. In. *Coping with natural hazards: Indian contest* (Ed. K.S.Valdiya), Oriental Longman, Hyderabad, pp.216-228.
Singh, R.B. and Kumar, A. (2015). Climate variability and water resource scarcity in drylands of Rajasthan, India. *Geo-environmental Disasters*, (2015) 2:7, pp.1-10
SRSAC, 2009. Resource Atlas of Rajasthan. SRSAC, Govt. of Rajasthan, p.272.
Subramaniam, A.R. (1964). *Drought and aridity studies of the Indian arid zone. Proc. on problems of Indian arid zone.* Min. of Education, Govt. of India, pp.398-401.
TERI, 2010. Draft Rajasthan State Action Plan on Climate Change. The Energy and Resource Institute, TERI, New Delhi, p.171

29

The Challenges Of Cartography Satellites Data Acquisition *And Its Data Ingest Systems*

A. N. Satyanarayana, B. Chandrasekhara Rao, K. Koteswara Rao and K.V. Ratna Kuma

Introduction

Data Acquisition from Cartography Satellites

There are hundreds of applications for satellite imagery and remotely sensed data. From the Indian remote Sensing satellite Series, nations used to use information derived from the satellite imagery for spying on each other under the guise of scientific experiments, industry has grown in leap and bounds and today every sphere of life, government decision making, civil defence operations, police, you name the sphere of life, every one of which is influenced by satellite imagery in particular and Geographic Information Systems (GIS) in general.

Earth Observation by Remote Sensing Satellites by NRSC began by commissioning an integrated facility with Data acquisition and Product generation at Shadnagar for Landsat MSS data in 1979. This was followed by development of LANDSAT-TM data processing and establishment of SPOT data processing & product generation facility.

Development of IRS Spacecraft Technology Remote sensing is a multi-disciplinary domain and substantial progress has been made in several technologies during the past few decades. As the demand for “four Resolutions” – Spatial, Spectral, Radiometric and Temporal increase, the complexity of imaging sensors and in turns the satellite systems. While reliability calls for heritage systems, lessons learnt and the new requirements warrant new technology developments. A brief overview on these technology developments is given in the following paragraphs.

Data Reception and Archival is located at Shadnagar Ground Station complex and has three data reception terminals, to receive Image data in X-Band and telemetry data in S band. These three terminals are configured to track and receive data from several National and international satellites (~18 passes in a day). Configuration supports mission clashes and redundancy for important data reception. The Ground station has the capability to receive and demodulate the signals of up to 105 Mbps data rate. The feed and demodulators are upgraded for dual polarization and to cater for higher data rates. It has a Bore sight test facility to evaluate the total data reception chain for all three terminals.

Functionally data reception and auxiliary data processing consists of Antenna & Tracking pedestal, RF systems, Servo systems, Base band & Data acquisition systems and Ancillary data processing systems. Most of the sub-systems of antenna receive chain and interconnecting panels are not amenable for remote monitor and control. Hence they are to be manually set up for every data reception. There are ten Direct Archival & Quick Look Browse DAQLB systems for data archival and ancillary data processing from different satellites. Five of these support multi-mission operations for the current satellites. Operations of Data receive systems and DAQLB systems are manual.

Cartography Satellite, IRS-P5: Cartosat-1 is the first dedicated stereoscopic mission of ISRO, offering 2.5 m resolution in panchromatic band. Weighing 1560 kg at lift off, Cartosat-1 was launched into a 618 km Sun Synchronous Polar Orbit (SSPO) by PSLV-C6 on 5th May 2005. Cartosat-1 mission objectives are directed at geo-engineering (mapping) application, for high resolution panchromatic imagery with high pointing accuracies. The spacecraft features two high-resolution panchromatic cameras for in-flight stereo imaging.

Brief description of the Ground station for data reception from IRS-P5.

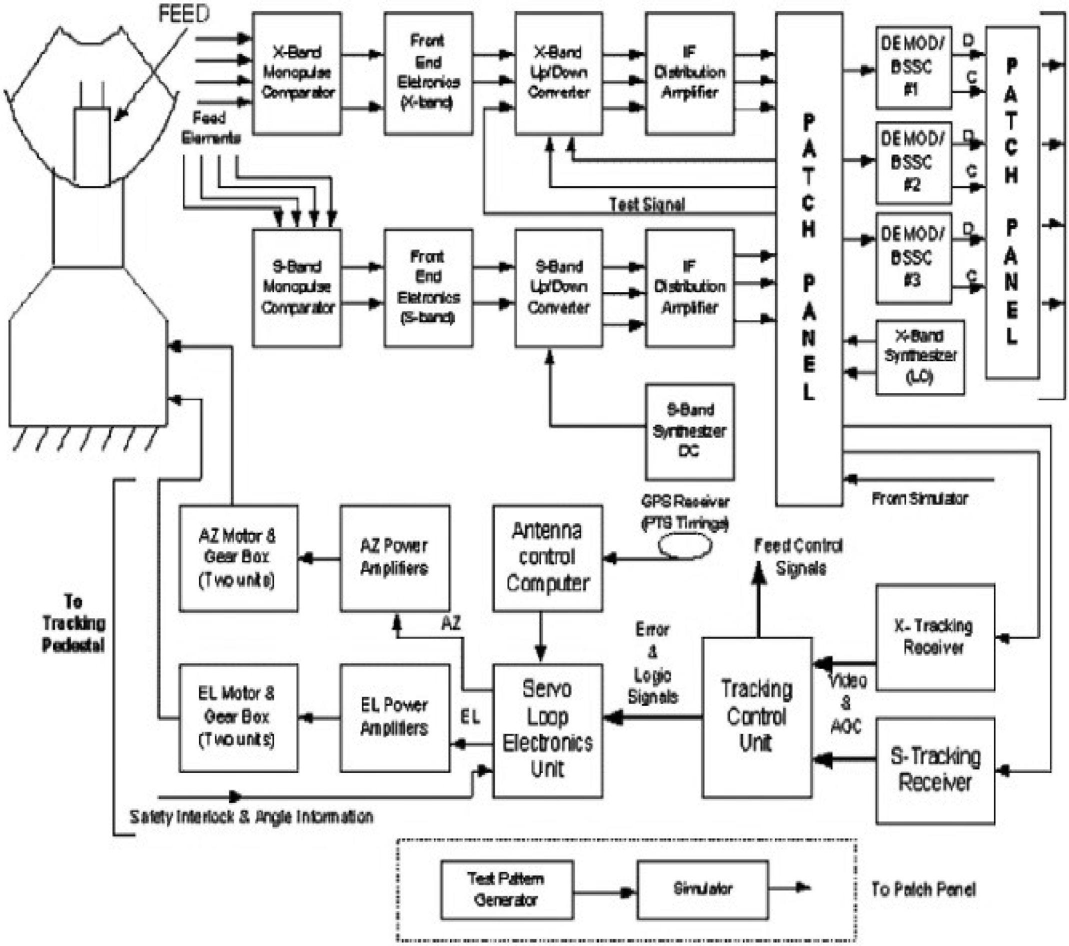
The ground station system configuration is explained with reference to the block diagram in Figure.1.2. The system consists of a diametric parabolic reflector antenna with cassegrain feed, mounted over an Elevation over Azimuth driven pedestal. The feed and front-end system realizes single channel monopulse signal tracking and data reception in X -Band frequencies. The sum and difference channel signals from the front-end system are fed to a five channel synthesized down converter are driven to the control room, wherein, after the amplitude equalization, the sum channel is fed to the data demodulation while the difference channel signal is fed to the tracking receiver. The data and clock signals from the demodulator and Bit synchronisers are fed to the archival systems during the pass. The tracking video output, corresponding to the antenna offset information in Azimuth and Elevation axes, from the tracking receiver is fed to the antenna control unit. The antenna control unit has several operational modes to control the antenna movement. The unit drives the antenna in auto track mode during the satellite pass with programme tracking mode operating as backup. The servo system [11] is a dual drive system with torque bias arrangements to avoid antenna backlash during tracking.

Initially the systems for receiving data from:

CartoSat-1 - formerly IRS-P5 (Indian Remote Sensing Satellite-P5)

IRS-P5 is a spacecraft of ISRO (Indian Space Research Organization), Bangalore, India. The objectives of the IRS-P5 mission are directed at geo-engineering (mapping) applications, calling for high-resolution panchromatic imagery with high pointing accuracies. The spacecraft features two high-resolution panchromatic cameras that may be used for in-flight stereo imaging. Prior to launch, ISRO renamed the IRS-P5 spacecraft to **CartoSat-1,** to describe more aptly the application spectrum of its observation data. In this mission, the high resolution of the data (2.5 m GSD) is being traded at the expense of multispectral capability and smaller area coverage, with a swath width of 30 km. The data products are intended to be used in DTM (Digital Terrain Model)/DEM (Digital Elevation Model) generation in such applications as cadastral mapping and updating, land use as well as other GIS applications.

Fig.1.1
Ground Station Block Diagram



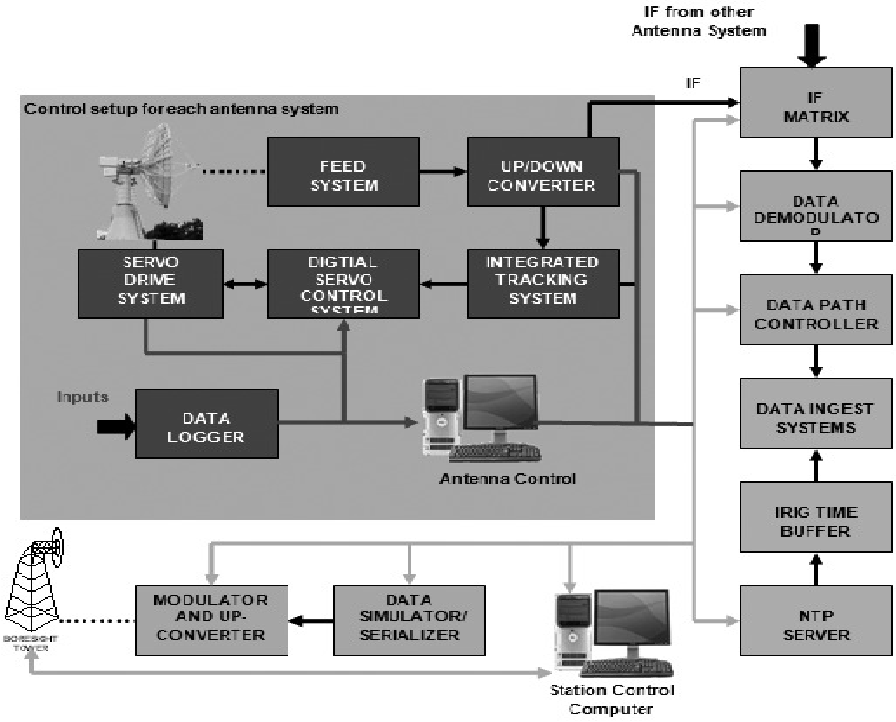
Present Ground Station Scenario (IMGEOS)

As the numbers of remote sensing missions have increased, and the scopes of supporting emergency requirements and disaster monitoring have increased, present mission specific model has several short comings. Hence there is a need to process re-engineer the entire chain, adopting an integrated multi-mission approach in order to minimize the satellite launch-to-product delivery and for improving the turn-around-time from data acquisition to product delivery to the user in near real time. To meet these objectives, an Integrated Multi-mission Ground segment for Earth Observation Satellites (IMGEOS) is proposed to be implemented at Shadnagar complex of NRSC.

The ground station configuration is shown in Figure 1-2. Four 7.5 meter antenna systems are used to track and receive data from different remote sensing satellites. There will be one antenna control computer (ACC) for each antenna systems and common station control computer (SCC) to perform the ground station operations.

Fig.1.2

Present Ground Station Block Diagram



Payload pass schedules & state vectors will be received through Sky-link on to SCC. After resolving the clashes, the SCC will assign the antenna systems for all scheduled passes after subjecting to acquisition strategies and archival policies. The SCC will configure base band systems automatically as per the schedules for all the four antenna systems and communicates its readiness to the ACC of the respective antenna system. The ACC in turn will configure the RF and IF sub systems before satellite pass tracking.

In real-time, the SCC and ACC monitor the required parameters from the base band and RF & IF systems respectively. The ACC will monitor all the parameters pertaining to RF & IF chain. In addition, it does program tracking which acts as a backup to the auto track mode. Subsequently it sends acquisition status to the SCC after the pass. During real-time, the Data Receivers log the data on to SAN based RAID system after doing demodulation and frame synchronization. The pre-processing system will provide the sub sampled quick look display in real-time. The station operations are planned to implement in fully automated environment aiming towards unmanned operations. The main objectives of the station automation are

- ✓ Visibility clash and elevation analysis
- ✓ Providing centralized control & configuration of the station

- ✓ Monitoring and control of the sub systems
- ✓ Building up of operational database
- ✓ Modularity for easy upgradeability to future missions

In multi-mission scenario, around 20 passes will be acquired covering both Indian and foreign satellites from four different Antenna Systems. These antenna systems will be operated simultaneously to acquire the data from different/ same satellites based on the clash scenario. In the operational scenario, it is required to reconfigure the chain and get ready for the next pass within 2 minutes. Around 25 parameters shall be monitored/ configured on various subsystems for each pass. Some of these important parameters are

Configuration parameters

- ✓ Local oscillator frequency and its output level of Down converter
- ✓ Gradient selection from Tracking servo control system
- ✓ Digital Phase shifter selections
- ✓ Routing of IF to different Data demodulators
- ✓ Demodulator, clock lock, polarity, data rate, output level, output mode

Monitoring parameters

- ✓ Auto errors, DC errors, Azimuth & Elevation Tacho
- ✓ AGC levels, Acquire/lock status from X & S bands
- ✓ Sector (CW/CCW) and limit checks of antenna
- ✓ Received signal strength C/No
- ✓ Quality factor (E_b/N_o)
- ✓ Demodulator and Bit Synchronizer (BSSC) lock status

2.2 System Configuration

The configuration has been worked out keeping in view of the simultaneous operations of all four antenna systems to track different satellites. Automation point of view, the total sub systems in the Data Reception System are divided into two categories- RF & IF systems (all the sub systems up to down converter in the data receive chain) and base band systems (from IF matrix onwards).

The RF & IF systems are dedicated to one antenna systems and there will not be any switching between the antenna systems in the operations scenario. The automation of these systems is carried out by the antenna control computer of the respective antenna system along with the program tracking of the satellite. Similarly, station control computer carries out the automation of base band systems. These systems include IF matrix, Data Demodulators, Data Simulators etc.

3.3 Data Ingest

Station workflow manager will initiate data ingest operation for archival of satellite data based on Payload pass schedules. For each antenna systems one data ingest system is configured. One additional ingest system is also configured as standby. Ingested satellite data will be qualified for quality in terms of data losses. Data ingest systems in the context of ancillary data processing and storage.

Ancillary Data Processing

In near real time, the ancillary data processing systems will generate ADIF, Browse and Histogram files for each pass. The generated ADIF will be populated on to the respective database for subsequent access and pre processing of data. The browse images are screened for quality & cloud automatically with a provision for manual certification before putting on to the Internet.

4.0 Storage Architecture

The Storage sub system is a Storage Area Network having an estimated storage of 25.0TB for acquisition & Level-0 processing, 15 TB for DP working area and around 720 TB of existing data of all satellites is archived on DLT/SDLT media (as on 31-Dec-2008)..

Data is stored online in 3 tier SAN storage. Provision is made for 100 TB (usable) accounting for three months of all satellites data in high performance storage. 400 TB (usable) accounting for 18 months data in medium performance SATA storage. All the data acquired and available archived data will be stored in Tape library in duplicate for backup and one more copy for vaulting. This 3 tier configuration is optimized for product generation and for data availability.

The following points are considered for selection of tiered storage

- ✓ For online processing or archival
- ✓ High performance vs. cost effectiveness
- ✓ Write once/ read many or continuous read/ write
- ✓ Frequently accessed or infrequently accessed
- ✓ File data or RDBMS data
- ✓ Heterogeneous platform access
- ✓ Multiple users or single user/ limited users
- ✓ Scenarios

- Data acquisition processes and data processing chains require high performance storage suitable for online processing etc.
- Archival data is mainly write-once read-many
- The past one year archival data is being accessed more frequently than earlier years' data.
- The storage is scalable to meet ever increasing data volumes with time. Storage architecture.

5.0 Data Archival for one day

Carto. Sat	DataRate	Streams	TotalVolume Data Acquired
Cartosat-01	105Mbps	Two	33.075
Cartosat-02	105Mbps	Two	14.175
Cartosat-2A	105Mbps	Two	3.938
Cartosat-2B	105Mbps	Two	33.075
Cartosat-2C	105Mbps	Two	33.075

CARTOSAT-3 TRANSMIT PARAMETERS IN Ka BAND

Orbit Height	:	450 Km
Modulation Scheme	:	8 PSK

Dual Polarization	:	RCP & LCP
Transmission Data Rate	:	3.8 Gbps

Conclusion

The Advances in satellite communications technology in recent years have led to a significant increase in throughput delivered from a raft of new 'High Throughput Satellite' (HTS) systems. Carto 2 Series satellites have been launched in recent years and several more will go into orbit in the coming years. These satellites support diverse user requirements and use cases – from 'connecting the unconnected' to providing secure and resilient communications to industries. The satellite communications industry supports a wide range of customers whose varying use cases and deployment locations place exacting requirements that must be fulfilled. Connectivity must be delivered to consumers located beyond the reach of traditional terrestrial networks and yet also to business and corporate clients requiring bespoke systems to support critical communications needs.

Acknowledgements

It is indeed a great pleasure my sincere gratitude to my centre Director Dr.Krishna Murthy, NRSC and Dy. Director Sri.K.V.Ratna Kumar, for encouragement for producing this paper on future Satellite applications for Cartography applications.

References

Krishnaswamy, "Sensors and Platforms for High Resolution Imaging for Large Scale Mapping Applications - Indian Scenario," Indian Cartographer,

M. Krishnaswamy, S. Kalyanaraman, "Indian Remote Sensing Satellite CartoSat-1: Technical features and data products.

"CartoSat-1 - A global IRS Mission for large scale mapping and Terrain Modeling applications," NRSA (National Remote Sensing Agency) Data Center, Hyderabad, India,

S. Kocaman, K. Wolff, A. Gruen, E. Baltsavias,(2008) Geometric Validation of CartoSat-1 Imagery, The International Archives of the Photogrammetry, *Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B1.* Beijing.

R. S. Ramayanam, "Indian Remote Sensing Satellites ResourceSat-1 (IRS P6) & CartoSat-1 (IRS P5),Data Availability".

Frithjof Barner, Rupert Haydn, Holger Maass, L. N. Remilla Murthy, "Contribution of the Indian IRS Program to the European Data Requirements through Euromap," ESA Living Planet Symposium, Bergen, Norway, June 28 to July 2, 2010, Special Publication SP-686.

30

Groundwater, Climate Change and Sustainable Well Being of the Poor: Policy options for India

Achiransu Acharyya

Introduction

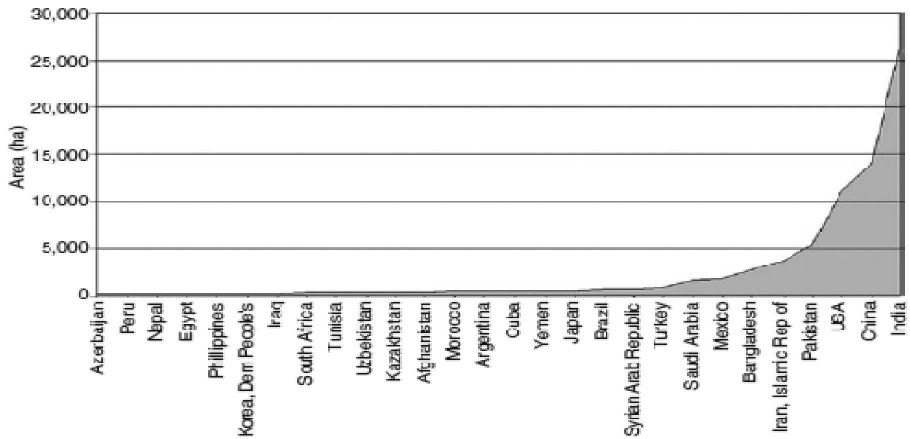
In India, while property rights to land are generally clearly defined, rights to groundwater are not. Hence water is an open access resource, a kind of free good that is not treated as an economic input. It is usually assumed that owners of the land become owners of the water below or in the vicinity of the land. It is perhaps for this reason and because of the ill-defined property rights to ground water, treating it as a free good, that the role of water has been relatively ignored while providing for explanations of the agricultural growth in India.

However, irrigation has always been central to life and society in the plains of South Asia—India, Pakistan, Nepal, Bangladesh, Sri Lanka as well as China. Irrigation has always played a central role in the agrarian economy of Asia, from supporting famed hydraulic civilizations in the ancient past to spearheading Green Revolution in the 1960s and 1970s. Asia accounts for 70% of the world's irrigated area and is home to some of the oldest and largest irrigation schemes (Molden, 2007). While these irrigation schemes played an important role in ensuring food security for billions of people in the past, their current state of affairs leaves much to be desired. Continued over-exploitation of groundwater has severely curtailed the resilience of aquifers and their ability to stabilize farming livelihoods in the face of heightened hydro-climatic variability. Groundwater here is pumped from great and increasing depths mostly using coal-based electricity; hence, these are also the regions which account for an overwhelmingly large proportion of Green House Gases (GHG) emissions from groundwater pumping. Groundwater pumping with electricity and diesel also accounts for an estimated 16 to 25 million metric tonnes of carbon emissions which is between 4 to 6% of India's total emissions (Shah, 2007).

Over the last fifty years, groundwater development has played a fundamental role in agricultural production in many parts of the developing world. For example, groundwater now accounts for nearly 50 % of all irrigation supply in South Asia and two thirds of supply in China (Fig1).

Fig 1

Groundwater-irrigated area in countries with intensive groundwater use in agriculture



From Food and Agricultural Organization, 2003

The rapid growth in use in these and other regions has played a vital role in maintaining the rise in grain output associated with the Green Revolution, transforming production and livelihood strategies for millions of small farmers. However, groundwater use has not come without problems both in terms of sustainability and quality. In India, plummeting water tables has brought into question the future use of the resource. From economic logic, it is generating a negative externality that must be internalized either using a tax (commonly known as Pigovian tax) or through some legal restriction. This is discussed in more detail later.

A major debate arising from the potential scarcity of groundwater resources in South Asia as mentioned above is the question of distribution of available groundwater among the farmers, given that a large number of poor farmers depend on it for irrigation (almost 65 to 75% according to Shah (2007)) as also the property rights.

In addition to use within the agricultural sector, many cities in developing countries use groundwater for urban water supply. However, shallow groundwater beneath these cities is frequently contaminated, largely as a result of the disposal of urban wastes that are rich in organic carbon and nitrogen. As a consequence, shallow aquifers are often abandoned in favour of deeper ones. Yet, pumping from these same deeper aquifers can impose steep vertical hydraulic gradients and induce significant leakage from shallow units. Incipient contamination of deeper aquifers caused by induced downward leakage of shallow groundwater has been observed in competition for groundwater from cities that makes it harder for farmers farming nearby cities to maintain supplies for agriculture. Such phenomenon has been observed in Thailand (Lawrence et al., 1994) and Mexico (Chilton et al., 1998).

Climate change is expected to significantly alter India's hydroclimatic regime over the 21st century (IPCC, 2001). According to IPCC (2001), most Indian landmass below the Ganges plain is likely to experience a 0.5–1 æ%C rise in average temperatures during 2020–2029 and 3.5–4.5 æ%C rise in 2090–2099. For Indian agriculture, hydro-climatic change will mean that Rabi and especially summer crops will experience enhanced evapotranspiration (ET) due to rising temperatures, needing larger, more frequent groundwater irrigation. However, with rising temperatures, surface water will be shrinking (due to evaporation) leading to a severe dependence on groundwater (Shah, 2009). With falling groundwater table in many parts of India's agricultural regions (Annual Report of Central groundwater Board, 2011) managing

Ground water storage will acquire greater significance for India than ever before. This is also true for the rest of South Asia and China (Shah, 2009 and De Fraiture, 2009).

From the above discussion, it seems likely that climate change will have a negative impact on groundwater resources in India. As per the Report of the International Panel on Climate Change in 2007 (IPCC, 2007), there is cause for concern as to the sustainability of agriculture in the region, since it is heavily groundwater dependent (Fig. 2, Fig3 and especially Table 2 which shows that almost 60% of the population in South Asia depend on groundwater for agriculture).

With growth and development in the region and rise in population, food demand will increase and habits will also change (Table 5). Since agricultural production is heavily dependent on groundwater as discussed above, the question of food security is also a big issue for the huge population in the region in this scenario.

This paper, keeping the above issues in mind, tries to address the groundwater problem and the impact of climate change on groundwater resources by looking into different alternative institutions from which countries like India can develop a judicious and sustainable use of ground water.

The paper is designed in the following way. Section 2 discusses the serious problem of irrigation and in general ground water resource scarcity across South Asia including India. Section 3 looks into the impact of climate change on ground water irrigation in India. Section 4 describes the various paths to sustainable ground water management in the long run as also ensure food security in the region through physical preparation and infrastructure building. Section 5 is the concluding section.

The crisis of groundwater resources and irrigation in India and South Asia

The booming industry of ground water irrigation has become the mainstay of farming in South Asia (Table 1 and Table 2) (Shah, 2006). The livelihoods of a vast majority of the people in this region depend critically on the use of groundwater irrigation. No country is more dependent on groundwater than India (Fig. 1) (Fig.2) (Fig.3) (Fig. 4) and Table 2. In fact, India is the largest user of groundwater in the world. Groundwater is a critical resource in India, accounting for over 65% of irrigation water and 85% of drinking water supplies (World Bank, 2010). However, on current trends it is estimated that 60% of groundwater sources will be in a critical state of degradation within the next twenty years (World Bank, 2010). In the most seriously affected north-western states, recent satellite measurements indicate an average decline of 33 cm per year from 2002 to 2008 (Rodell, M. et. al., 2009). Local observations of annual water table decline exceeding 4 metres are common throughout India (Groundwater Scenario of India 2009–10, Central Ground Water Board).

The factors underlying growth in groundwater irrigation in South Asia differ across countries of the region. For example, in India the perverse incentive resulting from energy subsidies is primarily responsible for this growth (Shah, 2006).Thus, the cost of groundwater irrigation does not reflect the true scarcity of water.

Table 1

Land endowment, arable land, intensity of irrigation, and intensities of rice and wheat cropping in South Asia, 1961–2002

Average of five years ending[a]	Land area (000 ha)	Agricultural land (000 ha)	Arable land (000 ha)	Irrigated area (000 ha)	Agricultural land as % of land area	Arable land as % of agricultural land	Arable land per capita (ha)[b]	Irrigated land as % of arable land	Rice area (000 ha)	Wheat area (000 ha)	Rice area as % of arable land	Wheat area as % of arable land
Bangladesh												
1965	13017	9519	8645	501	73.1	90.8	0.1626	5.8	8955	60	103.6	0.7
1985	13017	9739	8865	1841	74.8	91.0	0.0913	20.8	10281	569	116.0	6.4
2002	13017	9057	8062	4509	69.6	88.9	0.0606	56.0	10940	764	135.9	9.5
India												
1965	297319	176290	157185	25523	59.3	89.2	0.3505	16.2	35626	13102	22.7	8.5
1985	297319	180738	163056	40637	60.8	90.2	0.2130	24.9	40502	23246	24.8	14.3
2002	297319	181156	161733	57178	60.9	89.3	0.1567	35.4	42908	25654	26.5	15.9
Nepal												
1965	14300	3533	1808	77	24.7	51.2	0.1802	4.3	1096	109	60.6	6.1
1985	14300	4268	2286	673	29.8	53.6	0.1403	29.4	1333	440	58.3	19.2
2002	14300	4982	3150	1135	34.8	63.2	0.1314	36.0	1537	663	48.8	21.0
Pakistan												
1965	77088	22874	17722	11139	29.7	77.5	0.3543	62.9	1287	4984	7.3	28.1
1985	77088	25410	20031	15548	33.0	78.8	0.2131	77.6	1963	7211	9.8	36.1
2002	77088	27140	21468	17810	35.2	79.1	0.1314	83.0	2183	4984	10.2	37.7
Sri Lanka												
1965	6465	1950	709	361	30.2	36.4	0.0598	50.8	505	Neg	25.9	Neg
1985	6463	2308	839	548	35.7	36.3	0.0547	65.3	823	Neg.	35.7	Neg.
2002	6463	2354	906	618	36.4	38.5	0.0478	68.2	832	Neg.	35.3	Neg.

Source: Based on FAOSTAT data, 2004, accessed December 2005.
[a] Year ending 2002 refers to a two year average.
[b] The arable land per capita figures relate to 1961 and 2001. Neg. means negligible.

In assessing developments in South Asian agriculture, it is useful to consider the background information, presented in Table 1 above. Several important points emerge from the information contained in Table 1. In 2002, arable land per person in Bangladesh, India, Nepal, Pakistan and Sri Lanka was estimated to be 0.06, 0.16, 0.13, 0.13 and 0.05 ha respectively (FAOSTAT, 2004). The corresponding figures in 1961 were 0.16, 0.35, 0.18, 0.35 and 0.06 ha.

The proportion of total land area in agricultural use is highest in Bangladesh (around 70%) and India (around 60%). Bangladesh and India also have the highest ratios of arable land to agricultural land (around 90%). After increasing until 1990, the ratio of agricultural land to total land area declined for Bangladesh, suggesting that the extensive margin of cultivation may have been exhausted. By contrast, Nepal, Pakistan and Sri Lanka have only about 30% of their total land area classified as agricultural land, and this proportion has increased over time.

Incidence of irrigation (irrigated area as a percentage of arable land) has increased in all countries. Pakistan has the highest intensity of irrigation (83%), but Bangladesh has shown the most rapid growth, from a very low base in the early 1960s to more than 50% in 2002. In India, the growth in irrigated area over the same period has been relatively slow, from one-sixth of the arable area to just over one-third. This outcome may reflect the diversity of agro-climatic and ecological conditions and diversity in cropping patterns in India, where many areas are not suitable for irrigation. Another indicator of agricultural intensification is given by the intensity of irrigation (measured by the gross area irrigated expressed as a percentage of net area irrigated). In South Asia, Bangladesh is the most irrigation intensive country (165%) followed by Sri Lanka (150%), India (133%) and Pakistan (110%) (Weligamage et al., 2002). However, the average irrigation intensity masks differences in topography, soils, climatic conditions and cropping patterns among regions of these countries. This is particularly true for India. For example, the northern states of

Punjab, Haryana, Himachal Pradesh, Jammu and Kashmir, and Uttar Pradesh have irrigation intensities far higher than the national average while other states are below it (Weligamage et al., 2002).

Bangladesh is the most rice-intensive country in South Asia followed by Nepal, Sri Lanka and India. Pakistan is the most wheat-intensive and least rice-intensive country while Bangladesh is the least wheat-intensive country in South Asia except for Sri Lanka, which produces negligible quantities of wheat.

Bangladesh has experienced the highest degree of intensification of agriculture because of multiple cropping, which requires a substantial increase in the relative intensity of all non-land inputs. The incidence of multiple cropping grew as a result of the adoption of dry season irrigation as part of the Green Revolution. In general, the eastern part of Bangladesh has more groundwater available than the western part because higher precipitation and lower evapotranspiration lead to greater recharging of aquifers. In some parts of Bangladesh, particularly in the northern districts, problems with 'mining' groundwater are already evident. The energy costs of irrigation in Bangladesh are increasing. Furthermore, the uncertainty of energy supply resulting from frequent power failures is a serious cause for concern.

In Pakistan, high energy costs, falling water tables, and soil salinization have reduced the attractiveness of groundwater. In the Pakistani part of the fertile Punjab plain, the drop in water tables appears to be similar to that in India. Observation wells near the twin cities of Islamabad and Rawalpindi show a fall in the water table between 1982 and 2000 that ranges from 1 to nearly 2 meters a year. In the province of Baluchistan, water tables around the capital, Quetta, are falling by 3.5 meters per year. Richard Garstang, a water expert with the World Wildlife Fund and a participant in a study of Pakistan's water situation, said in 2001 that "within 15 years Quetta will run out of water if the current consumption rate continues." 21. ("Pakistan: Focus on Water Crisis," op. cit. note 20; Garstang quoted in "Water Crisis Threatens Pakistan: Experts," Agence France-Presse, 26 January 2001). Nevertheless, more than 90% of agriculture is directly or indirectly dependent on groundwater (Qureshi & Akhtar, 2003).

During the 1960s and the 1970s, the World Bank supported huge investments in rural electrification infrastructure to stimulate groundwater irrigation and agricultural growth. Not only that, there has been a huge subsidy on diesel in most South Asian countries, including India, making availability of cheap diesel a boost to groundwater pumping. Thus low energy price is an important reason behind the expansion of groundwater irrigation in some parts of South Asia. There could be other factors at work as well too for this large scale use of groundwater for irrigation. Ceteris paribus farmers have greater control and flexibility over groundwater due a lower degree of uncertainty. This reduces the risk associated with the investment in both labor and non-labor inputs such as high-yield-variety (HYV) seed, fertilizers, pesticides and other inputs required for augmenting agricultural productivity.

Almost 90% of the farmers in South Asia are marginal farmers, in the sense that they own less than one hectare of land. This makes them vulnerable as any change in output or productivity can take them below their sustainable level (there have been quite a number of studies on the farmers in South Asia such as include Rao (1995), Bardhan et. al, (2014), etc) and land them below poverty line. This makes them risk averse like those elsewhere in the developing world. Given limited access to surface water in the water deficit basins and uncertainty about rainfall, risk-averse farmers exploit groundwater despite its high extraction cost and scarcity value. It may also be that many farmers are not optimizers (that is, expected utility maximisers) but satisfiers (along the dimensions of both security and profit). (Roumasset, 1976).

The wasteful use of groundwater is important since, in many parts of South Asia, increased use of groundwater has caused serious environmental problems (Jahan et al., 1999; Alauddin & Hossain, 2001). The divergence between precipitation and potential evapotranspiration makes groundwater only a partially renewable resource in many cases.

One disturbing result of growth in the use of groundwater is the high incidence of arsenic in drinking water in Bangladesh and the adjoining areas of the Indian State of West Bengal. While the causes of the high incidence of arsenic are complex, overdraft of groundwater is an important factor.

Thus while groundwater irrigation has been central to the agricultural economies of South Asia (Table 1 and Table 2), the sector is under serious threat due to a number of reasons as discussed above that include heavy dependence of agriculture, overdraft and impact of climate change.

This scarcity of groundwater can be viewed from two perspectives. One that is called the physical perspective which analyses the old infrastructure of canal irrigation and its inefficiency followed by rampant use of ground water injudiciously. The other takes into consideration that accepting groundwater to be the main source of irrigation, how best we can use economic tools so that sustainability can be achieved in the long run.

To discuss the physical problem first, surface irrigation infrastructure has deteriorated due to lack of maintenance which often is a reflection of changing requirements of farmers that gravity flow irrigation can no longer provide. Crop diversification away from rice and wheat means that gravity irrigation structures constructed keeping in mind cereal crops do not readily adapt themselves to a more diversified cropping pattern that farmers in Asia are now moving towards. Massive efforts towards rehabilitation and more recently towards modernization of gravity flow systems have yielded less than satisfactory results. Irrigation reforms in the form of irrigation management transfer (IMT) or participatory irrigation management (PIM) have failed to deliver the promise of better and efficient delivery of irrigation services in South Asia. The reason is the following: - During the latter half of the 20th century, the canal-irrigated areas of South Asia led the charge in creating South Asia's groundwater boom, resulting in a widely held belief that large-scale tube well irrigation development occurs only in canal irrigated areas. There was a time perhaps when this was largely true; however, the groundwater reality of South Asia has transcended this stage. In fact, as the density of tube wells – and groundwater irrigation in India and Pakistan Punjab – seems to have less to do with availability of surface water for recharge than with population pressure on agriculture. The tube well density is high throughout the Gangetic basin in India, which does have high groundwater availability but also very high population density. It is also high in many other parts of India such as Tamilnadu, Andhra Pradesh and Karnataka where water resources are limited but population density is high. On the other hand, in many parts of central India, little of the available resource is developed; yet tube well density is low because these regions are sparsely populated (DebRoy and Shah, 2003). China too has a similar pattern: groundwater development is low in South China, which has abundant surface water and low population density (except in the eastern coastal region); but tube well densities are high in the North China Plain, which has low surface water resource and high population density. Compared to large public irrigation projects that are driven by hydrologic opportunity, groundwater development is democratic, providing irrigation wherever people are. Under the circumstances, increasingly, farmers in South Asia are turning to groundwater irrigation (Fig 2) which gives them a greater control over use of water.

Fig 2

Growth in groundwater use in select countries (FAO 2003)

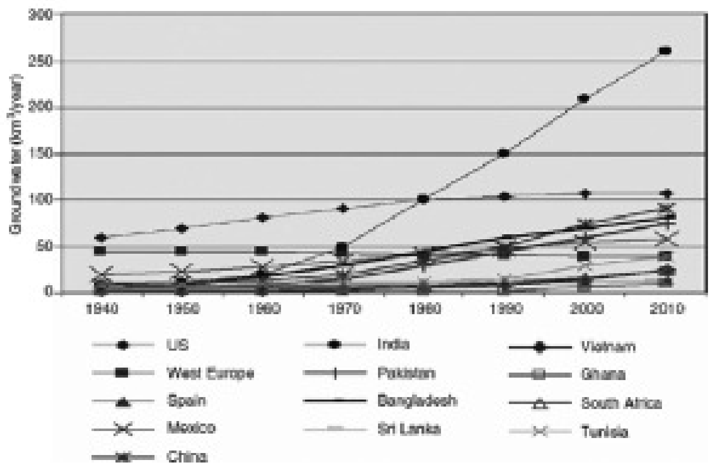


Table 2

South Asia's groundwater economy in a comparative perspective (Shah, 2006)

Country	Annual groundwater use km^3	Number of groundwater structures (million)	Extraction per structure (m^3/year)	Percentage of population dependent on groundwater
India	185-200	20	9000-1000	55-60
Pakistan	45	0.50	90,000	60-65
China	75	3.50	21,500	22-25
Iran	29	0.50	58,000	12-18
Mexico	29	0.07	414,285	5-6
USA	100	0.20	500,000	<1-2

Thus groundwater boom, while bestowing a large number of benefits, have created its own set of intractable problems in terms of over-exploitation and depletion of groundwater resources thereby putting in jeopardy the livelihoods of millions of farmers who depend on it. Globalization, urbanization, climate change, competing demands for water, changing aspirations, renewed emphasis on environmental water needs and the need to keep feeding millions of people in South Asia continue to offer great challenges to the irrigation and drainage sector.

There are major reasons for this groundwater dependency by farmers in India. These are as follows:

Underperformance and shrinkage of large scale surface irrigation systems

Of all the regions in Asia, it is India, where the problem of underperformance of irrigation systems has taken an epic proportion. Between 1994 and 2003, India lost more than 5.5 million hectares (ha) of canal irrigated area, despite, very large investment in rehabilitation of existing canals and construction of new ones. Even otherwise, productivity (both land and water) in far too many of these large scale surface irrigation scheme all across India is abysmally low (Molden et al., 1998).

Moving from centralized gravity flow systems to individual lift based irrigation

While India's large scale surface irrigation schemes continues to under-perform, total area under irrigation is on the rise everywhere in India. This is due to the rise of individualistic groundwater based irrigation fueled by cheap pumps and often supported by government subsidies in the form of cheap electricity. This 'water scavenging' irrigation, as it is often called (Shah 2008) is most visible in India and is on rise even in wetter parts of South Asia (Mukherji et. al., 2009). For instance in India there has been a transition from surface irrigation to groundwater based irrigation over the last few decades (Table 3) (Fig 3, Fig 4) mainly due to the high population density of farmers leading to a distribution crisis of surface (mainly canal water) as explained earlier as also due to ill maintenance of the canal systems (Shah, 2008).

Table. 3

Sources of Irrigation in India: 1950-51 to 2001-02 ('000 Hectares)

Year	Canal	Tanks	Tube Wells	Other Wells	Total Wells	Other Sources	Total Net Irrigated Area
1950-51	8295	3613	0	5978	5978	2967	20853
1960-61	10370	4561	135	7155	7290	2440	24661
1970-71	12838	4112	4461	7426	11887	2266	31103
1980-81	15292	3182	9531	8164	17695	2551	38720
1990-91	17453	2944	14257	10437	24694	2932	48023
1995-96	17120	3118	17894	11803	29697	3467	53402
2000-01	15710	2518	22324	11451	33775	2831	54833
2001-02	15877	2336	22816	12020	34836	2827	55876
Percentage Share of Various Sources							
1950-51	39.78	17.33	0.00	28.67	28.67	14.23	100
1960-61	42.05	18.49	0.55	29.01	29.56	9.89	100
1970-71	41.28	13.22	14.34	23.88	38.22	7.29	100
1980-81	39.49	8.22	24.62	21.08	45.70	6.59	100
1990-91	36.34	6.13	29.69	21.73	51.42	6.11	100
1995-96	32.06	5.84	33.51	22.10	55.61	6.49	100
2000-01	28.65	4.59	40.71	20.88	61.60	5.16	100
2001-02	28.41	4.18	40.83	21.51	62.35	5.06	100

Source: Central Ground Water Board, India (2003)

Fig. 3

Sources of Irrigation in India 1986 to 2001-02

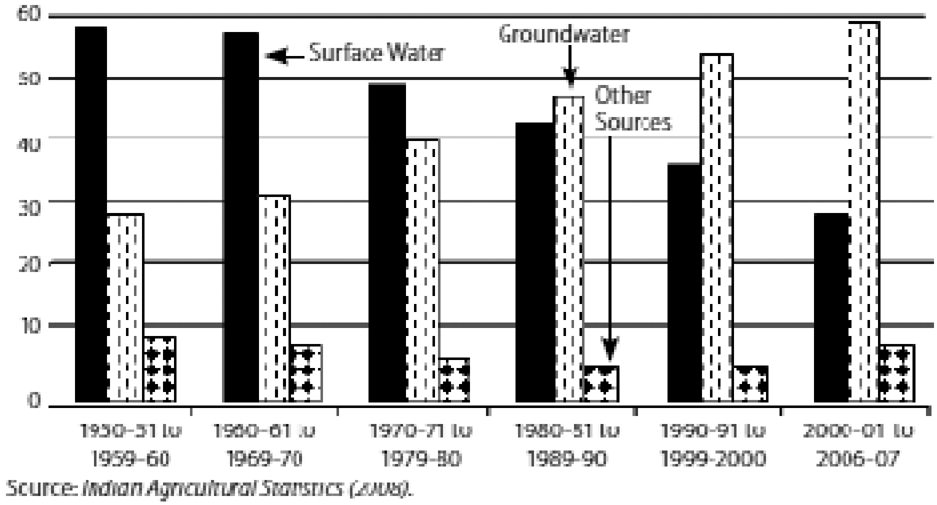
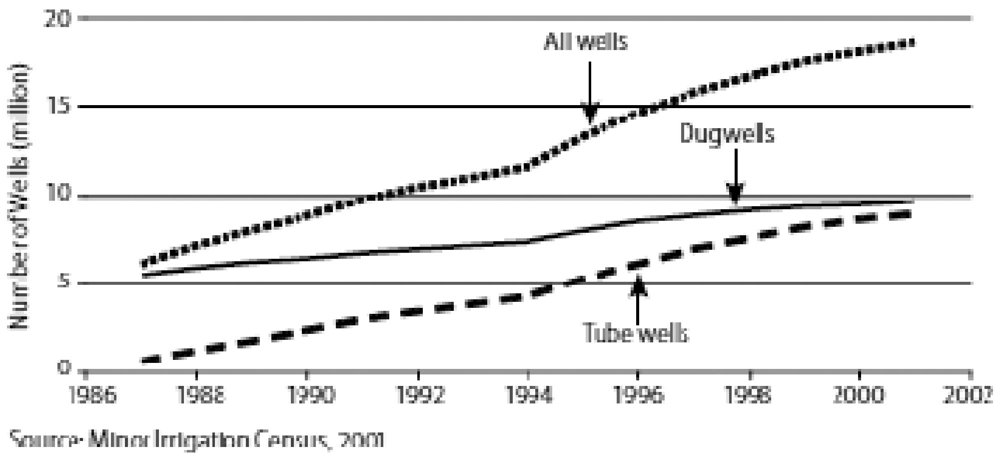


Fig. 4

Growth of groundwater use in India (1950 – 2006-07)



What pump irrigation is able to do, but large scale public systems are unable to match, is to provide farmers with water in timely and reliable manner to enable them to grow a wide variety of crops that caters to new market demands that farmers face (Shah, 2006, 2008). But this onslaught of groundwater irrigation has brought home its own set of intractable problems such as groundwater over-exploitation (Table 4 shows the aquifer depletion of blocks of different states in India) and rapid quality deterioration – thereby calling into question the long term sustainability of such an informal irrigation economy.

Table 4

Critically exploited groundwater resources of different blocks of states in India (CGWB, 2003)

		Number of Districts	Number of Block/ Taluka/ Watershed	Overexploited		Dark/Critical		Year
				Num ber	Per-cent	Num ber	Per cent	
1	Andhra Pradesh	22	1157	118	10.2	79	6.8	2001
2	Arunachal Pradesh	3		0	0.0	0	0.0	1998
3	Assam	23	134	0	0.0	0	0.0	2001
4	Bihar	42	589	6	1.0	14	2.4	2002
5	Chhatisgarh	16	145	0	0.0	0	0.0	1998
6	Goa	3	12	0	0.0	0	0.0	1998
7	Gujarat	20	184	41	22.3	19	10.3	1997
8	Haryana	17	108	30	27.8	13	12.0	2002
9	Himachal Pradesh	12	69	0	0.0	0	0.0	1998
10	Jammu & Kashmir	14	123	0	0.0	0	0.0	2002
11	Jharkhand	13	193	0	0.0	0	0.0	2002
12	Karnataka	19	175	7	4.0	9	5.1	1998
13	Kerala	14	154	3	1.9	6	3.9	1999
14	Madhya Pradesh	45	459	2	0.4	1	0.2	1998
15	Maharashtra	29	231	0	0.0	34	14.7	1998
16	Manipur	6	26	0	0.0	0	0.0	1998
17	Meghalaya	5	29	0	0.0	0	0.0	1998
18	Mizoram	3	20	0	0.0	0	0.0	1998
19	Nagaland	7	21	0	0.0	0	0.0	1998
20	Orissa	30	314	0	0.0	0	0.0	1999
21	Punjab	17	138	81	58.7	12	8.7	2002
22	Rajasthan	32	236	86	36.4	80	33.9	2001
23	Sikkim	4	4	0	0.0	0	0.0	1998
24	Tamil Nadu	27	385	135	35.1	35	9.1	1998
25	Tripura	3	17	0	0.0	0	0.0	2001
26	Uttar Pradesh & Utranchal	71	822	2	0.2	20	2.4	2000
27	West Bengal	16	341	0	0.0	61	17.9	2002
28	UTs		20	5	25.0	2	10.0	1998
	All India	516	6106	516	8.5	385	6.3	

Unit of Assessment: Andhra Pradesh, Maharashtra: Watershed; Gujarat, Karnataka: Taluka; Rest of the states-Blocks

Over exploited. >100%, Dark. >85% <100%

Source: Central Ground Water Board 2003

The extraction of groundwater requires greater energy than water from surface or canal irrigation (Molden, 1998). The high energy consumption of lift based irrigation systems as compared to gravity flow systems also makes long term sustainability an issue. Such a deep structural change in irrigation sectors composition, also calls for a paradigm shift in our thinking on irrigation.

Failed Attempts at Irrigation Sector Reforms

Concerned with the poor performance of irrigation systems, donors and governments in India had embarked upon a path of institutional reforms way back in the 1980s. Poor operation and deferred maintenance was diagnosed as a problem resulting from lack of involvement of farmers in management decisions. This resulted in policies aimed at increasing farmers' stake in day to day management of irrigation systems through Participatory Irrigation Management (PIM). However PIM had failed for various reasons:

The first conceptual weakness stems from the assumption that community managed irrigation systems are analogous with public irrigation systems and therefore farmers would be able to manage these systems just as well as they have managed community irrigation systems for centuries. Hunt (1989) carefully analyzed the spuriousness of such an argument. Stemming from the first is the second conceptual weakness, namely that irrigators within a command area are a homogenous group of people with similar interests and stake in the system. This is not true given the very different stakes the head reach and the tail end farmers have and hence the difficulty in engineering successful farmer management in public irrigation systems. The third conceptual weakness is the most glaring of them all. The most important problem facing the public irrigation system has been diagnosed to be the lack of incentive of the irrigation bureaucracy and their lack of accountability to the user. However, quite paradoxically, in most PIM models, these very same officials are entrusted with the task of turning over their responsibilities and power to the users without any reforms to better align the incentives of the irrigation managers with those of the users (Suhardiman, 2008).

Indian agricultural development has become increasingly dependent on irrigation (more specifically, groundwater irrigation). The intensive use of groundwater in India implies that Indian agriculture is highly environment-intensive, if the environment, including groundwater inputs is treated as a factor of production.

What is important here is that the price of an environmental good, in this case, groundwater, does not reflect its social opportunity cost and hence is used more intensively than is socially optimal.

The emerging factor proportions problem arises from the higher intensity with which environmental capital is used in the agricultural production process. While internal land-augmentation measures can relax the constraints on land, they may, in the long run, expose the fragility of the physical environment.

Overuse of environmental resources is likely to generate externalities, which result in a divergence between social costs and private costs. With a degrading physical environment, both marginal private costs and social costs rise steadily. As pressure on the environment increases, so does the risk of a breakdown of crucial environmental and ecological systems, leading to an accelerating rate of increase in social costs.

Overall, therefore, the problems with groundwater irrigation in South Asia have resulted from a series of policy failures. Policymakers have failed to: (a) put in place an appropriate energy pricing policy regime; (b) devise a policy regime that reflects the scarcity of ground and surface water; (c) adequately deal with externalities arising from groundwater irrigation; (d) treat groundwater as a communal/societal resource; (e) define property rights appropriately.; and (f) take appropriate account of attitudes toward risk. Thus, the groundwater industry embodies significant market and policy failures. This paper attempts to find a solution to both the problems.

Climate change impacts on groundwater in India

Climate change is expected to signiûcantly alter South Asia's hydro-climatic regime over the 21st century. It is widely agreed that the Indo-Gangetic basin is likely to experience increased water availability from snow-melt up to around 2030 but face gradual reductions thereafter. Parts of the Indo-Gangetic basin may also receive less rain than in the past; but the rest of India is likely to beneût from greater precipitation. According to IPCC (2001), most Indian landmass below the Ganges plain is likely to experience a 0.5–1æ%C rise in average temperatures during 2020–2029 and 3.5–4.5æ%C rise in 2090–2099. Many parts of peninsular India, especially the Western Ghats, are likely to experience a 5–10% increase in total precipitation (IPCC 2001); however, this increase is likely to be accompanied by greater temporal variability. Throughout the sub-continent it is expected that ‘very wet days’ are likely to contribute more and more to total precipitation, suggesting that more of India’s precipitation may be received in fewer than 100 ha of thunderstorms—and half in less than 30 ha—as has been the case during recent decades. This is likely to mean higher precipitation intensity and larger number of dry days in a year. Increased frequency of extremely wet rainy seasons (Gosain and Rao, 2007) is also likely to mean increased run-off. According to Milly et al (2008), compared to the period 1900–1970, most of India is likely to experience 5–20% increase in annual run-off during the period 2041–60. All in all, India should expect to receive more of its water through rain than through snow; get used to snow-melt occurring faster and earlier; and cope with less soil moisture in summer and higher crop evapotranspiration (ET) demand as a consequence.

To the extent that climate change results in spatial and temporal changes in precipitation, it will have a strong inûuence on natural groundwater recharge. Moreover, since a good deal of natural recharge occurs in areas with vegetative cover, such as forests, changing evapotranspiration rates resulting from rising temperatures may reduce inûltration rates from natural precipitation and thus reduce recharge. Recharge responds strongly to temporal pattern of precipitation as well as soil cover and soil properties. If climate change results in changes in natural vegetation in forests or savanna, these too may inûuence natural recharge; however, the direction of the net effect will depend upon the pattern of changes in the vegetative cover. Simulation models developed by Australian scientists have showed that changes in temperatures and rainfall inûuence growth rates and leaf size of plants that affect groundwater recharge (Kundzewicz and Doll, 2007). The direction of change is conditioned by the context: in some areas, the vegetation response to climate change would cause the average recharge to decrease, but in other areas, recharge to groundwater would more than double. Changing river ûows in response to changing mean precipitation and its variability, rising sea levels and changing temperatures will all inûuence natural recharge rates (Kundzewicz and Doll, 2007)[1]

We know little about how exactly rainfall patterns will change, but increased temporal variability seems guaranteed. This will mean intense and large rainfall events in short monsoons followed by long dry spells. All evidence we have suggests that groundwater recharge through natural inûltration occurs only beyond a threshold level of precipitation; however, it also suggests not only that run-off increases with precipitation but the run-off coefficient (i.e. run-off/precipitation) itself increases with increased rainfall intensity (or precipitation per rainfall event) (Carter 2007). Higher variability in precipitation may thus negatively impact natural recharge in general. What will be the net impact on a given location will depend upon the change in both the total precipitation and the variability of that precipitation.

The Indo-Gangetic aquifer system has been getting heavy recharge from the Himalayan snow-melt. As snow-melt-based run-off increases during the coming decades, their contribution to potential recharge may increase; however, a great deal of this may end up as ‘rejected recharge’ and enhance river ûows and intensify the ûood proneness of eastern India and Bangladesh. As the snow-melt-based run-off begins declining, one should expect a decline in run-off as well as groundwater recharge in this vast basin[2].

A major interplay of climate change and groundwater will be witnessed in coastal areas. Using the records of coastal tide gauges in the north Indian Ocean for more than 40 years, Unnikrishnan and Shankar (2007) have estimated a sea level rise between 1.06 and 1.75 millimetre (mm) per year, consistent with the 1 to 2 mm per year global sea level rise estimates of IPCC (2001). Rising sea levels will threaten coastal aquifers. Many of India’s coastal aquifers are already experiencing salinity ingress. This problem is particularly acute in Saurashtra coast in Gujarat and Minjur aquifer in Tamil Nadu. In coastal West Bengal and Bangladesh, Sundarbans (mangrove forest) are threatened by saline intrusion overland, affecting its aquifers. The precarious balance between freshwater aquifers and sea water will come under growing stress as sea levels rise. Coastal aquifers are thus likely to face serious threats from climate-change-induced sea level rise.

Thus climate change is expected to significantly alter India's hydro climatic regime over the 21st century. (IPCC Report, 2001) Added to this is the menace of arsenic and fluoride contamination in India and Bangladesh. Hence it is important to develop a policy whereby farmers adopt different irrigation technologies in response to climate change mainly on precipitation, temperature and water availability like watershed management and rainwater harvesting in order to have a sustainable groundwater extraction without depleting the resource.

Path to Sustainable groundwater management

Asia's population will reach 5 billion by 2050. How much more food would we need by then? Table 5 provides projection on future food demand for South, East and Central Asia.

Table 5

Food supply projections for Asia (million metric tons)

	South Asia			East Asia			Central Asia		
	2000	2050	% change	2000	2050	% change	2000	2050	% change
Wheat	96	205	114%	121	193	60%	13	26	100%
Maize	17	32	88%	184	341	85%	0.8	1.3	63%
Rice	113	202	79%	219	287	31%	0.4	1.1	175%
total cereals*	249	471	89%	529	935	77%	15	30	102%
Meat	8	32	300%	75	190	153%	1.5	3.7	147%
Milk	114	382	235%	19	60	216%	10	23	131%

Includes food, feed and other uses

(Source: De Fraiture 2009)

Feeding 1.5 billion additional Asian people by 2050 will require water development and management decisions that address tradeoffs between food and environmental security as also address the bigger question of sustainability of groundwater resources.

Thus it is clear that there is a need to produce more food with the available water resources and for that purpose, South Asia's irrigation systems need to be revamped keeping in mind that future irrigation systems will need to be efficient and flexible to meet the demands of many sectors, including farming, fishing, domestic use and energy supply. These systems would need to generate more value per drop of water and enable farmers to respond to challenges posed by volatile market conditions and climate change. How is this to be done?

From the above discussion it is clear that the countries of South Asia have a common problem of sustainable groundwater management. The way to solve the problem is to first address the institutional issues and look for a sustainable future by designing appropriate policies that will require an eclectic approach that must look into the issues of equity and justice in terms of property rights, address the externality problem generated by over extraction of groundwater resources, look at the feasible market structure for water transaction and build a roadmap for sustainability.

Property Rights to groundwater and addressing the externality problem

The central recommendation of the private property rights school was that environmental problems should be dealt with by the creation of secure, unambiguous and attenuated property rights over environmental assets. Transactions costs were to be dealt with by allocating property rights to the party in the best position to manage a given environmental problem, a task that Coase (1960) and Posner (1972) felt was best handled by courts interpreting common law.

However, as Randall (1983) pointed out, these two prescriptions pull in opposite directions. If property rights are secure and unambiguous, they cannot be rearranged in the interests of efficiency. The tension between security and efficiency has emerged in many cases where policymakers have adopted a property rights solution to problems of unsustainable water use (Quiggin 2001; Tan and Quiggin 2004).

The limitations of the Coasian property rights analysis have led to a resurgence of interest in ideas of common property. Ciriacy-Wantrup and Bishop (1975) and Dahlman (1980) refuted Hardin's description of the open field system. This was followed by work, such as that of Jodha (1986) and Wade (1987) that described the actual operations of contemporary common property systems in less developed countries. The most comprehensive treatment of the issue is that of Ostrom (1990).

The concept of common property has proved useful in the analysis of traditional irrigation systems. In the Sri Lankan system examined by Mahendrarajah (1986), land is privately owned and operated, but irrigation works are common property, and access to water during periods of drought is collectively managed. Common property ideas have also been applied to more general environmental issues such as the management of air sheds and river systems.

A Pigovian tax is a tax applied to a market activity that is generating negative externalities. The tax is intended to correct an inefficient market outcome, and does so by being set equal to the negative externalities. The Pigovian externality framework provides a useful set of tools for analyzing the causes of unsustainable patterns of resource use and for formulating appropriate policy responses. Quiggin (2001) refers to the distinction between unilateral externalities, in which the actions of one party affect the welfare of another, and congestion externalities in which many users of a resource create mutual externalities. Quiggin argues that the analysis of congestion externalities raises theoretical difficulties that are not easily resolved within the externality framework, and that analysis using the externality approach is best confined to the case of unilateral externalities. The classic remedy for externality is the imposition of a Pigovian tax, designed to equate marginal private costs and marginal social costs. In practice, however, regulatory restrictions combined with a legal right to damages or injunctive reliefs commonly provide a more workable approach

Market and Community based Options

Both externality and private property rights frameworks imply the need to 'set prices right'. Setting prices 'right' entails setting resource prices so that they approximately reflect their shadow prices. Prices of material inputs such as fertilizers, pesticides and irrigation equipment and other machinery have been brought closer to their true social costs through the removal of subsidies over the past two decades. The most pressing problems relate to valuing environmental resources such as groundwater. The market price of groundwater under conditions of open access is zero. Under these conditions, groundwater use exceeds the socially optimal level. To avoid overuse and wastage it is necessary to increase effective prices for groundwater. The effect would be to promote substitution of surface water for groundwater and to encourage the use of more water-efficient technology. An increase in the effective price of environmentally-generated inputs such as water would offset the prevailing bias towards environment-intensive technology.

Conserving groundwater requires, amongst other things, that it be regarded as a communal resource. This entails the existence of adequately defined property rights. This may involve assigning greater control over groundwater resources to local communities. Effective conservation policy will also require the provision of targeted financial rewards and incentives to conservation values.

Historically, environmental conservation or protection of environmental resources in South Asia , China and Africa has been the domain of the state, and a regulatory approach based on bureaucratic rationality has been the dominant discourse. However, this approach is under considerable strain (Singh, 1995). Critics argue that state-based conservation commonly requires elimination of subsistence agriculture undertaken by members of local communities

The preservation of environmental resources can, however, impose high costs on local communities in low-income countries, even though in some circumstances they benefit economically from the conservation of natural environments. Each case must be assessed individually. Where engaging in conserving environmental resources would disadvantage a local community, social gains would exceed the loss of the local; all could gain if there were adequate compensation for loss from engaging in conservation.

Improving the regulatory framework as well as physical infrastructure

Sustainability theory provides a useful starting point for the analysis of resource management issues, since it yields a set of binding constraints on permissible resource use paths. Under plausible assumptions about the social welfare function, sustainability criteria can be used to rule out resource use paths that imply degradation of natural resources, at least if the services supplied by those resources cannot be replaced at a lower cost. The rate of degradation of land and water resources in South Asia and China discussed above, appears, at least on a preliminary analysis, to be associated with an unsustainable resource use path. More detailed analysis of particular problems, such as declining water tables, is required to confirm this conclusion, and to develop specific options for remediating degraded resources or replacing the flow of services generated by those resources. Nevertheless, it seems likely that, once sustainable paths of resource use are identified, changes in policy will be required to meet the constraints implied by those paths. These include the following:-

a. Research and Development, Education and Extension

The central focus of the sustainability framework is on the identification of sustainable patterns of production and, conversely, of unsustainable patterns of resource use. A natural policy implication is the need for additional effort in research and development, education and extension. Better information is necessary to identify the set of sustainable options. Both research and development and extension activities can expand the frontier of the sustainable production sets, either by increasing the yield of agricultural production or by finding ways to reduce or mitigate the associated resource depletion.

South Asia has one of the lowest agricultural research intensities in the world. Ahmed in a paper (Ahmed, 2000) estimated that public investment in agricultural research in Bangladesh constituted only 0.25 per cent of its agricultural value-added. This is far less than in other countries of South and Southeast Asia. India and Pakistan invested 0.50 per cent and 0.58 per cent of their respective agricultural value-added.

A natural policy implication is the need for additional effort in research and development, education and extension. Better information is necessary to identify the set of sustainable options. Both research and development and extension activities can expand the frontier of the sustainable production sets, either by increasing the yield of agricultural production or by finding ways to reduce or mitigate the associated resource depletion.

If new approaches are to be successful, investors will need to direct funds towards training existing staff, attracting new talent through forward-thinking curricula and realistic remuneration packages and building the capacity of all stakeholders (including the irrigation bureaucracy). Initiatives might include updating engineering courses in universities, conducting in-depth training workshops for farmers and irrigation officials, and revamping irrigation departments to empower their workforces.

The results of research and development can only be implemented on the basis of a higher investment in education, extension and training with a view to: (a) building community awareness and sustaining interests in protection of environmental resources; (b) achieving better environmental management and outcomes; (c) building human capital embodying scientific knowledge and vocational skills; (d) valuing and enhancing complementarity between livelihood and conservation; and (e) empowerment of women.

b. Modernizing the surface based systems and changing the administrative structure

In Asia, most irrigation schemes were built before the 1970s, and have operated for 40 years and more and now needs to be modernized – both technically and institutionally, for example by being redesigned, operated and managed for a range of uses. Smart irrigation technologies, both old and new, will be essential to meet changing demands. For example, surface irrigation schemes could be used to recharge aquifers or fill intermediate storage structures, such as farm ponds, providing farmers with greater reliability and control.

Re-engineering or modernizing canal systems to mimic flexibility inherent in groundwater irrigated systems is the top investment priority in the region. This would involve a number of interventions; both hardware (physical) and software (capacity building).One of the main objectives in this context would be storage of rainwater through rainwater harvesting and aquifer recharge through watershed management. Some of the suggested option would be unbundling of irrigation services much on the lines of unbundling of electricity utilities in the region, use of piped delivery from tertiary and below tertiary level, better measurement at all levels, construction of farm level storage ponds to increase flexibility and re-orientation of canal bureaucracy towards better service delivery. In areas of physical water scarcity, there is huge potential for using precision irrigation and micro irrigation technologies and the time to promote them is now. Investing in managed aquifer recharge will help in controlling groundwater over-exploitation in the region. Farmers across South Asia are investing in supply augmentation through unplanned and ad hoc recharge. This needs to be done in a planful and sustainable manner.

The irrigation sector is embedded within Asia's wider political economy and therefore affected by external forces. Policies and programmes that influence agriculture, both directly and indirectly, come to drive developments in irrigation and it will become even more pronounced in the future. Framing policies to ensure external influences on water sector are properly understood and planned is one way to indirectly influence irrigation performance.

In sum, the strategy is to look for institutional solutions that work in practice and these need not necessarily be the 'text book' first best solutions. In much of the developing world, indeed, the 'second best' solutions often hold the key to successful policy changes (Molden et al., 2010).

Efforts to reform large-scale irrigation schemes by transferring management to farmers have had less-than-expected success throughout Asia. Many believe that the private sector could help irrigation entities improve water delivery, but it needs to be tested. For example, irrigation departments could outsource irrigation services, create public-private partnerships or provide incentives for irrigation officials to act as entrepreneurs in publicly managed operations. The roles government and the private sector would play in maintaining and operating irrigation systems should be clearly defined. There is a need for increasing accountability of the irrigation staff towards their clients (farmers) and for this purpose; there is a need for formulating better irrigation performance benchmarks.

c. Support to farmers' initiatives

While the area of surface irrigation has remained stagnant or been shrinking, farmers in South, East and Southeast Asia have raised yields using locally adapted irrigation technologies to scavenge water from surface sources, waste-water and groundwater using cheap motorized pumps. There are opportunities for investors to identify successful initiatives and direct funds towards schemes that emulate farmers' methods. New models are needed for managing groundwater in areas where 'individualistic' pump based irrigation has largely replaced centralized surface irrigation.

Conclusion

Over a period of the last four decades, South Asian agriculture has experienced significant intensification. The process of agricultural intensification due to a range of factors is both a cause and an effect of the extraordinary growth in groundwater irrigation. The livelihoods of a vast majority of the people in the region are critically dependent on the booming groundwater industry. However, as documented in this paper, the continued increase in groundwater-intensity of agriculture has caused significant damage to the physical environment and threatened the sustainability of agricultural production.

The central idea canvassed in this paper is that no single policy option or analytical framework can provide an adequate solution for the policy problems associated with irrigated agriculture and shared water resources. Rather it is necessary to adopt an eclectic analytical approach involving theoretical underpinnings of externalities, property rights, environmental and ecological economics and to employ both market and non-market instruments.

References

Adger, W.N. (2006). Vulnerability. *Global Environmental Change*, *16,* 268-281.

Ahmed, R. (2000, June 17), Agri-research ignored, *Daily Star*, p. 3.

Alauddin,M.& Hossain, M. (2001). *The Environment and Agriculture in a Developing Economy: Problems and Prospects for Bangladesh*. Cheltenham, UK : Edward Elgar.

Annual Report (2003).India. Central Ground Water Board.

Annual Report (2011).India. Central Ground Water Board.

Bardhan et. al. (2014). Evolution of land distribution in West Bengal 1967–2004: Role of land

reform and demographic changes. Journal of Development Economics 11,pp. 171–190

Carter, R. C. (2008 June) *Climate, population and groundwater in Africa*. Paper presented at the International Conference on Groundwater and Climate, Africa.

Chen, S. & Ravallion M. (2008). The Developing World Is Poorer Than We Thought, But No Less Successful in the Fight against Poverty. *World Bank Policy Research Working Paper No. 4703*. Washington D.C. USA.

Chilton PJ, Stuart ME, Escolero O, Marks R J, Gonzalez A and Milne CJ (1998). Groundwater recharge and pollution transport beneath wastewater irrigation: the case of Leon, Mexico. In Robins N S (Ed.). *Groundwater Pollution, Aquifer Recharge and Vulnerability.* Geological Society , London, Special Publications, 130, 153-168.

Ciriacy-Wantrup, S. and Bishop, R. (1975).Common property as a concept in natural resource policy. *Natural Resources Journal* 15(4), 713—727.

Coase, R. (1960). The Problem of Social Cost. *Journal of Law and Economics*, 3(1), 1–44.

Dahlman, C. (1980). *The Open Field System and Beyond*, Cambridge University Press, Cambridge.

DebRoy, A. and Shah, T. (2003) Socio- ecology of groundwater irrigation in India. In: Llamas R. and Custodio, E. (eds) *Intensive Use of Groundwater: Challenges and Opportunities*. Swets & Zetlinger, The Netherlands, pp. 307–336.

De Fraiture, C. (2009, October). Scenarios of water and food in Asia. *Background Paper # 2, submitted to Asian Development Bank*.

De Fraiture, C. & Wichelns, D.& Rockström, J.& Kemp-Benedict, E.(2007). Looking ahead to 2050: Scenarios of alternative investment approaches. In Molden, D. (Ed.), *Water for Food, Water for Life: A Comprehensive Assessment of Water management in Agriculture*. Earthscan, London; International Water Management Institute, Colombo.

Ebi, K.L.& R.S. Kovats & Menne.B. (2006). An approach for assessing human health vulnerability and public health interventions to adapt to climate change. *Environmental Health Perspectives,* 114, 1930-1934.

Ford, J.D.& B. Smit & J. Wandel (2006). Vulnerability to climate change in the Arctic: a case study from Arctic Bay, Canada. *Global Environmental Change*, 16, 145-160.

Foster, S. S. D. & Tuinhof, A.& Garduño, H. (2008). Groundwater in Sub-Saharan Africa – A strategic overview of developmental issues. In S. M. A. Adelana & A. M. MacDonald (eds) *Applied groundwater research in Africa*. IAH Selected Papers in Hydrogeology 13. Amsterdam: Taylor and Francis

Galllopin, G.C. (2006). Linkages between vulnerability, resilience and adaptive capacity. *Global Environmental Change*, 16, 293-303.

Giordano, M. (2005). Agricultural groundwater use in Sub-Saharan Africa: What do we know and where should we go? *Water Policy*. 7, 613-626.

Giordano, M. (2006). Agricultural groundwater use and rural livelihoods in Sub-Saharan Africa: A first-cut assessment. *Hydrogeology Journal*. 14 (3), 310-318.

Gosain, A. K. & Rao S. (2007). Impact assessment of climate change on water resources of two river systems in India. *Jalvigyan Sameeksha,* 22 21- 30.

Groundwater Scenario of India 2009–10, Central Ground Water Board, Ministry of Water Resources: http://www.cgwb.gov.in/documents/Ground Water Year Book%2 02009-10.pdf.

Hahn M.B.& A.M. Riederer & Foster S.O. (2009). The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change – a case study in Mozambique. *Global Environmental Change*, 19, 74-88.

Hongyun, H. & Liange, Z. (2007). Chinese agricultural water resource utilization: problems and challenges. *Water Policy* 9, (S1), 11–28.

Hunt, R.C.(1989) Appropriate social organization? Water user associations in bureaucratic canal irrigation systems. *Human Organization*, 48, 30-45.

Intergovernmental Panel on Climate Change (IPCC). (2001). *Third Assessment Report on Climate Change*. Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change (IPCC). (2007). *Fourth Assessment Report on Climate Change*. Cambridge University Press, Cambridge.

Jahan, N.& Alauddin, M.& Tisdell, C.A. (1999). Structural Reforms in Bangladesh Their Impact on Efficiency in Resource-Use, Equity and Environment. In Shand, R.T. (Ed.), *Economic Liberalisation in South Asia.* New Delhi, 436–464, Macmillan.

Jodha, N.S.(1986).Common Property Resources and Rural Poor in Dry Regions of India, *Economic and Political Weekly*, 21(27), 1169–1181.

Kay, M. (2001). Smallholder Irrigation Technology: Prospects for Sub-Saharan Africa. *IPTRID, Knowledge Synthesis Report No. 3*. FAO, Rome.

Kundzewicz, Z. W. & Doll P. (2008, June). *Will groundwater ease freshwater stress under climate change?* Paper presented in International Conference on Groundwater and Climate in Africa, Kampala.

Lawrence AR., Barker JA, Boonyakarnkul T, Chanvaivit S, Nagaesuwan P, Stuart ME, Thandet P and Varathan P. (1994). Impact of urbanization on groundwater: Hat Yai, Thailand. British Geological Survey Technical Report WD/ 94/16.

Lin, E. et al. (2006).*National Assessment Report of Climate Change (II): Climate Change Impacts and Adaptation. Advances in Climate Change Research*. 2(2),51-56.

Mahendrarajah, S. (1986). *Management of Common Property Resources: Intertemporal Exploitation of Village Dams in Sri Lanka.* Australian National University, Canberra, Australia.

Mainuddin, M. (2003, January). *Groundwater irrigation in Bangladesh: tool for poverty alleviation or cause of mass poisoning?* Paper Presented at Workshop on “Groundwater Socio-Ecology of Asia: Governing a Colossal Anarchy”, Colombo, Sri Lanka: International Water Management Institute, 26 January.

Masiiyandima, M. and Giordano M. (2007). Sub-Saharan Africa opportunistic exploitation. In: Giordano M and Villholth K (eds.) *The Agricultural Groundwater Revolution: Opportunities and Threats to Development. Comprehensive Assessment of Water Management in Agriculture Series 3*. IWMI and CAB International, Wallingford.

Milly, P. C. & Betancourt J.& Falkenmark M & Hirsch R. M. & Kundzewicz Z. & W, Lettenmaier D. P. & Stouffer R. J. (2008). Stationarity is dead: wither water management? *Science* 319, 573–574.

Molden, D. (Ed.) (2007) *Water for food, water for life. A comprehensive assessment of water management in agriculture*. London: Earthscan and Colombo: IWMI.

Molden, D. *et. al.* (2007). Trends in water and agricultural development. In: Molden, D. (ed.), *Water for Food, Water for Life: A Comprehensive Assessment of Water management in Agriculture*. Earthscan, London, and International Water Management Institute, Colombo.

Molden, D. *et. al.* (1998). Indicators for comparing performance of irrigated agricultural systems, IWMI Research Report 20, Colombo: International Water Management Institute

Molden, D. *et. al*. (2010). Governing to grow enough food without enough water: second best solutions show the way. *International Journal of Water Resources Development*, 26(2):249-263

Mukherji, A. & Fuleki B. & Shah T. & Suhardiman D. & Giordano M. & P.Weligamage.(2009). Irrigation reforms in Asia: A review of 108 cases of irrigation management transfer. *Background paper # 3. Submitted to Asian Development Bank.*

Namara R.E. & Horowitz L. & Nyamadi B. & Barry B (2011). *Irrigation Development in Ghana: Past Experiences, Emerging Opportunities, and Future Directions*. GSSP Working Paper No.27. Ghana Strategy Support Program, Accra, Ghana.

Ostrom, E. (1990) .*Governing the Commons: The Evolution of Institutions for Common Actions*, Cambridge: Cambridge University Press.

Posner, R. (1972) *Economic Analysis of Law*, Boston: Little Brown.

Quiggin, J. (2001). Environmental economics and the Murray–Darling river 32 system. *Australian Journal of Agricultural and Resource Economics* 45(1), 67–94.

Qureshi, A.S. & Akhtar, M. (2003, January). *Groundwater Economy of Pakistan*. Paper presented at Workshop on 'Groundwater Socio-ecology of Asia: Governing a Colossal Anarchy'. International Water Management Institute, Colombo.

Qureshi, R.H. & Barrett-Lennard, E.G. (1998). *Saline Agriculture for Irrigated Lands in Pakistan*. Monograph No. 50, Australian Centre for International Agricultural Research, Canberra, Australia.

Randall, A. (1983).The Problem of Market Failure. *Natural Resources Journal* 23, 131–4.

Rao Mohan J. (1995). Agrarian Forces and Relations in West Bengal, *Economic and Political Weekly*, Vol. 30, No. 30 (Jul. 29, 1995), pp. 1939-1940

Report on Global water supply and sanitation. (2008). Joint Monitoring Programme. WHO/UNICEF. Geneva: World Health Organization

Reid S. & Smit B. & Caldwell W. & S. Belliveau. (2007). Vulnerability and adaptation to climate risks in Ontario agriculture. Mitigation and Adaptation Strategy for Global Change, 12, 609-637.

Rodell, M., Velicogna, I. and J. Famiglietti (2009). Satellite-based estimates of groundwater depletion in India, *Nature*, Vol. 460, pp. 999-1002.

Roumasset, J.A. (1976). *Rice and Risk, Decision Making among Low-Income Farmers.* North Holland Publishing Co, Amsterdam.

Shah, T.(2006). Groundwater and human development: challenges and opportunities in livelihoods and environment. In: Sharma, B.R.& Villholth, K. & Sharma, K.D. (Eds.), *Groundwater Research and Management: Integrating Science into Management Decisions. Proceedings of IWMI-ITP-NIH International Workshop on "Creating Synergy Between Groundwater Research and Management in South and Southeast Asia"*, Rorkee, India 8–9 February 2005. International Water Management Institute, 14–26, Colombo.

Shah, Tushaar. (2007). The Groundwater Economy of South Asia: An Assessment of Size, Significance and Socio-ecological Impacts. In Giordano M. & and Karen G. Vilholth (Eds.) *The Agricultural Groundwater Revolution*, International Water Management Institute, Colombo.

Shah, T. (2008). *Taming the Anarchy: Groundwater Governance in South Asia*, Washington D.C.: The RFF Press.

Shah. T. (2009). Climate change and groundwater: India's opportunities for mitigation and

Adaptation. Environ. Res. Letters. 4, pp. 1-13.

Siebert S. & Burke J. & Faures J.M. & Frenken K. & Hoogeveen J. & Doell P & Portman F.T.(2010).Groundwater use for irrigation–a global inventory. *Hydrology & Earth System Science* 14, 1863-1880.

Singh P and Arora M. (2007). Water resources potential of Himalayas and possible impact of climate. *Jalvigyan Sameeksha* 22: 109–132.

Stringer L.C. & Dyer J.C. &. Reed M.S and A.J. Dougill. (2009). Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. *Environmental Science & Policy*, 12: 748-765.

Tan, P.L. & Quiggin, J. (2004). Sustainable management of the Great Artesian Basin: an analysis based on law and environmental economics. *The Australasian Journal of Natural Resources Law and Policy*, 9(2), 255–303.

The State of Food and Agriculture (2010), Food and Agricultural Organization, Rome, 2011.

Unnikrishnan A. S. & Shankar D. (2007). Are sea levels trends along the North Indian Ocean coasts consistent with global estimates? *Global Planetary Change* 57: 301-322.

Jelle Bruinsma (Ed.). (2003). *World Agriculture: Towards 2015/2030, An FAO Perspective*, Earthscan Publications, Food and Agriculture Organization (FAO), 2003.

Wada Y. (2010).Global depletion of groundwater resources. *Geophysical. Research. Letters*. 37. L20402

Wade, R. (1987). The Management of Common Property Resources: Finding a Cooperative Solution. *World Bank Research Observer* 2(2), 219–34.

Wang, J., S.G.A. Rothausen, D. Conway, L. Zhang, W. Xiong, I. P. Holman and Y. Li.(2012) China's water–energy nexus: greenhouse-gas emissions from groundwater use for agriculture. Environmental Research Letters 7(1), 14-35.

Weligamage, P., Barker, R., Hussain, I., Amarasinghe, U., Samad, M., 2002. *World Irrigation and Water Statistics*. International Water Management Institute, Colombo.

World Development Report (2010): *Development and Climate Change*; World Bank, Washington

World Bank (2010), Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India, World Bank.

31

Estimation of Natural Groundwater Recharge by using Soil Moisture Balance Approach in Different Geohydrological Settings of Barddhaman District, West Bengal

Biswajit Ghosh and Namita Chakma

Introduction

Increasing population and demand of food are accelerating the stretch of agricultural dimension which in turn are creating severe stress on availability of water. Food and Agricultural Organisation in a report stated that food production will be required to increase by 70% by mid of this century (www.fao.org/docrep/016/.../i3027e.pdf.). This will indeed create additional pressure on already stressed water resource due to which ecological supply system and ecological balance of water will get destroyed. Therefore, estimation and management of groundwater resources need a careful attention at this juncture for sustenance of human being.

Groundwater recharge can vary over time and space. Apparently, quantification of spatial and temporal rate of recharge of groundwater should be the fundamental pre-requisite for proper management of this important natural resource particularly in those areas where groundwater is in high demand as the key natural resource to economic development (Kumar, 2003). Various approaches are there to estimate groundwater recharge. Three main approaches of study are the Darcian approach, the Soil Water Balance approach and the Groundwater Level Fluctuation approach. Each of them has its own limitations.

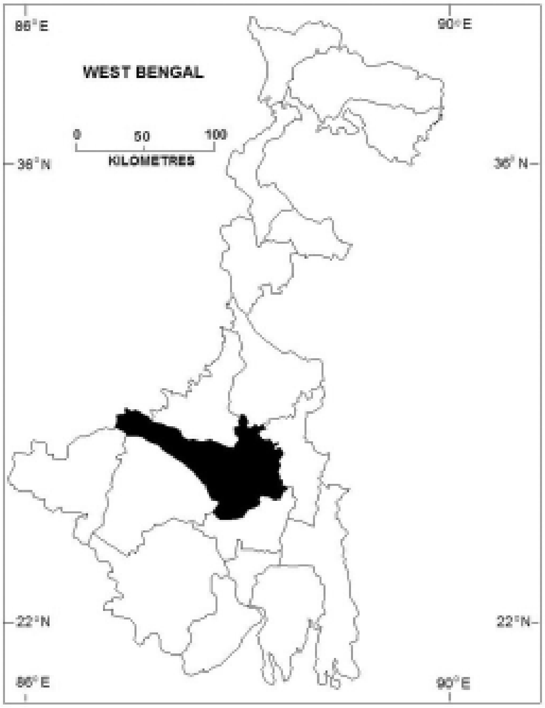
Therefore, the present study attempts to estimate a comprehensive and holistic picture of recharge of groundwater resources in different geohydrological settings incorporating different climatic parameters in Barddhaman district, West Bengal.

The Study Area

Barddhaman district holds prime position in rice production in West Bengal, India and therefore, precisely known as 'rice bowl' of the state. In **the** district about 58 percent of the total population is engaged in agricultural and allied activities (Census of India, 2011).The hydro-geological setting of Barddhaman district has created abundant groundwater resource. But intensive uses of groundwater for irrigation purposes and conventional agricultural practices particularly, in last two decades have caused significant reduction of these natural resources. Most of the C.D. Blocks in eastern Barddhaman produces three crops in a year. Major cropping patterns include paddy-wheat-vegetables, paddy–potato–sesame, paddy–vegetable–mustard and jute–paddy–vegetables. As per a report of the State Water Investigation Directorate (Ray and Shekhar, 2009), five C.D.Blocks in eastern part of the district namely, Bhatar, Ketugram-I, Mangalkot, Memari-II and Monteswar are at ‘semi-critical stage’ (based on stage of ground water development and long term pre-monsoon and post monsoon water level trend).

In the present study five C.D.Blocks of the district have been selected on the basis of their different level of dependency on groundwater resources. Manteswar and Memari-II have a high percentage (66.64% and 80.74%) of net shown area irrigated by groundwater whereas, three blocks Katwa-I, Katwa-II and Jamuria have different geological settings and low coverage of net shown area irrigated by groundwater (32.66%, 27.01%, and 0.2% respectively). Such selection clearly manifests the importance of estimation of recharge of groundwater resource in these blocks (see Fig.1).

Fig.1



Objective of the Study

The objective is to quantify the amount of groundwater recharge in different geohydrological settings of the study area.

Materials and Methods

To assess the recharge rate of groundwater different climatic data have been collected from secondary source (http://122.176.66.254/GISWEB/map1.htm). The date ranges from January, 2014 to September, 2015. Collected data have been analysed and represented using Microsoft Office Excel 2003, SPSS-16, and Map-Info professional (0.7) software. Recharge rate has been assessed using Soil Moisture Balance approach applied by Kumar (2003) and the formula is as follows:

$$Gr = P - Ea + ÄS - Ro$$

Where,

Gr = recharge;

P = precipitation;

Ea = actual evapotranspiration;

ÄS = change in soil water storage; and

Ro = run-off.

Recharge co-efficient has been calculated as a ratio between total amount of rainfall and total amount of recharge at a particular period of time.

Geo-Hydrological settings of the selected C. D. Blocks, Barddhaman District

Among the selected five blocks, Monteswar, Memari-II, Katwa-I and Katwa-II are located in the western sub-Basin part of the Bengal Basin, the largest fluvio-Deltaic to shallow marine sedimentary basin on Earth today. The western sub-Basin is placed between western fault and the narrow 'hinge zone' covering a significant part of western West Bengal. A series of buried basement ridges, marking the western margin of the Bengal Basin, presumably kept the Gondwana continental basins isolated from the main Bengal Basin through most of the Tertiary time (Sengupta, 1966). The western sub-Basin represents a complete lithostratigraphic succession from Lower Cretaceous to the most recent Alluvium.

The collision of the Indian plate with the Tibetan plate and Burmese plate in the Miocene resulted in a rapid switch in sedimentation pattern in the Bengal Basin. With the Miocene collision of the Indian plate there was a change from flysch to molasses sedimentation. The present day basin configuration with the Ganges – Brahmaputra Delta and the Bengal deep sea fans of the south was established in the Pliocene (Alam, 1989). In the process of shifting the river Damodar two alluvial fans have formed i.e. the Memari fan trending east and the Tarakeswar fan trending south. Cretaceous fluvial and deltaic sedimentation was slowly taken over by open marine and deep sea fan sedimentation under shallow water. This was actually succeeded by a downward movement and associated marine transgression in the upper cretaceous period. At the beginning of Cenozoic Era, a phase of marine regression occurred. It was followed by a pronounced transgressional phase during the Eocene period (Alam, 1989). Table 1 clearly manifests the connection of Bengal Basin to our study area.

Table 1

Stratigraphic succession of the study area along with western Sub basin of the Bengal Basin

Group	Formation	Lithology
Holocene	Alluvium	Sand, clay and gravel
Plio-Pleistocene- *Barind*	Barind	Clay, minor sand
Oligocene to Late Pliocene- *Bhagirathi*	Debogram/Ranaghat	Sandstone, siltstone, shale
	Pandua/Malta	Sand/mud stone
U. Palaeocene to Eocene- *Jayantia*	Memari/Burdwan	Sand/mud stone
	Kopili	Shale, mudstone, sandstone

	Sylhet Limestone	Limestone with sandstone
	Jalangi	Sandstone, mudstone
Rajmahal	Ghatal	Sandstone, limestone, shale
	Bolpur	Mudstone, sandstone and trapwash
	Dhananjaypur	Grey shale
	Rajmahal Trap	Basalt, and esite, intertrappeans

Source: Roy and Chatterjee, 2015

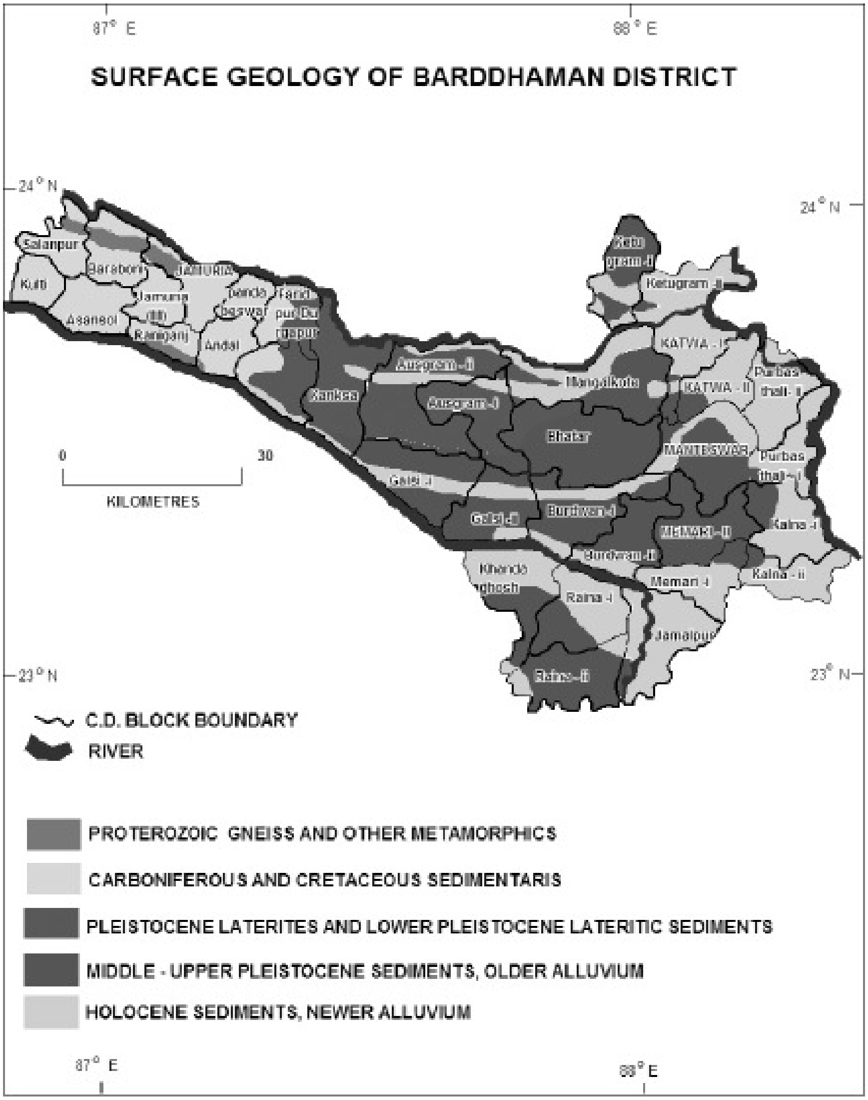
Therefore, it can be said that our study area except Jamuria C.D. Block is a part of Bengal Basin originated by a combined effect of sedimentation, plate tectonic, marine transgression and regression in different geological period of time. The area concerned got sediments by the river Bhagirathi-Hugli and its tributaries and the source of sediment was the peninsular Indian shield though the rate of sedimentation was varied in different time periods due to westward movement of Burma plate. Before late Pleistocene Himalayan sediments did not reach to the western part of Bengal Basin. But after that deposition of Himalayan sediments in Holocene period changed the geometry of the area to a greater extent.

The surface geology of the selected five blocks can be divided into three groups as follows:

Carboniferous-Cretaceous Sedimentaries: Most of the areas of Jamuria block which is a part of Chhotonagpur plateau is covered by this formation. This is called as the Raniganj formation with the lithology of sandstone-coal-shale. Another formation called supra-Panchet with the lithology of coarse grained ferruginous sandstone-red siltstone can be noted in a very little portion in the eastern part of Jamuria block.

Upper Pleistocene to lower Holocene sediments: It consists of older alluvium. Most of the areas of Monteswar and Memari-II blocks are covered by this formation. It is called as Sijua formation with the lithology of oxidised boulder-pebble-sand-silt-clay with *kankar*. It represents alluvial fill deposit characterised by oxidized sand, silt and clay impregnated with caliches and minor ferruginous concretion with development of Pedocal soil.(reference?)

Holocene sediments: It consists of newer alluviam deposited recently by the river Bhagirathi-Hugli and its tributaries. This sediment covers the entire part of Katwa-I and Katwa-II blocks which are nearer to Bhagirathi-Hugli and Ajay river. Same deposition can be seen on both sides of Khari river in Monteswar block. Low topographic bench occurring along the present day channels and present day levee consists of recently deposited alluvium with the lithology of sand-silt-clay having lateral and vertical extension and areas in such location which are relatively distant from the channels consists of Bhagirathi-Hugli formation, Arambag formation and Katwa formation with the lithology of boulder-pebble-sand-silt-clay. This formation is characterized by unoxidised sand with subordinate silt and clay. It is marked by abandoned channels, swamps and water logging. (reference?)



Hydrogeological units of the study areas

Two broad hydrogeological units can be identified in the study area as follows:

1. Porous hydrogeoological unit: The eastern part of the Barddhaman district is covered by a thick pile of unconsolidated sediments laid down by the Bhagirathi-Hugli river system. These unconsolidated sediments are made up of succession of clay, silt, sand and gravel of Quaternary age overlying Mio-Pliocene sediments. The Quaternary sediments are made up of recent and older alluvium. Occurrence and movement of ground water in this hydrogeological unit is controlled by the primary porosity of the sediments (Ray and Shekhar, 2009). Monteswar, Memari-II, Katwa-I and Katwa-II are the blocks where all the natural phenomena related to groundwater are conditioned by this unit to a greater extent.

2. Fissured hydrogeological unit: Fractures, Joints and other fissures form the secondary openings, through which ground water moves down the gradient, and occurs mainly under confined condition. These are developed in the Archaean to Proterozoic gneisses and schists in peninsular region occurring in western part of Barddhaman district (including Jamuria C.D.Block).

Aquifer condition in three different geohydrological settings of the study areas

(i) In Jamuria the aquifer consists of Gondwana sandstone. Here groundwater occurs in weathered residuum of sandstones with 12-20 metres in thickness. Yield of open wells constructed in such residuum ranges between 5 & 15 m^3/hr. In sandstones belonging to Lower Gondwana group of rocks, bore wells tapping fractured zones down to the depth of 100 m may yield 10 to 25 m^3/hr of water with a maximum draw down of around 20 m. The heterogeneity of fractures has limited the scope of large-scale development of ground water in this part of the state. Ground water abstraction structures like large dia open well, dug cum bore well, bore well and radial wells on the river beds, as enunciated above, are all feasible structures within sandstones as well. Gondwana sandstones are quite hard and compact and construction of deep bore well unlike other Gondwana Formations in the country, is done deploying DTH rig only (Ray and Shekhar, 2009).

(ii) Monteswar and Memari-II blocks are laying at the most eastern part of the study area. The thickness of older alluvium increases from 30 metres in the western marginal part to 150 metres towards east with increasing groundwater potentialities of aquifers from 50 to 120 m^3/hr. Individual aquifer in older alluvium is of limited thickness and discontinuous in nature. The water table is moderately deep with moderately high seasonal fluctuation. Depth to water level of the unconfined aquifer varies from 5 m to 10 mbgl. Big *dia* dug wells are feasible. If the dug wells are penetrated through the Laterites down to the lithomargic clay, chances for drying up the wells are less. Medium duty tube wells (about 100 m3/hr) in the depth zone of 100-400 m depth are feasible. Collector wells with radial infiltration galleries in stream bed tapping considerable thickness of sand bed are feasible. Due to high rate of fluctuation of groundwater these two blocks have been declared as semi critical (Ray and Shekhar, 2009).

(iii) Aquifers of Katwa-I and Katwa-II are comprised of unconsolidated recent alluvium. Ground water occurs both under unconfined and confined condition within the maximum explored depth of 600 m bgl. Aquifers are fairly thick & regionally extensive with large yield prospect of about 150 m3/hr. Heavy duty tube wells (>100 m^3/hr) of 150-300 m depth with housing about 35-40 m, if fitted with 18-20 HP pump may yield about 150-200 m^3/hr. Low duty tube well (50 m^3/hr) of 60 m depth tapping cumulative 8-10 m thick granular zones and fitted with 5 HP centrifugal/ submersible pump (depending on the depth to water level), may yield around 30 m^3/hr. Wherever aquifer is unconfined and depth to water level is shallow, dug wells are also feasible.

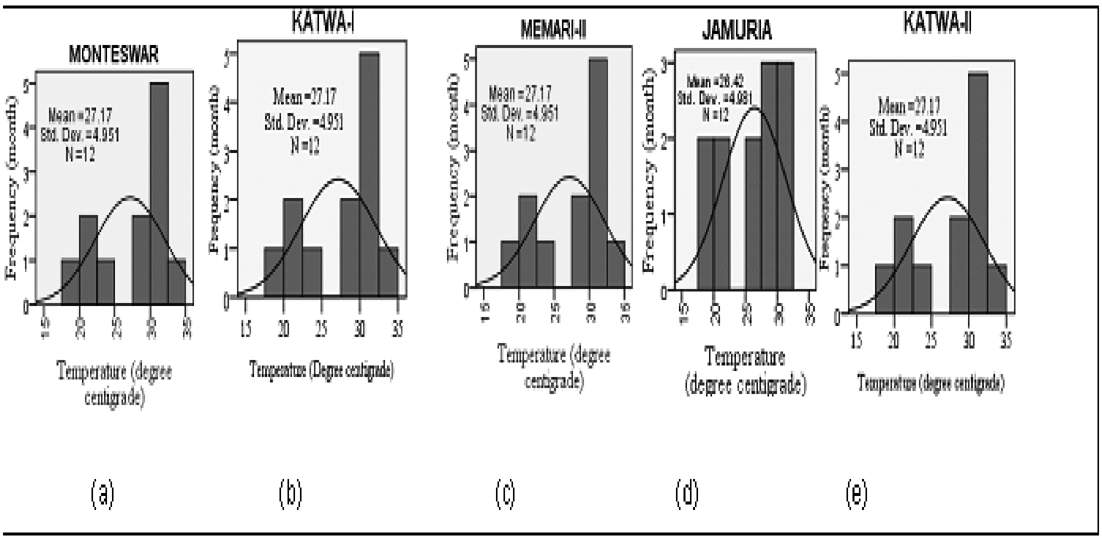
Results and Discussion

Recharge of groundwater is a natural phenomenon and it is dependent on a number of climatic variables like temperature, precipitation, surface runoff, soil moisture storage and evapotranspiration of the area concerned. The characteristics of these variables have been analysed in the selected blocks.

Temperature estimation

Being located in the same tropical region, Manteswar, Memari-II, Katwa-I and Katwa-II C.D.Blocks are experiencing similar temperature condition throughout the year. Temperature distribution in these blocks is negatively skewed indicating dominance of summer. Average temperature of these blocks is 27.17°C and in Jamuria it is 26.42 °C where eight months (March to October) experience temperature more than average and rest four winter months (November to February) experience temperature less than average. The month of April shows the maximum temperature (33 °C) whereas; the minimum temperature is experienced by the month of January (see Fig. 2 a,b,c,d&e).

Fig. 2
Distribution of temperature in the study area, 2014



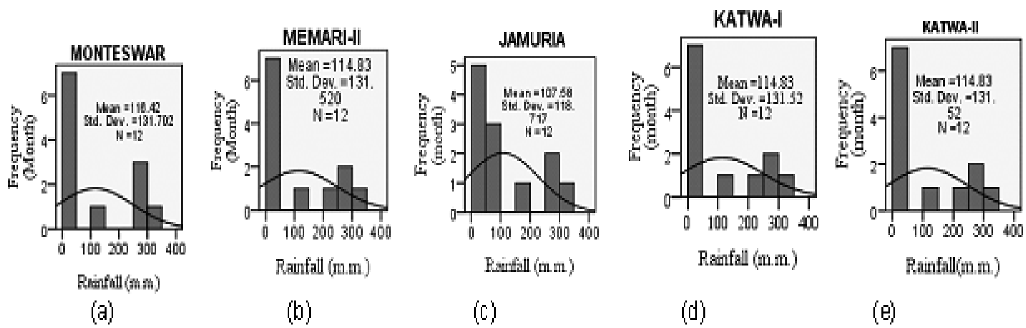
Source: Computed by the authors

Rainfall estimation

Due to monsoon climatic condition rainfall is not uniformly distributed throughout the year. 82% of rainfall occurs in summer i.e. from the month of July to September in all the blocks. Positive skewness of both the distribution of rainy days and distribution of amount of rainfall has been observed (see Figs. 3: a,b,c, d & e; Fig. 4: a,b,c,d&e). Total rainfall of the block of Monteswar, Memari-II, Jamuria, Katwa-I and Katwa-II have been recorded as 1397, 1378, 1291, 1386, 1380 millimeters respectively in 2014. Maximum rainfall occurred in the month of August (326 mm) in Jamuria and for other blocks it was the Month of September. In winter (December to February) number of rainy days and amount of rainfall are found to be at minimum. The months of April and November are devoid of any rainfall in Jamuria and for other blocks such months are January and November. Such uneven distribution of rainfall plays an important role in creating an uneven pattern of recharge of ground water. The deviation of rainfall in the block of Jamuria is relatively less than other blocks indicating less variability in its distribution.

Fig. 3

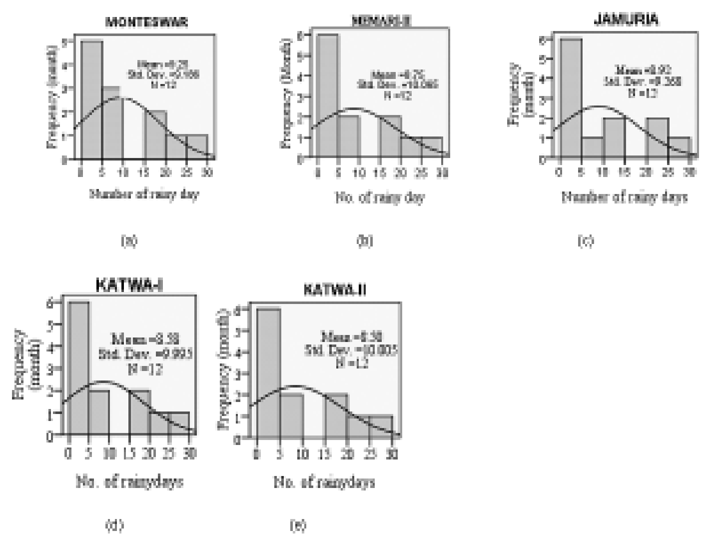
Distribution of rainfall in the study area, 2014



Source: Computed by the authors

Fig. 4

Distribution of rainy days

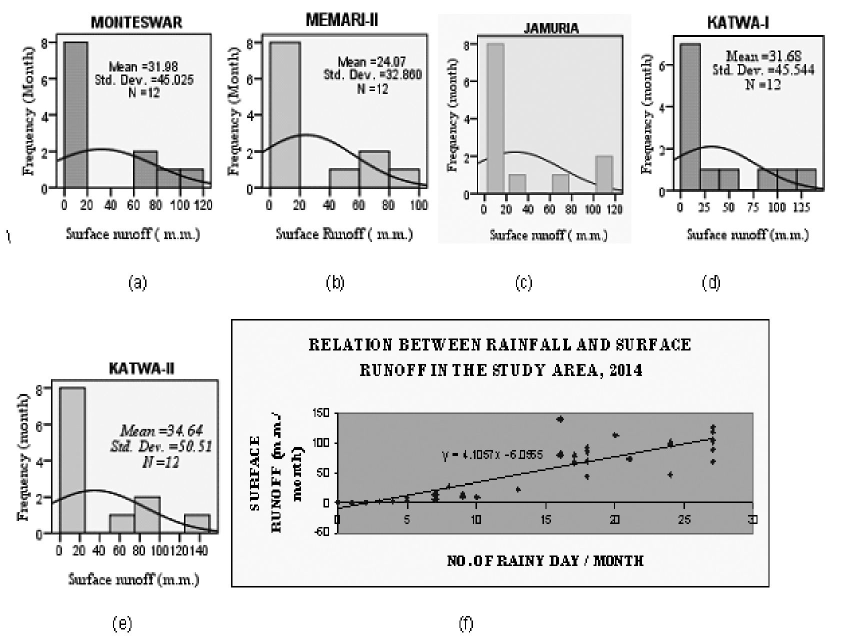


Source: Computed by the authors

Surface runoff estimation

Surface runoff in all the C. D. Blocks is positively related with the pattern of rainfall throughout the year and distribution pattern is not normal. It is significant in rainy season (June to September) and creates a favourable condition for groundwater recharge. In all the blocks its distribution is positively skewed but the mean surface runoff in Manteswar (31.98 mm/month), Jamuria, Katwa-I (31.36 mm/month) and Katwa-II (34.64 mm/month) is more than in Memari-II (24.07 mm/month). Khari river in Manteswar C.D. Block, Ajay river in Jamuria and Katwa-I C. D. Block and Hugli river in Katwa-II block play an important role in enhancing the surface runoff particularly in rainy season. It has also been found that Memari-II is showing less deviation in terms of its distribution than other C.D. Blocks. Eight months (October to May) with very low surface runoff creates an unfavorable condition with more discharge than recharge (see Fig. 5: a, b, c, d& e).

Fig. 5
Surface Runoff Estimation



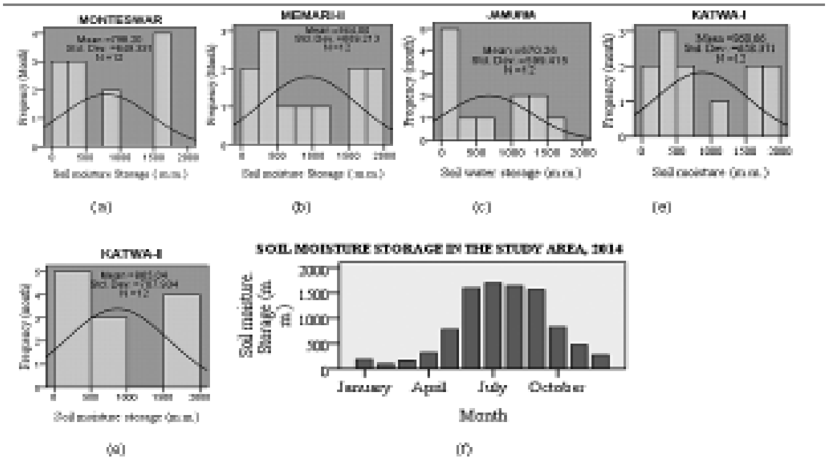
Source: Computed by the author

Soil moisture storage estimation

Soil moisture storage is dependent on the quality of soil and infiltrated water through soil increases the level of groundwater. Such recharge of groundwater is high in rainy season due to increased amount of rainfall. The rainy season records more storage of soil moisture in both the blocks and its pattern of distribution is positively skewed throughout the year. The mean value of this variable is more in Memari-II (944 mm^3) than other C.D. Blocks. Due to unfavourable surface geological condition the soil of Jamuria store less moisture (670 mm^3) (see Fig. 6: a, b,c,d,e&f).

Fig 6

Soil Moisture Storage Estimation



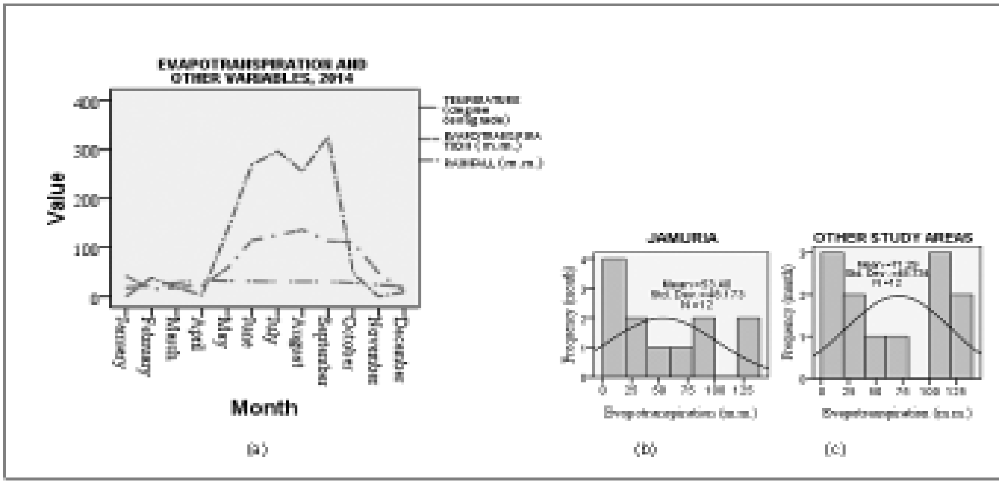
Source: Computed by the authors

Evapotranspiration estimation

Evapotranspiration is positively related with temperature and rainfall in all the C.D.Blocks. It is very high in rainy season when both rainfall and temperature are high whereas, when temperature is high and rainfall is low in summer then due to lack of moisture in the atmosphere evapotranspiration is found to be low. In winter evapotranspiration is normally low due to decreased temperature and rainfall. Its distribution is positively skewed in these C.D. Blocks. Its mean value is more in Memari-II than Manteswar but deviations from mean are equal (see Fig. 7: a, b& c).

Fig. 7

Evapotranspiration Estimation

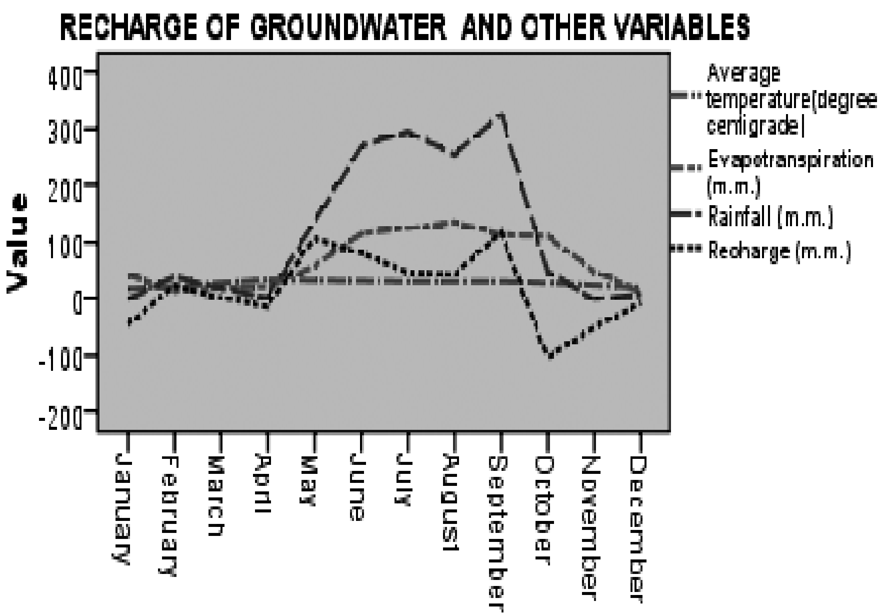


Source: Computed by the authors

Groundwater recharge estimation

Therefore, groundwater recharge is a combined effect of temperature, rainfall, surface runoff, change in soil moisture storage and evapotranspiration. Amount of recharge in Manteswar, Memari-II, Jamuria, Katwa-I and Katwa-II is 14.42%, 16.86%, 24.27%, 14.45%, and 13.31% of the total rainfall respectively in the year of 2014. Due to lack of rainfall, loss of soil moisture caused by evapotranspiration and withdrawal of groundwater; the months of January, March, April, October, November and December experience discharge of groundwater. Discharge is found to be at maximum in the months of October and November which is caused by lack of rain and relatively high temperature resulting in continuous evapotranspiration from moist soil immediately after rainy season than in winter season. High amount of rainfall by summer depression in the month of May and by south-east monsoon in the month of June, July, August and September; groundwater is recharged significantly in both the C.D.Blocks. Average recharge of groundwater in Manteswar, Memari-II, Jamuria, Katwa-I and Katwa-II is 16.78 m.m./month, 19.36 m.m./month, 28.11 m.m./month, 16.59 m.m./month and 16.28 m.m./month respectively in 2014. The distribution of recharge is positively skewed throughout the year but deviation of recharge from its average value is more in Memari-II, than other C.D. Blocks (see Fig. 8 & 9: a,b,c,d& e).

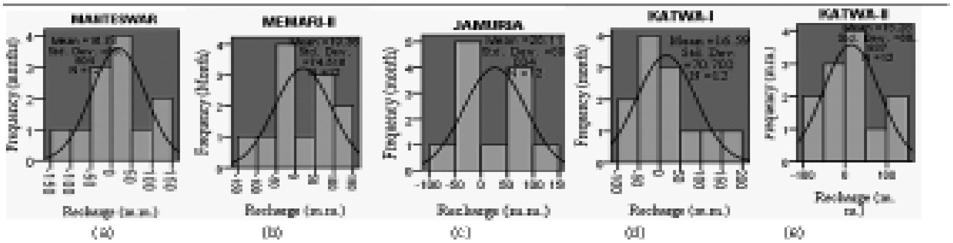
Fig. 8



Source: Computed by the authors

Fig. 9

Groundwater recharge in the study area, 2014



Source: Computed by the authors

Groundwater recharge estimation during 2014 and 2015: A comparison

To make a comparative study, data have been collected for 2015 also (up to September) and groundwater recharge has been estimated applying the same method. Finally, the results of both the years along with other climatic parameters have been compared using 'z' test (Das, 2010) as follows:

Let us take the *null hypothesis* that there is no significant difference in average temperature (°C) b... 14 and 2015 in Manteswar, against alternative hypothesis that average temp... n 2014 than that in 2015. That is symbolically we can write as, ...st *alternative, i.e., H_1: $\mu_1 < \mu$*

$$z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$= -0.29$

where H_o is null hypothesis and H_1 is alternative hypothesis;[Unable to lock or other memory problem | In-line.JPG *]* the mean, *S* the standard deviation and *n* is the sample size. (The same statistics has been applied in all other cases.)

Since, the calculated value of | Z | = 0.29 is lesser than the critical value of 1.64 at 5 % level of significance, the *null hypothesis* is accepted. Hence, it is inferred that there is no significant difference in average temperature (°C) between the year of 2014 and 2015 in Manteswar. Similar calculation has been used for other cases. Thus the result is showing that recharge of groundwater along with other climatic variables differ significantly between the year 2014 and 2015 in all the selected C.D. Blocks and are more in intensity in 2015 than in 2014 (see Table-1; Fig. 10: a, b, c, d, e).

Though temperature in both the years are similar but number of rainy days and amount of rainfall in 2015 are more than in 2014, therefore, intensity of surface runoff, soil moisture storage have been increased in 2015 with the resultant increase in recharge of groundwater. Groundwater in the month of January in 2015 due to sudden rainfall is experiencing recharge instead of discharge in 2014. Due to more intensive rainfall, the months of March, June, July and August in all the C.D.Blocks are experiencing more recharge of groundwater in 2015 than 2014. Highest amount of recharge is found in the month of July, 2015. Because of higher rate of evapotranspiration caused by prevailing dry condition and very low amount of rainfall, the months of April, May and September of 2015 have experienced more discharge of groundwater in all selected areas.

Table 2

Groundwater condition and hydrogeological set up of the study area

C. D. Blocks	Average temperature (°C)		Rainfall (mm/year)		Evapotranspiration (mm/ month)		Soil moisture storage (mm/day)		Surface geology	Lithology	Aquifer condition	Depth of groundwater (mbgl)	Yield prospect (m^3/hr)	Recharge co-efficient		Remarks
	2014	2015	2014	2015	2014	2015	2014	2015						2014	2015	
Monteswar	27.17	27.16	1397	2136	67.85	70.69	26.6	35.2	Upper Pleistocene to lower Holocene sediments	Oxidised boulder – pebble – sand - silt - clay	Unconsolidated/ Older Alluvium	5 to 20	50 to 120 m^3/hr	0.144	0.142	Semi-critical
Memari-II	27.17	27.42	1378	1927	71.29	78.90	31.5	43.1	Upper Pleistocene to lower Holocene sediments	Oxidised boulder – pebble – sand - silt - clay	Unconsolidated/ Older Alluvium	5 to 20	50 to 120 m^3/hr	0.169	0.165	Semi-critical
Jamuria	26.42	27.55	1291	1699	53.40	72.14	22.33	33.53	Carboniferous-Cretaceous Sedimentaries	Sandstone – coal - shale	Gondwana Sandstone	12 to 20	5 to 15 m^3/hr	0.243	0.274	Safe
Katwa-I	27.17	27.16	1378	1969	65.53	70.37	28.97	38.5	Holocene sediments	Sand - silt -clay	Unconsolidated / Recent Alluvium	5 to 10	150 m3/hr	0.144	0.167	Safe
Katwa-II	27.17	27.16	1378	1969	64.81	70.92	28.3	42.23	Holocene sediments	Sand - silt -clay	Unconsolidated / Recent Alluvium	5 to 10	150 m3/hr	0.133	0.158	Safe

Source: Compiled by the authors

Conclusion

Monteswar, Memari-II, Katwa-I and Katwa-II are identical in term of geomorphic characteristics. There is small difference in geological and meteorological perspectives which create minor differences in recharge rates of groundwater. Irrespective of this fact Monteswar and Memari-II are showing semi critical state in terms of groundwater condition due to high rate of fluctuation of groundwater level between pre monsoon and post monsoon period whereas, Katwa-I and Katwa-II are in safe condition. This fact indicates that the withdrawal of groundwater in post monsoon period in two semi critical blocks causing too much fluctuation of groundwater level.

On the other hand, Jamuria with totally different geological and geomorphological settings is showing a different picture. Here due to weathered residuum at the upper surface and existence of fractures in rocks recharge rate is more than other blocks. Though the geological setting of this block helps the groundwater to be recharged more but it also creates several difficulties like seepage of groundwater in mines, drying up of open wells in summer season, pollution of groundwater due to seepage of polluted water in mines into groundwater. Construction of tube wells is very difficult in this area. That is why agricultural use of groundwater in this area is very less in percentage.

Considering hydrogeological conditions, geomorphological set up, groundwater resources potential and the resulting recharge rate of groundwater proper strategy for further ground water development should be formulated particularly in Monteswar and Memari-II blocks. Ground water development in these blocks located in older alluvial areas, falling under “Semi critical” category, may be done with caution and in a phased manner. Effective planning is needed based on the results of monitoring of water levels and trend of water levels during different seasons. Here too much discharge of groundwater during dry winter is the main impediment for groundwater development. Therefore, a sustainable planning is required without affecting the agricultural perspective. For this nature of agricultural practice need a careful and detailed monitoring. Beside this, in the hard rock terrain of Jamuria C. D. Block, in order to mitigate the problem of sustained drinking water supply, even during the rainy season, the dug/ dug-cum-bore wells may be constructed tapping the entire thickness of the saturated weathered residuum and part of the fractured rocks where a greater thickness of the saturated fractured rocks exist.

References

Alam, M., Alam, M. M., Curray, J. R., Chowdhury, M. L. R. and Gani, M. R.,(2003), An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basinfill history. *Sediment. Geol.*, **155**, 179–208.

Census of India, 2011.

CGWB, 2006; Report on Ground Water Resources of West Bengal, based on GEC, 1997, Methodology.

CGWB, 2007; Hydrogeological Framework And Groundwater Resources Of West Bengal State.

CGWB, 2008;Ground Water Year Book, 2007-08, of West Bengal, Central Ground Water Board, Eastern Region.

Das, N.G. (2010). *Statistical Method* Combined Edition (Volume I & II), Tata McGraw Hill Education Private Limited, New Delhi.

Geological Quadrangle map 73M and 79A, Geological Survey of India, Kolkata.

GoWB: Provisional Census, 2011. Barddhaman District

GSI, 1999; Geology & Mineral Resources of the States of India, Part-I, West Bengal, Geological Survey of India, Miscellaneous Publication No. 30, 1999.

http://122.176.66.254/GISWEB/map1.htm WEB GIS of West Bengal Accelerated Development of Minor Irrigation Project

Kommadath, A. (2000), Estimation of Natural Ground Water Recharge, http://ces.iisc.ernet.in/energy/water/proceed/section7/paper5/section7paper5.htm#SWB

Kumar, C. P. (2014), *Groundwater Data Requirement and Analysis*, Scientific Essay, 978-3-656-75553-1, GRIN Publishing GmbH, Munich, Germany.

Kumar, C. P (2003), Estimation of Ground Water Recharge Using Soil Moisture Balance Approach, National Institute of Hydrology, Technical Report No. TR-142, pp: 66

Kumar, C. P. and Surjeet Singh (2011), Impact of Climate Change on Water Resources and National Water Mission of India, Proceedings of National Seminar on Global Warming and its Impact on Water Resources, 14 January 2011, vol-1, Kolkata, pp. 1-9

Kumar, C. P. (2012), Climate Change and Impact on Groundwater Resources, *International Journal of Engineering and Science, Vol. 1,* PP: 43-60

Ray, A. and Shekhar, S. (2009) Ground Water Issues and Development Strategies in West Bengal, *Bhujal News*, v.24(1), pp.1–17.

Roy, A.B., and Chatterjee, A., (2015), Tectonic framework and evolutionary history of the Bengal Basin in the Indian subcontinent, *Current Science, 109*, 271 – 279.

Ruston, K.R.,Eilers, V.H.M and Carter, R.C, (2006), Improved soil moisture balance methodology for recharge estimation, *Journal of Hydrology, 318(1-4),* 379 - 399.

Sengupta, S., (1966), Geological and Geophysical studies in the western part of Bengal Basin, India, *Am. Assoc. Pet. Geol., Bull., 50*, 1001 – 1017.

Silva, C.S.D & K. R. Rushton, (2007), Groundwater Recharge Estimation Using Improved Soil Moisture Balance Methodology For A Tropical Climate With Distinct Dry Seasons, *Hydrological Sciences Journal, 52 (5),* 1051- 1067.

www.fao.org/docrep/016/.../i3027e.pdf The state of food insecurity in the world-2012-Food and Agricultural Organisation. Retrieved on February 2, 2015

32

Geomorphological characteristics of Doon Valley in Uttarakhand based on Remotely Sensed Digital data and GIS tools

D. K. Mandal

Introduction

The invention of Remote Sensing and GIS has opened new vistas in the field of geoscientific studies, viz. landform mapping, geological mapping, ground water targeting, mineral exploration, geo-hazard studies etc. The use of aerial photographs and satellite imagery is known for visualizing the landscape since time immemorial. The synoptic view provided by the satellite imagery helps in understanding and correlating various landforms, which cannot be readily observed from the ground due to limited range of observation.

The Doon Valley is an asymmetrical longitudinal synclinal Valley, which lies between two hill mountain ranges. The Lesser Himalayan mountain ranges lie in the north, and Sub-Himalayan (Siwalik) hill ranges in the south. Two major rivers of the Indian subcontinent, Yamuna, in the west and Ganga in the East form the boundary. The Valley has general elevation of 600m from MSL whereas the hills are as high as 2000m from MSL in the northeastern part of the study area (DEM, i.e. figure 2).

The Song River, one of the tributaries of Ganga river system is considered to be the principle drainage system of the study area. The upper reaches of the Song River is perennial whereas the lower reaches appear dry due to base flow. In lower reaches, the river displays braided pattern. Structurally controlled drainage is commonly seen in the study area. Drainage texture and patterns are controlled by different litho units, structure and morphology. In Siwalik region drainage pattern is sub-dendritic to sub-parallel and while in pre-tertiary rocks, sub-dendritic pattern is seen. The hilly region is characterized by fine drainage texture and the Valley area by coarse texture.

Objectives

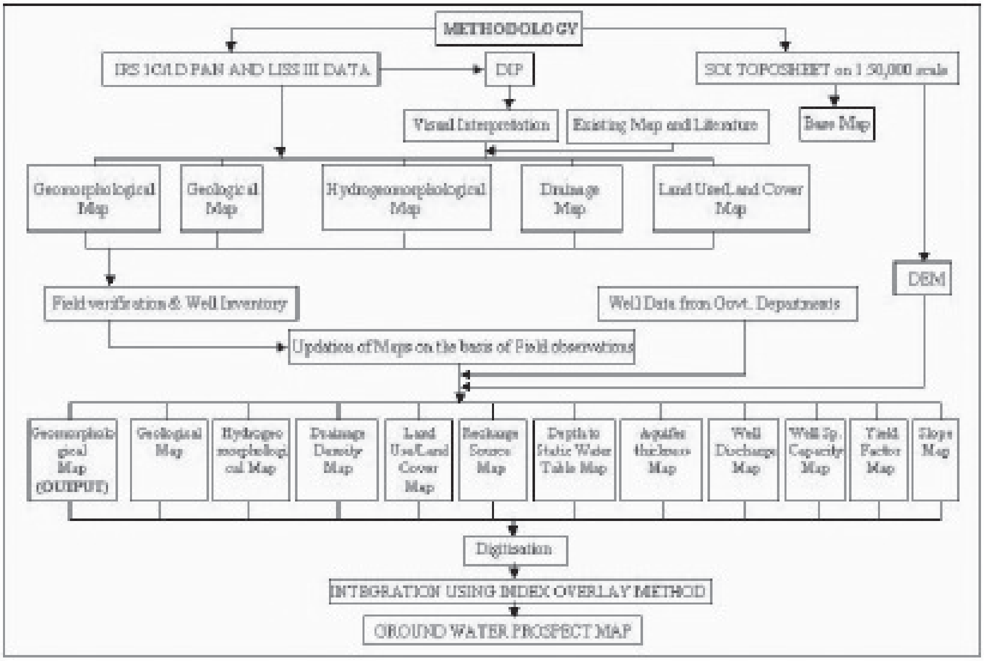
The prime objectives of the present study are as follows:

i) To understand the geomorphic processes involved.
ii) To identify and map different landforms/ geomorphic units.
iii) To identify and map parameters controlling the rate of denudation, such as lithostratigraphy, structure, drainage density, slope, land use/land cover, etc.

Methodology

The methodology adopted in preparing this paper has been shown in the given flow chart (figure 1).

Figure 1



Study area

The study area covers eastern part of Doon valley and its surroundings having association with lesser Himalayas in the north, Siwalik Hills in the south, River Ganga in the Southeast and Dehradun town in the west. It covers about 740 sq. km and is bound between 78º 05’N and 78º 25’E longitude, and 30º 05’ and 30º 30’N latitude. It falls in SOI Toposheet Nos. 53J/3, 4, 7and 8.

Geomorphology

Importance of Remote Sensing in Geomorphological study

The science, which measures, describes and classifies the various forms of land, ice and water at the earth’s surface is called geomorphology. Descriptive Geomorphology is concerned with surface configuration, dynamic geomorphology with the process, which modifies this configuration. Photo and image interpretation is employed intensively in descriptive geomorphology and to varying degrees in the areas of dynamic geomorphology.

Remote Sensing and Geographical Information System are being considered as most important tool in geomorphological study since 1970s. In earlier days, geographers have often been handicapped in the pursuit of their fieldwork by considerations of time, expenses, distance and weather. Now-a-days, aerial photograph and satellite imagery are used to increase the efficiency of geographic fieldwork. Even in some circumstances, they provide the near equivalent of field conditions. When used in the laboratory, aerial photographs and satellite imagery often reveal details that cannot be seen on the ground and show spatial relations which are realized in the field with great difficulty or not at all.

When used in the field, a photograph enables the geographer to increase the speed, accuracy and detail of his survey. The geomorphologists employ aerial photographs and satellite imagery as a tool, a source of information, and a permanent record. Photographs as tools help him to define his problem, get acquainted with the area of study, plan field traverses, extend his field of view into areas beyond the horizon while on reconnaissance, and study inaccessible areas. Geomorphologists also use the photographs and imagery as a map substitute or as a base upon which to record information

Many landforms are so large that they cannot be seen as a whole from any position on the ground. Moreover, the orientation and pattern of landforms cannot be readily observed from the ground, though details can be mapped in the field. Aerial photographs and satellite imagery greatly extend the geomorphologists range of observation, and even reveal features, which could not be observed in the field at all. Geographic geomorphology stresses more on distribution than structure, process and stage. The geographer's view of landform is discussed by Keseli (1950), Pettier (1954) and by Russell (1949). The literature on photo-interpretation in geomorphology is voluminous. Photo interpretation in geomorphology is generally carried on at the scale of 1:20000. At this scale most landforms can be seen very clearly. Hemphill (1958) shows that scale smaller than 1: 50000 are sometimes desirable. It may be noted that geomorphologists are not only determining past climate through changes in terrain pattern, but also determining the effects of past changes in climate upon present geomorphology (Smith 1949b).

General Geomorphic Set-up

Doon Valley is an intermontane valley located within Siwalik foreland basin in Garhwal Himalayas. It is 80 km in length and 20 km in average width with Siwaliks range to its south and Mussorie range to its north. Along the northern margins of the Doon valley, the Main Boundary Thrust (MBT) brings the Precambrian rocks of the lesser Himalayas zone to override the Siwalik group, whereas a sudden topographic rise of the Siwalik range demarcates the Himalayan Frontal Thrust (HFT), locally called the Mohand thrust that separates the Siwalik group from the recent alluvium of the plains. The large part of the valley is occupied by a broad synclinal depression, called the Doon syncline. To its south, lies a complementary fold structure, Mohand anticline, and to its north is the Satokgarh anticline. The fold structure has folded the Siwalik strata and owes their origin as fault-propagation folds developed as a result of southwestward propagating Mohand Thrust. The Mohand anticline, a growing fold structure, uplifted the Siwalik range and retracted the drainage within the Doon valley. The upliftment of Siwaliks created a water divide separating the northeast flowing streams into the valley from the southwest flowing streams across the Siwalik ranges into the Bhabar plains. In the northern part of the study area, streams originated from the southern slopes of the Massurie range flowing south and southwest and joining south east flowing river Song (Thakur, 1995). The Doon gravel, the post-Siwalik sediments, was deposited as co-eval sediments with the growth of fold structures and neotectonic activity along the main boundary thrust.

To the north and northeast, the rocks of the foreland basin are separated from the older, mostly Precambrian formation of the Lesser Himalaya along the Main Boundary Thrust (Karunakaran & Rao, 1979). The Lessser Himalaya is characterized by higher elevation (2000-4000m) than the outer Himalayan, and there is an abrupt change in relief north of the MBT. To the south, the sudden rise of Siwaliks from the Indian alluvial plains is demarcated by south verging Himalayan Frontal Thrust system. This fault system is considered to be the principal present day tectonic displacement zone with convergence rate of 10-15 mm/yr, i.e. about one fourth of the convergence rate between Indian and Eurasian plates (Yeats, et al., 1991& 1992).

Figure 2

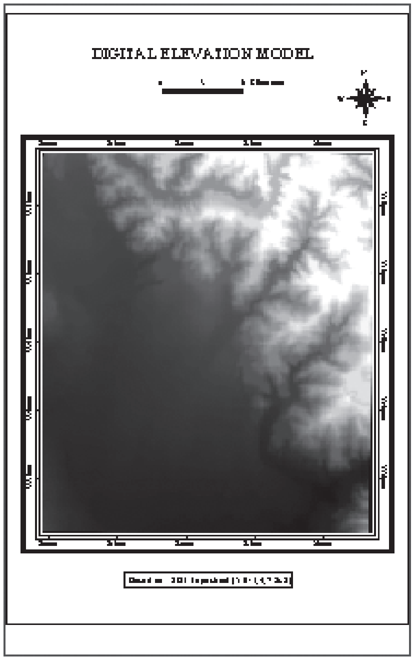


Figure 3

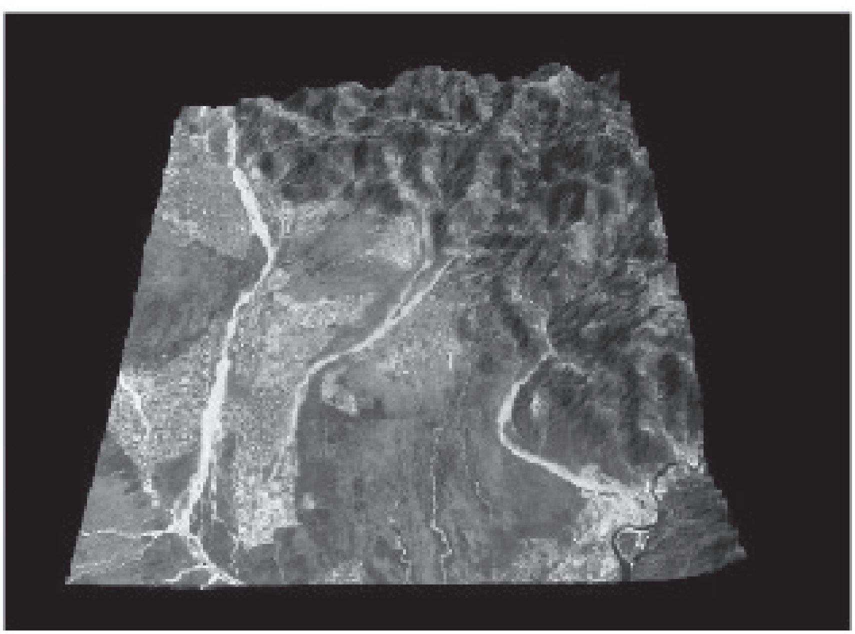
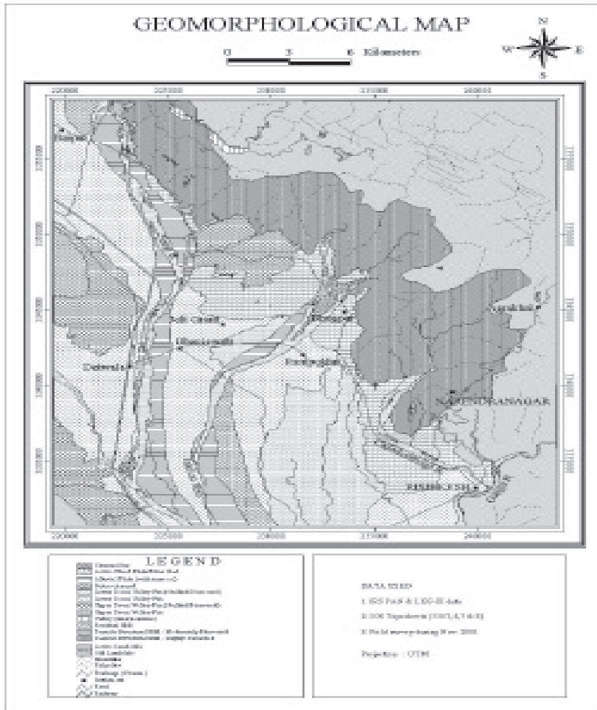


Figure 4



Conclusion

1. Remote Sensing and GIS techniques are useful tools in geomorphological studies.
2. Based on visual interpretation of satellite, different landforms/geomorphic units have been identified and mapped in the study area, viz. Denudo-structural hills-moderately/Highly dissected, Residual Hills, upper Doon Valley Fan, Alluvial Plains, Flood Plains, Channel/ Point/ Braided Bars, plaeaochannels, etc. The denudo-structural hills are basically formed by the Siwaliks and Pre-Tertiary rocks. Residual hill is formed by the old Doon gravel. The central and southern hill is formed by the old Doon gravel. The central and southern part of the area is occupied by the Doon Fan. The area on either side of the major rivers like Song and Jakhan Rao is characterized by fluvial deposits.
3. The distribution and type of land forms/geomorphic units as mapped from the satellite data in conjunction with the field checks helped understanding the geomorphic processes involved in carrying out the present day topography.

References

Burrough, Peter A. and McDonnell, Rachael A., 2000: *Principles of Geographical Information System: Spatial Information Systems and Geostatistics,* Oxford University Press, Noida, India, 1st. Edi. 333p.

Cromley, Robert G., 1992: *Digital Cartography,* Prentice Hall, New Jersey, 317p.

Davis, John C., 1986: *Statistics and Data analysis in Geology,* John Wiley & Sons, New York, 2nd. Edi., 646p.

Doornkamp, John C. and King, Cuchlaine A., 1970: *Numerical analysis in Geomorphology: an introduction,* Edward Arnold (Publishers) Ltd., London, pp. 115-203.

Graeme F. Bonham-Carter, 1993: *Geographic Information Systems for Geoscientists: Modeling with GIS,* Pergamon (Elsevier Science Ltd.), New York, pp. 1-335.

Hemphill, W. R., 1958: *Small scale Photographs in Photogeologic Interpretation,* Photogrammetric Engineering, 24: 562-567.

Hutchinson, M. F. and Gallant, J. C., 1999: *Representation of Terrain,* In: Geographical Information Systems. Edi. by Longley, Paul A., Goodchild, Michael F. Maguire, David J. and Rhind, David W., John Wiley & Sons Inc., New York, Vol. I, pp. 105-124.

Jensen, John R., 1996: *Introductory Digital Image Processing: A Remote Sensing Perspective,* Prentice Hall, New Jersey, 316p.

Joshi, R., 2000: *Geology of Doon Valley: A review,* Quaternary Journal of Geological Association & research Centre, Balaghat (M.P.), Misc. Pub. No. 12, pp. 1-24.

Karunakaran, C. and Rao, A., 1979: *Status of exploration of hydrocarbons in the Himalayan region–contributions to stratigraphy and structure,* Miscellaneous Publication, Geological Survey of India, 42, 1-66.

Kesseli, J. E., 1950: *Geographic Geomorphology,* Yearbook of Association of Pacific Coast Geographers, Presidential Address, 8p.

Lee, J. B., Woodyatt, S., and Berman, M., 1990: *Enhancement of High Spectral Resolution Remote Sensing Data by a Noise-adjusted Principal Components Transform,* IEEE Transactions on Geoscience and Remote Sensing, 28(3):295-304.

Miller, C. L. and Laflamme, R. A., 1958: *The Digital Terrain Model – theory and application,* Photogrammetric Engineering, 24(3): 433-42.

Nakata, T., 1972: *Geomorphic history and crustal movements of the foot hills of the Himalayas,* Report of Tohoku University, Japan, 7th Series (Geography), 22, 39-177.

33

Status of Soil pH and its' Impacts on Agricultural Productivity in Mangolkote C.D. Block, Barddhaman, West Bengal

Kshudiram Chakraborty and Biswaranjan Mistri

Introduction

Soil pH depicts concentration of hydrogen ion [H^+] ion in respect to hydroxyl ion [OH^-] and acid soil solution has [H^+] > [$OH^–$]; an alkaline solution has [H^+] < [$OH^–$], and equal concentration of [H^+] and [$OH^–$] in neutral soil solution (Chesworth, 2008). pH is the most important property among all other chemical characteristics of soil for determining the chemical environment of higher plants and soil microbes (Bolan and Kandaswamy, 2005; Thomas, 2006). Lowering of pH starts from initial phase of soil formation but rate of acidification accelerates through agricultural activity because of deposition of sulfur (S) and nitrogen (N) compounds (Hicks et al., 2008; de Klein et al., 1997; Helyar and Porter 1989). Availability of molybdenum in pH range 6 to 7 favours nitrogen fixation and mineralization of organic nitrogen (Thomas, 2006). Generally, pH range of 6 to 7 indicates optimum soil condition for crop growth, with minimum negative consequences (Thomas, 2006; Foth, 1990).

However, change of pH in soil happens when production of hydrogen ion (H^+) exceeds the consumption of H^+ (Bolan et al. 1991). Nitrogen enters into agro-ecosystem mainly through biological N_2 fixation and addition of fertilizer, and removes through NO_3^- leaching, denitrification, NH^3 volatilisation, and product removal (de Klein et al., 1997).

Table 1

Production of H^+ in soil system (Van Breemen et al. 1983; Bolan et al.1991)

Process	Reaction equation	H^+ production (molc/mol N)
NH4+ assimilation	NH_4^++R.OH'! R.NH_2+H_2O+H_+	+1
NH3 volatilisation	NH_4^+ '! NH_3 + H^+	+1
Nitrification	NH_4^+ + 2 O_2 '! NO_3^- + H_2O + 2 H^+	+2

In humid region, acidity develops through weathering of primary minerals through replacement and leaching of base-forming cations like calcium (Ca^+), magnesium (Mg^+), potassium (K^+) and sodium (Na^+) by H^+, Al^{+3} (Foth, 1990). Excessive use of sodium, potassium and nitrogenous fertilizer make negative impact on pH and structure of soil (Savci, 2012). Declination of soil pH in agro-pedological systems may create moderate to severe Al^{+3} and Mn^{+2} toxicity which affects long-term economic viability of farming system and degradation of soil resource (Rengel, 2003). Maintaining 'healthy' soil pH 6 to 7 through application of lime provides satisfactory growing condition by reducing Al^{+3} and increasing calcium (Wolf and Snyder, 2003). So, a soil acidification model can be used to calculate requirement of lime for maintaining the soil pH at the desired level (i.e. 6-7) (Rengel, 2003; de Kelin et al., 2010). In this research work, the status of soil pH in different cropping system has been studied as a principal property of the soil and influential factor for productivity of crops.

Study Area

The area of the Block is 365.442 km^2 and population density is 640 person/km^2 whereas physiological density is 793 person/km^2 (Census, 2011). The latitudinal and longitudinal extensions are 23° 27' 49" to 23° 39' 14" N and 87° 43' 49" to 88° 03' 46" E respectively. Net Shown Area (NSA) is 295.43 km^2 (80.84%) and rice is cultivated in 64% of NSA with 72% land under canal irrigation. Single, double and triple cropped lands are 7.53%, 53.62% and 38.85% respectively with cropping intensity of 235. River Ajay is flowing through northern boundary and Kunur river is drained northward in middle. Brahmani and Khandeswari river are flowing eastward in eastern part in the study area.

Materials and Methods

Soils

For collecting of soil samples (0-15cm), the Block has been divided into grids of one sq. km. A total of 342 soil samples have been collected from 12 pre-categorized cropping systems (CS) as (i) rice (*Oryza sativa*) (R), (ii) rice-rice (R-R), (iii) rice-potato (*Solanum tuberosum*) (R-P), (iv) rice-potato-sesame (*Sesamum indicum*) (R-P-S), (v) rice-mustard (*Brassica niger L.*)-sesame (R-M-S), (vi) rice-mustard-rice (R-M-R), (vii) rice-potato-rice (R-P-R), (viii) rice-lentil (*Lens culinaris*)-rice (R-L-R), (ix) jute (*Corchorus capsularis*)-peas (*Pisum sativam*) (J-P), (x) sugarcane (*Saccharum officinarum*) (S), (xi) chilli (*Capsicum annuum L.*) (C), and (xii) brinjal (*Solanum melongena*) (B). Detailed interview of concerned farmers has been carried out on perspective of techniques of cultivation, use of fertilizer, productivity of the crops and management practices of the soil.

Soil Testing

The collected soil samples have been dried in air and pHw has been tested with distilled water at soil-water ratio of 1:2.5 by glass electrode pH meter. The pH_{KCl} has been measured with 1M KCl at soil-KCl solution ratio of 1:2.5. To measure the charge of clay surface, $\Delta pH = pH_{H2O} - pH_{KCl}$ has been calculated. Buffer capacity has been measured with 0.01 N NaOH and expressed as $\hat{a} = db / d(pH)$, where '*db*' is the amount of added base causes *d*(pH) change (Sarkar and Halder, 2003). Total acidity has been measured by 1N NaOAC solution, adjusted to pH 8.2. Lime requirement has been tested by the method of Schoemaker et al. (1961). Total nitrogen (TN) has been measured as per the method of Subbiah and Asija, 1956. Organic carbon has been tested after Walkley and Black method (1934) using potassium-di-chromate and concentrated sulphuric acid to oxidize as well as burning of carbon what is removed from soil. Soil texture has been tested with hydrometer method.

Representation

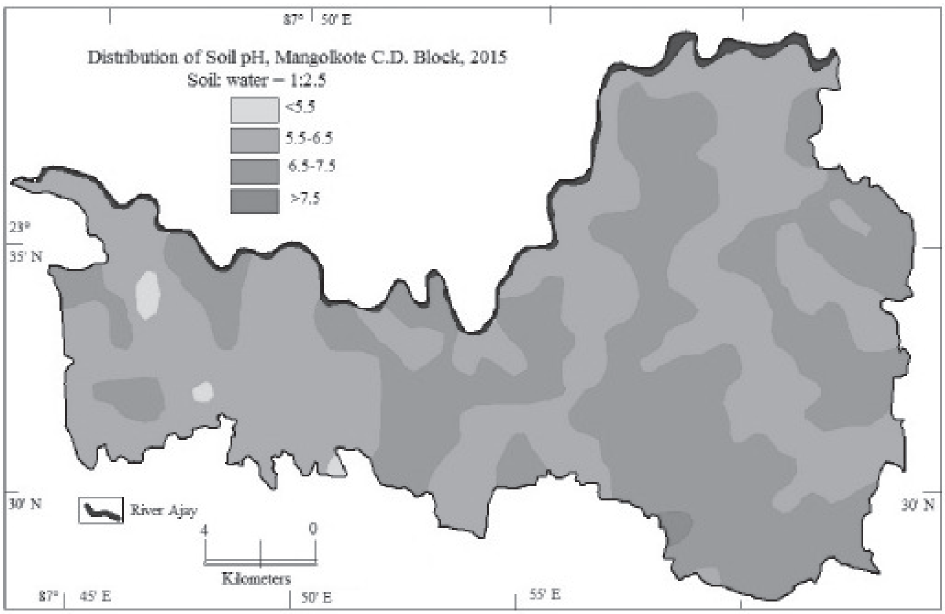
To analyze the data, regression (linear, curvilinear and multiple) has been computed in MS Excel, 2007 and Statistica 10.0. Correlation values was tested its significance at N - 2 degree of freedom [N - 2 = (342 - 2) = 340]. Principal component and thematic maps have been prepared in Past 3.0 and Map Info 7.0 respectively.

Result and Discussion

The mean pHw of the study area is 6.41. Acidic nature of soil (pHw <5.5) has been observed in 2.92% land in western part. About 52.92% land is characterized of pHw range of 5.5-6.5 (slightly acidic soil) in western and eastern part. The neutral condition of soil has been found in 43.56% land in middle and south-eastern part (Map No. 1).

Map No. 1

Distribution of Soil pHw, Mangolkote C.D. Block, 2015



The multiple regression value of pHw (0.2933, p =<0.01) is signified with SOC concentration and clay content (Eq. No.1). Again, the coefficients of variance of the clay (0.233, p = <0.05) and buffer capacity (0.291, p = <0.05) are signified at 95% level (p = <0.05) (Eq. No.2). The multiple correlation value is 0.4141 (p=<0.01, explained 17.147%). In equation no. 3, only the coefficient value of BC is signified (coefficient value =0.2706, p =<0.05). The correlation value (0.4075, p=<0.01) is explained at 16.605% variance which is not higher than the equation no. 2 in spite of having seven variables. So, SOC concentration, clay and BC can be considered as determinants of the pHw.

The bivariate correlations of pHw with SOC concentration (0.1308, p=<0.05), sand (-0.227, p=<0.01), clay (0.2919, p=<0.01), N-addition (-0.125, p=<0.05), and BC (0.31, p=<0.001) are signified at 95% confidence level. The sand content and N-addition are negatively correlated with pHw whereas SOC, clay, and BC are positively correlated with pHw. The SOC concentration and clay content can act as protector of pHw through adsorption of H^+ ions.

Yc (pHw) = $5.96788 + 0.053 \times SOC + 0.334 \times Clay$, r = 0.2933, R = 0.0841, p = <0.01 [Eq. No. 1]

Yc (pHw) = 5.869 + 0.053 × SOC + 0.233 × Clay + 0.291 × BC, r = 0.4141, R = 0.17147, p=<0.01 [Eq. No. 2]

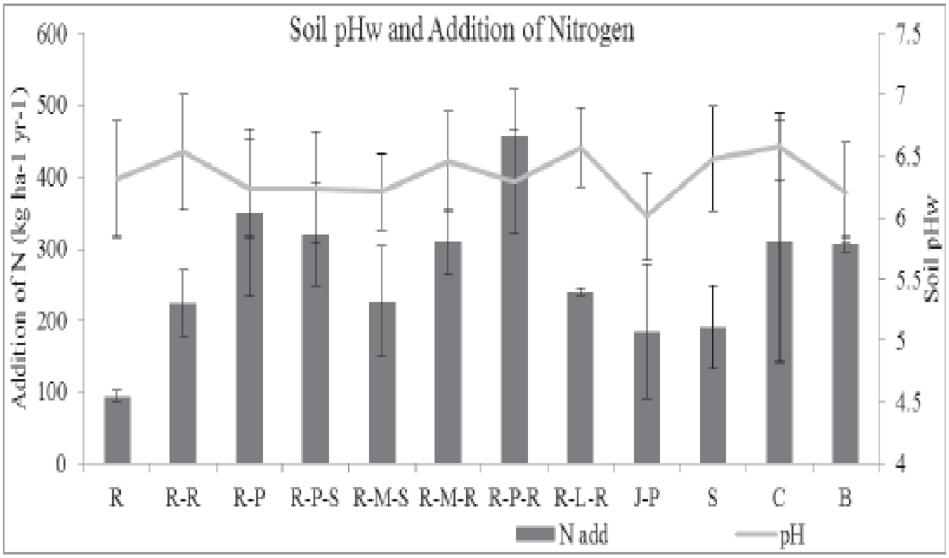
Yc (pHw) = 10.3223 + 0.0467 × SOC - 1.6035 × Sand - 0.97122 × Silt - 0.8393 × Clay-0.065 × N addition + 0.013 × N removal + 0.2706 × BC, r = 0.4075, R =0.16605, p= <0.01 [Eq. No. 3]

Cropping System and Soil pHw

The pHw in rice cropping system (CS) is 6.31 ± 0.47 where 93.631 ± 7.64 kg N ha^{-1} yr^{-1} is applied. In the R-R CS, pHw is 6.531 ± 0.462 using 224.31 ± 46.2 kg N ha^{-1} yr^{-1}. The pHw in R-P CS is 6.241 ± 0.4 in which on an average 348.941 ± 116.85 kg N ha^{-1} yr^{-1} is used. In the cultivation of potato, recommended amount of fertilizer is not followed by the farmers and they apply more than double of N from the recommended quantity. The pHw in J-P CS (6.011 ± 0.35) is the lowest in spite of using minimum N fertilizer (184.14 ± 93.4 kg N ha^{-1} yr^{-1}) and turnover of N in this CS is greater than other CS because peas can assimilate 40-70 kg N ha^{-1} yr^{-1} and farmers generally apply less N fertilizer in this CS. Maximum N fertilizer is applied in R-P-R CS (457.3 ± 63.73kg N ha^{-1} yr^{-1}) where pHw is 6.29 ± 0.424. In the CS of brinjal, the pHw is 6.2 ± 0.403 where 305.86 kg N ha^{-1} yr^{-1} is applied (Fig. No. 1).

Fig. No. 1

Soil pHw and Addition of Nitrogen



The correlation between addition of N and pHw in different CSs is 0.2024 in a curvilinear relation where 270 kg N ha^{-1} yr^{-1} has been found in highest pHw of 6.34 and pHw decreases with application of lower or higher amount of N in soil. The addition of N through fertilizer has been accounted in leguminous system excluding biological fixation of N in this system. If proper amount of N could have been measured, the relation of addition of N and pHw might be signified positive.

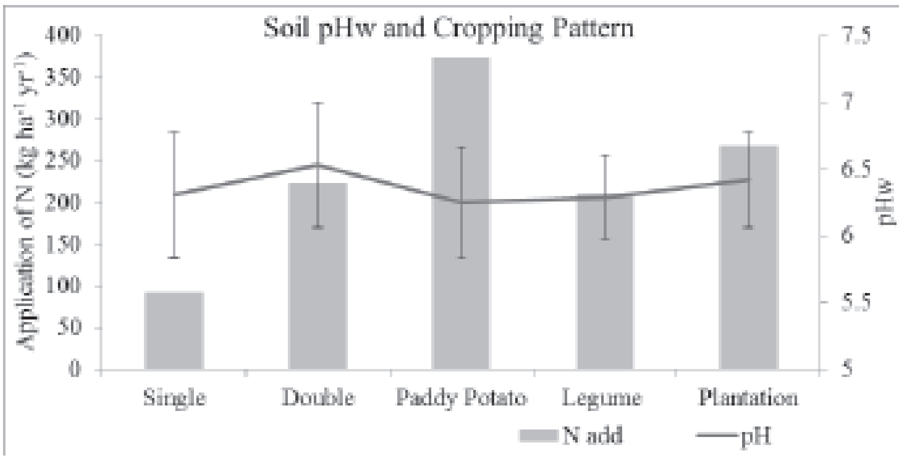
Cropping Pattern and Soil pHw

The pHw in single rice cropping system is 6.31 ± 0.47 using lowest amount of N fertilizer (93.67±7.64 kg N ha^{-1} yr^{-1}). In double cropped paddy cultivation, pHw is 6.53 ± 0.47 in addition of 224.3 ± 46.2 kg N ha^{-1} yr^{-1}. The pHw is lowest (6.25±0.42) in the rice-potato system where highest amount of N (457.63 ± 63 kg

N ha^{-1} yr^{-1}) is applied. In legume based cropping pattern, pHw is 6.29±0.32 with addition of 206 ± 72 kg N ha^{-1} yr^{-1}. In plantation cultivation, pHw is 6.42 ± 0.367 because in cultivation of sugarcane, chilli and brinjal, 266.57 ± 101 kg N ha^{-1} yr^{-1} is applied (Fig. No. 2).

Fig. No.2

Soil pHw and Cropping Pattern

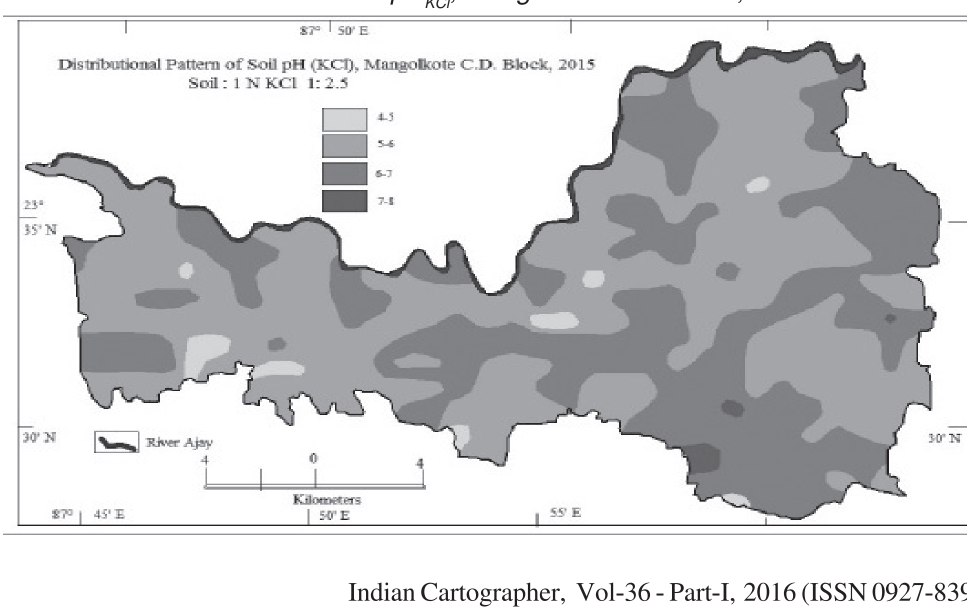


Soil pH$_{KCl}$

Soil pH$_{KCl}$ is the parameter of soil to measure charge of clay surface. When “pH (pHw - pH$_{KCl}$) is positive, the charge of clay surface is negative. Generally, negative charged clay surface implies higher cation exchange capacity and nutrient holding capacity. The value of “pH is greater than zero in the study area which indicates negative charged clay surface. In this study area, 6.75% land has been found under pH$_{KCl}$ of 4-5where pHw is lower than 5.5. There is 53.98% land in pH$_{KCl}$ of 5-6. The pH$_{KCl}$ of 6-7 is the character of 38.34% land under pHw range 6.5-7.3. Only 0.98% land is under pH$_{KCl}$ of 7-8 (Map No.2).

Map No. 2

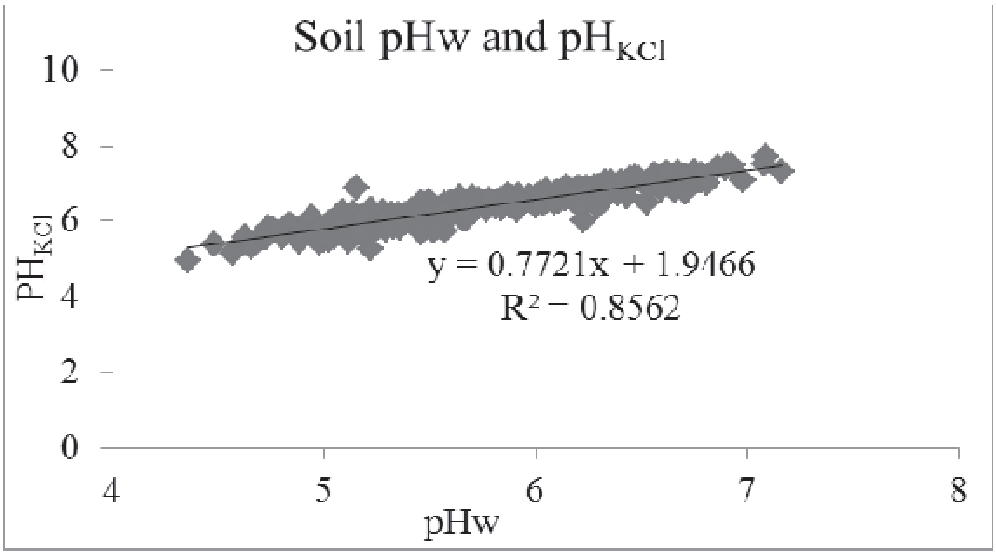
Distribution of Soil pH$_{KCl}$, Mangolkote C.D. Block, 2015

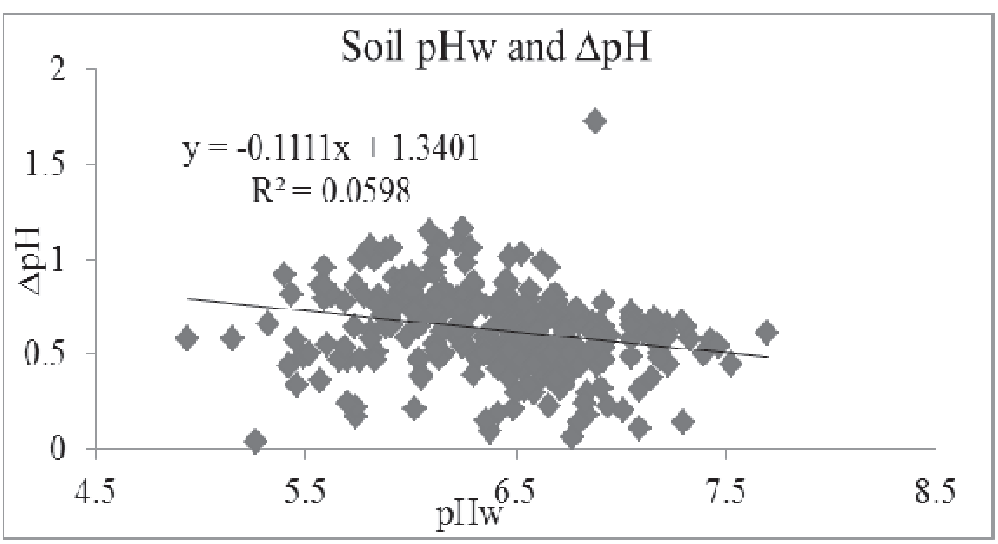


The correlation between pHw and pH_{KCl} (0.9252, p = <0.001) is signified at 99% level (Fig. No.3). Again higher concentration of H^+ ions has been found due to lowering of soil pHw. The correlation between pHw and “pH (- 0.24289, p = <0.01) is signified at 99% confidence level (Fig. No.4). The “pH value is low in higher pHw (>6.0) due to lower concentration of H^+ ion.

Fig. No.3

Soil pHw and pH_{KCl}



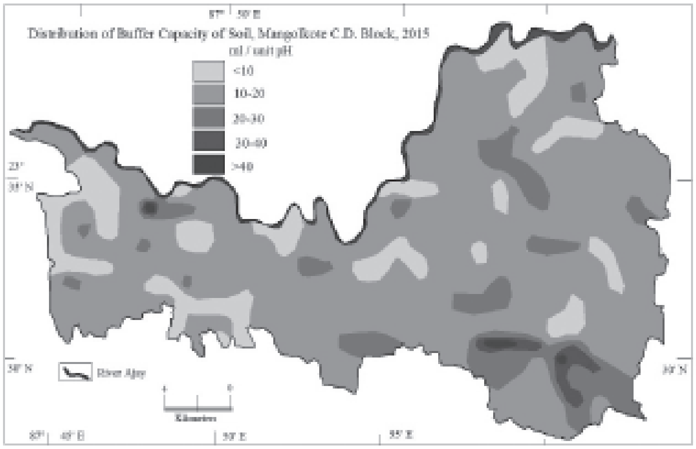


Buffer Capacity (BC)

Buffer capacity is ability of soil to resist rapid change of pH in addition of acid or base in soil (Chesworth, 2008; Brady, 1990). Adsorption capacity of clay-humus complex determines the ability of BC and lower buffer capacity tends to reduce soil pH where higher amount of clay-humus complex protects lowering of pHw. In this case, 68.42% of land is characterized by BC of 10-20 ml/unit pH at pHw range of 6.0-6.5. Lowest BC of 0-10ml/unit pHw has been found in 16.67% land at pHw of <6.0. BC of >40ml/unit pH has been noticed in 2.63% land at >7.0 pH range (Map No.3).

Map No. 3

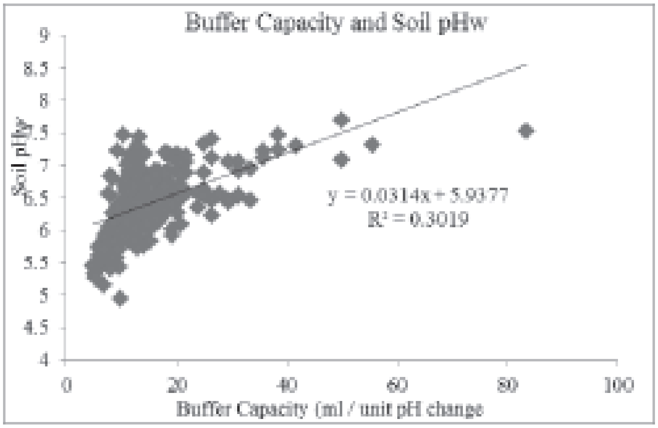
Distribution of Buffer Capacity of Soil, Mangolkote C.D. Block, 2015



The correlation between pHw and BC (0.54863, p=<0.01) is signified at 99% level (Fig. No.5). The signified coefficient value of clay has been found with buffer capacity (Eq. No.4). As organic carbon of the soil (SOC) is low, SOC cannot act as protector of soil the pHw. Low buffer capacity of the soil is responsible for low pHw. The pH of less than 6.0 is the result of lower buffer capacity of <10ml/unit pH and 10-20 ml/unit pH has been found pH range of 6.0-7.0 and pHw of >7 has been observed in the BC of >20ml/unit pH change. Yc (BC, ml/unit pH) = 9.0302 + 0.029 × SOC + 0.148 × Clay, r = 0.1581, p= <0.05 [Eq. No. 4]

Fig. No.5

Buffer Capacity and Soil pHw



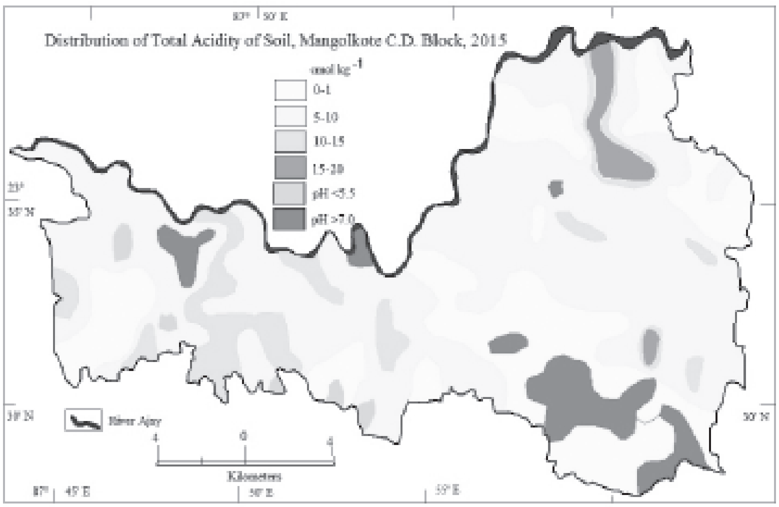
Soil pHw and Total Acidity

Total acidity is called hydrolytic acidity or titratable acidity at pH range 5.5-7.0 which includes salt replaceable and residual acidity of soil (Sarkar and Halder, 2005; Soil Survey Staff, 1999; SSSA, 2008). The value of total acidity may differ at same pH level due to differential adsorption of H^+, Al^{+3}, Fe^{+3} and requirement of lime may vary according to total acidity on adsorbed cations (Bloom et al., 2005).

In this area, 46.85% of land has been found under total acidity of 0.5-1.0 $cmol_c\ kg^{-1}$ at pHw range of 6.0-6.5. 23.42% of land is characterized of TA <0.5 $cmol_c\ kg^{-1}$ under pHw range of 7.0-6.5. Highest total acidity 1.5-2.0 $cmol_c\ kg^{-1}$ is measured in 6.64% land under pHw of 6.0-5.5 (Map No.4).

Map No. 4

Distribution of Total Acidity of Soil, Mangolkote C.D. Block, 2015

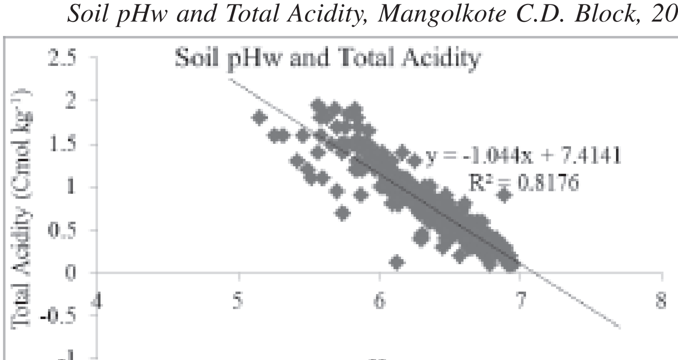


The coefficient value of pHw (0.91, p=<0.01) is significant at 99% level. The coefficient of SOC (-0.01) is not satisfactorily signified (Eq. No.5). The correlation of TA with pH (-0.9038) and clay (+ 0.2182) are signified at 99% level (Eq. No. 6; Fig. No.6). Due to low SOC concentration, the coefficient of SOC is not satisfactorily significant.

Yc (TA, $cmol_c\ kg^{-1}$) = 7.42165 - 0.91 ×pHw - 0.01 ×OC - 0.019 ×Clay, r=0 .9044, R= 0.817, p=<0.001 [Eq. No. 5] Yc (TA, $cmol_c\ kg^{-1}$) = -1.044 × pHw + 7.414, r= 0.9038, R= 0.817, p= < 0.001 [Eq. No. 6]

Fig. No.6

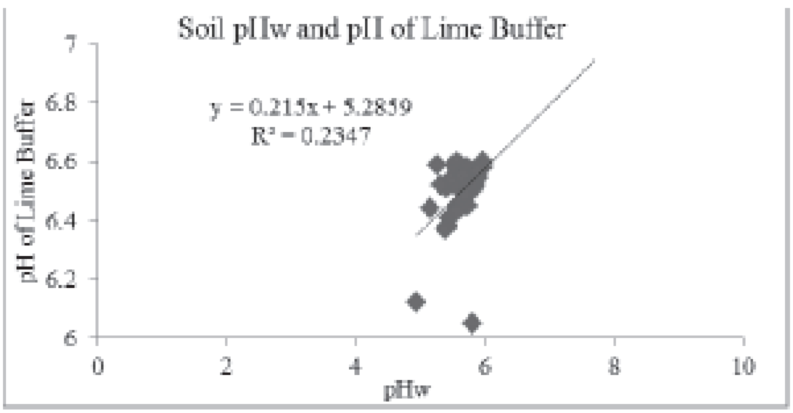
Soil pHw and Total Acidity, Mangolkote C.D. Block, 2015



Lime Requirement and pHw

Application of lime in arable soil is necessary to maintain suitable pH range through ameliorating toxic cations, (H^+, Al^{3+}) and lime ($CaCO_3$) is applied in soil to change from initial to optimum pH for plant growth. Generally, lime is not required if pHw is greater than 6.0. In this case, lime is required for only 16.67% (57 soil samples) of arable land due to pHw of <6.0. In 7.89% land, pH of lime buffer solution is 6.50 where 4.37 ton of $CaCO_3$ is required to increase pHw at 6.0. The pH of lime buffer of 6.5 has been found in 5.55% land where 3.4 ton of $CaCO_3$ may be applied for pHw 6.0 (Table No.2; Map No.5). The correlation value between lime requirement and pHw is signified at 95% level ($r = 0.483$, $p = < 0.05$) (Fig. No.7). Yc (pH of lime buffer) = 5.285+ 0.215 × pHw, $r = 0.4837$, $R = 0.234$, $p = < 0.01$ [Eq. No. 7]

Fig. No. 7
Soil pHw and pH of Lime Buffer



Map No. 5
Distribution of pH of Lime Buffer, Mangolkote C.D. Block, 2015

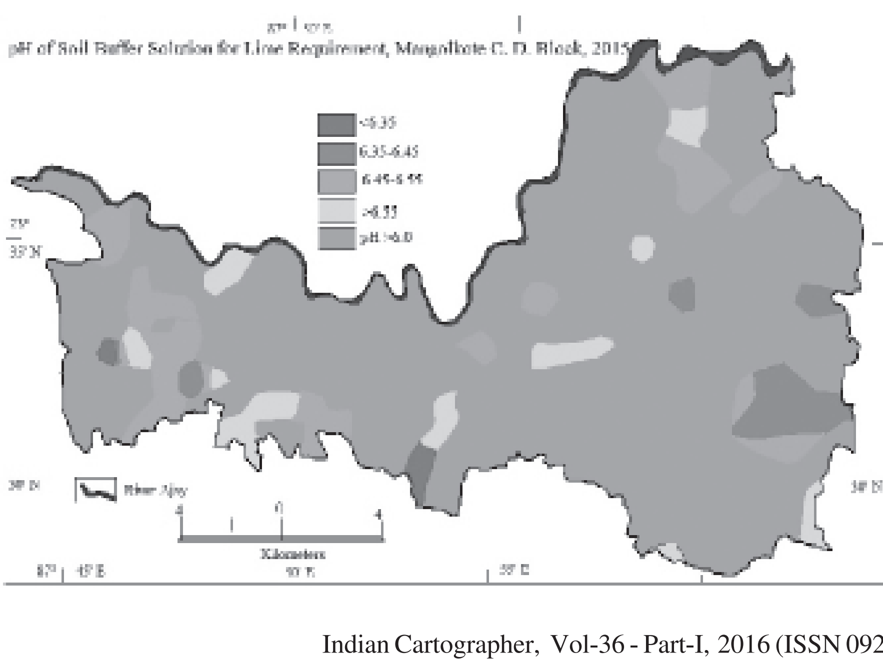


Table No.2

pH of Buffer Suspension and Requirement of Lime

pH of Buffer Suspension	pH of Buffer Suspension	% of Land	Requirement of Lime (tons/ha of pure CaCO3)		
			pH 6.0	pH 6.4	pH 6.8
<6.35	6.3	0.58	6.56	7.78	8.99
6.35-6.45	6.4	2.63	5.59	6.56	7.53
6.45-6.55	6.5	7.89	4.37	5.35	6.05
>6.55	6.6	5.55	3.4	4.13	4.61
pH_{H20} >6.0		83.33			

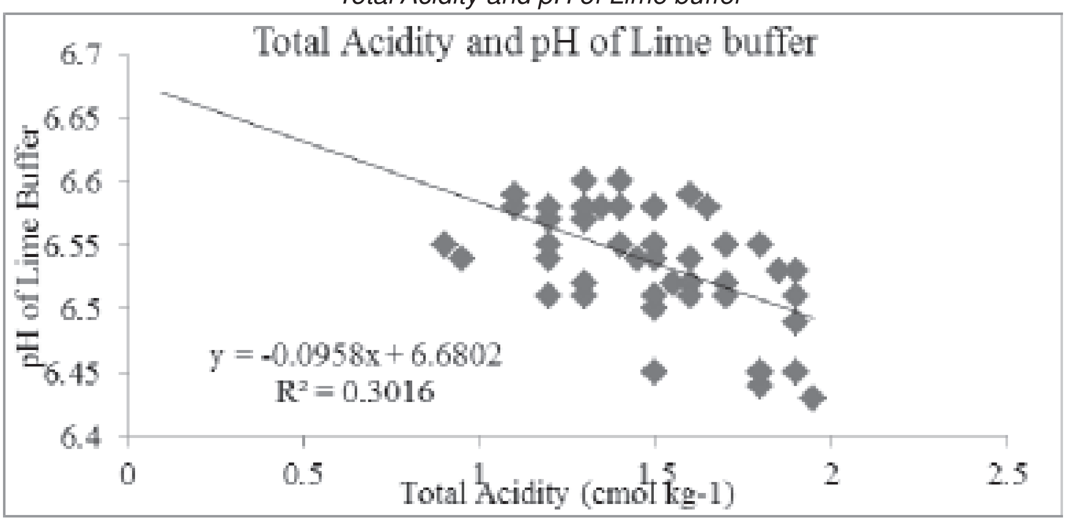
Total Acidity and Lime Buffer

The requirement of lime is highly dependent on total acidity because higher amount of Ca^+ ions is required to replace H^+ ion concentration at lower pHw. The correlation between lime requirement and total acidity is signified at 95% level (r = 0.5486, p = <0.05) (Fig. No.8).

Yc (pH of lime buffer) = 6.680 - 0.095×TA, r=0.5486, R=0.301 [Eq. No. 8]

Fig. No.8

Total Acidity and pH of Lime buffer



Productivity of Rice

The production of rice in *kharif* season is not highly dependent on soil pHw because the coefficient of variance of pHw (-0.03) on production of rice is not satisfied enough (p =>0.1) (Eq. No. 9). The coefficient of SOC (0.229, p =<0.01) and total nitrogen (0.22, p =<0.01) are signified at 95% level. But bivariate correlation between pHw and rice productivity is signified at 90% level (r= 0.1189).

Yc (rice, Q ha^{-1}) = 87.8779 - 0.03 × pHw + 0.019 × BC + 0.134 × pH_{KCl} + 0.229× SOC - 0.78 × Sand - 0.056 × Silt-0.51× Clay + 0.03 × N-addition + 0.22 ×TN, r=0.2250, R=0.05065, p=0.070572 [Eq. No. 9]

Productivity of Rice (*rabi* season, Q ha^{-1})

The coefficient of pHw (0.04725, p =<0.05) and SOC (1.027, p =<0.05) are signified in production of rice (*rabi* season) (Eq. No.10). The bivariate correlations of productivity of rice (*rabi*) is signified with pHw (0.1315, p=<0.05) and clay (0.1485, p=<0.01) at 95%level. The productivity of rice is decreased with lowering of soil pHw and in the coarse textured soil.

Yc (*boro*, Q ha^{-1}) = 58.567 + 0.475 × pHw - 0.1911 × BC - 0.1828 × pH_{KCl} + 1.027 × SOC - 0.006 × Silt + 0.094 × Clay + 0.012 × N add - 0.048 × TN, r = 0.314, R = 0.099, p = <0.001 [Eq. No. 10]

Productivity of Potato

The productivity of potato is highly influenced by pHw (0.635, p=<0.05). But negative coefficient values of sand, silt, and clay as well as positive coefficient with N addition and TN are not satisfactorily significant. But, bivariate correlation between productivity of potato and total nitrogen is signified at 95% level (r = 0.1482, p=<0.05).

Yc (potato, Q ha^{-1})= 359.0372 + 0.635 × pHw + 0.029 × BC - 0.44 × pH_{KCl} - 0.23 × SOC -0.75 × Sand - 0.49 × Silt - 0.46 × Clay - 0.19 × N addition + 0.148 × TN, r = 0.3717, R = 0.1381, p = 0.149635 [Eq. No. 11]

Factor Analysis of the Soil System

Sand, clay, and pHw have found as principal components in the first factor loading. Sand and clay content of the soil determine the buffer capacity, cation exchange capacity and adsorption of cations. Total eigen value of first factor loading is 2.924 with 32.485% explained variance. Soil pHw and pH_{KCl} which are the components of second factor loading with eigen value of 1.868 and 20.759% explained variance determine the adsorption of H^+ ions and total acidity. In third phase of factor loading, SOC concentration and total nitrogen have been found as dominant components with eigen value of 1.579 with 17.547% explained variance (Table No.3).

Table No. 3

Factor Loading of Agro-pedological System (after principal component analysis)

Factors	PC1	PC2	PC3
pHw	**.607**	**.716**	.199
BC	.347	.361	.126
pH_{KCl}	.529	**.760**	.186
SOC	.452	-.431	**.694**
Sand	**-.848**	.288	.401
Silt	.564	-.327	-.490
Clay	**.784**	-.153	-.174
N Applied	-.473	.195	.069
TN	.275	-.458	**.756**
Total Eigen	2.924	1.868	1.579
% of eigen	32.485	20.759	17.547
Cumulative %	32.485	53.245	70.792

Conclusion

From this empirical investigation, the pHw has become a prime controlling factor of total acidity and requirement of lime of the soil. But the rate of acidification is maintained through SOC concentration, clay, BC and accelerated with addition of nitrogen. Maximum turnover of N fertilizer in R-P and J-P is responsible for lowering of the pHw. Significant positive correlation has been found between pHw and agricultural productivity (rice and potato). Sand, clay, pHw and SOC concentration are the principal components of the agro-pedological system. As pHw and BC are positively related with SOC concentration, organic manure can be used to maintain suitable pHw for the agricultural productivity. So, application of organic manure and practice of organic farming with minimum application of N fertilizer are to be followed for maintaining suitable pHw level and sustainability of the agro-pedological system of the Block.

References

Brady, N.C. (1990). *The Nature and Properties of Soils*, Macmilan Publishing Company, New York, pp- 91-122.

Bloom, P. R., Skyliberg, U. L. and Sumner, M.E. (2005). Soil acidity. In: Chemical Processes in Soils. SSSA Book Series 8. M. A. Tabaiabai. And D. L. Sparks (eds.). SSSA. Madison. WI. pp. 411-460. In: Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). *Estimating Total Acidity from Soil Properties Using Linear Models, Soil Science, Volume 174, Number 2, USDA-NRCS*. National Soil Survey Center, DOI: 10.1097/SS.Ob013e3 181975044.

Bolan, N.S. and Kandaswamy, K. (2005). pH, In: Hillel, D., Rosenzweig, C., Powlson, D., Scow, K., Singer, M. & Sparks, D. (2004). *Encyclopedia of Soils in the Environment, Academic Press,* New York.

Chesworth, W. (2008). *Encyclopedia of Soil Science*, Springer, Netherlands.

Daji, J.A., Kadam, J.R. & Patil, N.D. (1996). *A Text Book of Soil Science,* Media Promoters and Publishers pvt. Ltd., Bombay.

de Klein, C.A.M., Monaghan, R.M. & Sinclair, A.G. (2010). *Soil Acidification: a Provisional Model for New Zealand Pastoral Systems*, Taylor & Francis, London, Retrieved on 27 March 2014, 06:23p.m.

Foth, H.D. (1990). *Fundamentals of Soil Science*, 8th Edition, John Wiley & Sons, New York, pp-42-53.

Helyar, K. R. & Porter, W. M. (1989). Soil Acidification, its Measurement and the Processes Involved. In: Robson, A. D. ed. *Soil Acidity and Plant Growth*. Marrickville, Academic Press. Pp. 61-101.

Hicks, W.K., Kuylenstierna, J.C.I., Owen, A., Dentener, F., Seip, H. and Rodhe, H. (2008). *Soil Sensitivity to Acidification in Asia: Status and Prospects. Vol. 37, No. 4,* Royal Swedish Academy of Sciences, pp. 295-303, http://www.jstor.org/stable/25547901.

Rengel, Z. (2003). *Handbook of Soil Acidity*, Marcel Dekker, Inc. New York.

Sarkar, D. & Halder, A. (2005). *Physical and Chemical Methods in Soil Analysis Fundamental Concepts and Analytical Chemistry and Instrumental Techniques*, New Age International (P) Ltd. Publishers, New Delhi.

Savci, S. (2012). An Agricultural Pollutant: Chemical Fertilizer, *International Journal of Environmental Science and Development, Vol. 3, No. 1*, February 2012

Shoemaker, H.E., McLean, E.O. and Pratt, P.F. (1961). Buffer Methods for Determining Lime Requirement of Soils with Appreciable Amounts of Extractable Aluminium. Proc. Soil Sci. Soc. Am. 25: 274-277 In: Sarkar, D. & Halder, A. (2005). *Physical and Chemical Methods in Soil Analysis Fundamental Concepts and Analytical Chemistry and Instrumental Techniques*, New Age International (P) Ltd. Publishers, New Delhi.

Soil Survey Staff. (1999). Soil Taxonomy: A Basic System of Soil Classification for Making and interpreting Soil Surveys. 2nd Ed. Agric. Handb. 436. U.S. Gov. Print. Office, Washington, DC. In Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity From Soil Properties Using Linear Models, Soil Science • Volume 174, Number 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.Ob013e3 181975044.

SSSA. (2008). Glossary of Soil Science Terms. Soil Science Society of America, Madison, WI. In: Seybold, C.A. Finnell, P.R. and Elrashidi, M.A. (2009). Estimating Total Acidity from Soil Properties Using Linear Models, Soil Science, Vol.174, No. 2, USDA-NRCS. National Soil Survey Center, DOI: 10.1097/SS.Ob013e3 181975044.

Subbiah, B.V. and Asija, G.L. (1956). A Rapid Procedure for the Determination of Available Nitrogen in Soils. Curr. Sci. 25: 259-260 In: Sarkar, D. & Halder, A. (2005). *Physical and Chemical Methods in Soil Analysis Fundamental*

Concepts and Analytical Chemistry and Instrumental Techniques, New Age International (P) Ltd. Publishers, New Delhi.

Thomas, G.W. (2006) pH In: Lal, R. (2006). *Encyclopedia of Soil Science*, Taylor & Francis.

Van Breemen, N., Mulder, J. and Driscoll, C. T. (1983). Acidification and alkalinization of soils. *Plant and soil, 75*: 283-308.

Walkley, A. and Black, I.A., An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method. Soil Sci. 34: (1934). 29-38. In: Sarkar, D. & Halder, A. (2005). *Physical and Chemical Methods in Soil Analysis Fundamental Concepts and Analytical Chemistry and Instrumental Techniques,* New Age International (P) Ltd. Publishers, New Delhi.

Wolf, B. & Snyder, G.H. (2003). *Sustainable Soils The Place of Organic Matter in Sustaining Soils and Their Productivity*, Food Products Press, New York.

34

IMPACT OF CLIMATE CHANGE ON JHARKHAND AGRICULTURE : MITIGATION AND ADOPTION

Madhumita Minz

Introduction

The climate of the earth has always changed. Since the formation of Earth, its surface conditions have fluctuated. Past changes have etched on the landscape. They have influenced the evolution of all life forms and have become a subtext of our economic and social history (Garner 2011, p.3). Generally, climate is defined as the average weather for a specific location, region or the entire globe over an extended period of time (Critchfield 1983, p.3; Tebteba 2000). The landscape, plants and animals in it, are all determined to a large extent by climate acting over long intervals of time. Over geological time, climate has helped to shape mountains, build up the soil, determine the nature of the rivers, and build flood plains and deltas (Pittock 2009, p.1).

Previously, it was climate that changed humans but now, human being is changing the climate with high rate.

Agriculture in Jharkhand is mainly rained and is characterized by undulating terrain, shallow soil depth, low water retentive capacity, poor soil fertility and fragmented holdings with meagre irrigation potential (10-12%). Rainfall and temperature play a decisive role in suitability, adaptability and productivity of crops in a given region. The Intergovernmental Panel on Climate change predicts that during the next decades, billions of people, particularly those in developing countries, will face changes in rainfall patterns that will contribute to severe water shortages or flooding, and rising temperature that will cause shift in cropping pattern and growing seasons.

Impacts of changes in the rainfall (pattern and magnitude) and temperature as well as an increase in extreme events have profound effect on food availability and socio-economic conditions of a region and alternate cropping pattern may be needed to accommodate such changes. It is reported that during the past 100 years, global mean surface air temperature have risen by 0.740C and it is projected to rise by 1to 30C during this century. Hingane et.al., (1985) reported that the Country-wide annual surface air temperature has increased by 0.4 oC /100 years in this century but the rate of increase slowed down in the recent three decades. The monsoon season rainfall was in decreasing trend over east Madhya Pradesh and adjoining areas, North-east India and parts of Gujarat and Kerala (Kumar et. al., 2002). Climate change is a global phenomena but the rate of change and its expected consequences is region specific. Hence, the use of indigenous knowledge and local coping strategies has to be taken as a base line and starting point of the adaptation planning.

Objectives

There are two main objectives of my study:

- ***To study the changes in rainfall pattern.***
- ***To study the impact of climate change on Jharkhand agriculture.***

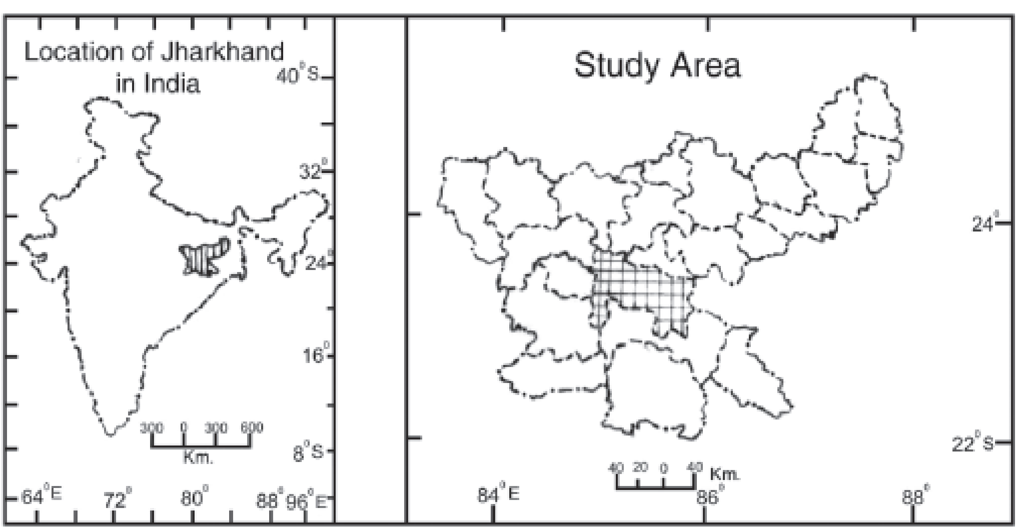
Methodology and Data Base

The study is mainly based on the secondary sources of data which have been obtained from Agro- meteorological observatory located at Kanke (Ranchi). The analysis made here follows statistical methods and cartographic work. Trend of rainfall and temperature vary significantly at regional scales and studies are very limited for the Jharkhand region. Here I study only Ranchi area. Rainfall, maximum and minimum Temperature (1961-2008) data recorded for the given place were analyzed following standard statistical procedures. Trends of rainfall was studied for annual, winter (January to February), summer (March to May), monsoon (June to September) and post monsoon (October to December) seasons for the region. Different varieties of wheat crop were grown in 2008 and 2009, with recommended package of practice, to see the effect of temperature variations on crop performances.

Study Area

The state of Jharkhand has a geographical area of 79,714 Km2 which is 2.4% of the country's geographical area .The state lies between 22°28' N-25°30' N latitude and 83°22' E- 87°40' E longitude. It shares its boundaries with Bihar in the north, Orissa in the south, West Bengal in the east and Chhattisgarh and Uttar Pradesh in the west. Physiographically, the state is mainly in the form of a plateau, the Chotanagpur plateaus, and is drained by four major rivers-Subarnrekha, Damodar, Koel and Son. The climate is tropical (Kumar 2010). The total population of the state is 32, 966 ,238 with the average population

Figure 1



Results and Discussion

Changes in Rainfall Pattern

Table 1

Decadal Variability in Annual and Seasonal Rainfall in Ranchi Region in %

	Rainfall (mm)					
Seasons	1961-70	1971-80	1981-90	1991-2000	2001-08	1961-2008
Annual	1250.5(13)	1430.0(18)	1430.5(14)	1623.5(20)	1375.4(19)	1423.9(19)
Winter	40.6(48)	63.8(58)	43.9(64)	43.7(99)	46.6(92)	47.8(72)
Summer	100.8(56)	99.5(44)	132.3(34)	94.9(43)	115.4(54)	108.3(46)
Monsoon	1026.2(16)	1160.9(20)	1156(16)	1371.5(21)	1183.3(21)	1168.6(21)
Post-monsoon	82.9(78)	105.8(76)	98.3(64)	113.3(64)	95(120)	99.2(77)

Source: Agro - meteorological observatory, Kanke (Ranchi)

On an average Ranchi region receives annual rainfall of 1423.9mm spread over 73 rainy days with 19% coefficient of variation. The season-wise rainfall distribution indicated that 82 % of annual rainfall is confined within the four monsoon months (June - September). Summer and post monsoon rain contributes about 8% and 7 %, respectively whereas the least rainfall is received in winter (3%). Variation in annual as well as seasonal rainfall may be considered as a measure to examine climatic variability/change over the region. Inter and intra decadal variability of rainfall (Table-1) revealed that annual and monsoon season rainfalls are more reliable than other seasons. The variability of annual rainfall was relatively high (19%) during the period 2001-2008 than the decade 961-71 (13%). Very high values of rainfall variability in winter (92%), summer (54%) and post monsoon (120%) in the recent years (2001-08) has created a kind of uncertainty for the crops being grown in seasons other than monsoon season. Hence, raising crops in rabi season (post-monsoon) as well as in pre-monsoon seasons requires assured irrigation facilities. Hence, rainwater harvesting during its plenty and its re-use during its scarcity seems to be the only alternative in Jharkhand state. This will be helpful in growing successful crops in rain-scarce periods as well as in giving life saving irrigations to standing crops raised in monsoon season (rain abundance period) in the events of prolonged dry spells.

Table 2

Rainfall Trends (mm/year) for Decades and the Period 1961-2008

	Decades					
Annual	1961-70	1971-80	1981-90	1991-2000	2001-08	1961-08
Winter	+1.6	-15.1	+35.3	+29.7	+20.8	+5.6
Summer	-1.3	+1.9	-3.5	+5.4	+4.5	-0.03
Monsoon	+8.1	+2.3	+0.7	-4.6	+0.42	+0.29
Post	+7.8	-8.5	+29.8	+28.4	+38.7	+5.24
Monsoon	-13.0	-11.0	+8.4	+0.48	-22.8	+0.12

Source: Agro - meteorological observatory, Kanke (Ranchi)

Trends in rainfall on annual and seasonal basis were also worked out decade-wise and are presented in Table 2. The annual rainfall showed an increasing trend over a period of 48 years from 1961 to 2008 for Ranchi region. The incline was at the rate of 5.6 mm/year. Similar trend was noticed in monsoon (5.2 mm/year), summer (0.29 mm/year) and post monsoon (0.13 mm/ year) rainfall but slight decline trend was noticed in winter rainfall (-0.03 mm/year). In recent years (2001-2008) an increasing tendency of annual, winter, summer and monsoon was noticed whereas post monsoon rainfall showed a decreasing trend by at a rate of 22.8 mm/year. Increasing trends for annual as well as monsoon rainfall were also noticed for three decades 1961-70,1981-90, 1991-2000 and in recent years except for the decade 1971-80s.

Table 3

Frequency Distribution of Mean Erosive Rainfall (mm) Events in Different Decades

	Ranges (mm)				
Decades	25-50 mm	50-75 mm	75-100mm	>100 mm	Total
1961-70	10.9	3.4	0.5	0.5	15.3
1971-80	11.1	3.7	1.2	0.7	16.7
1981-90	12.3	3.4	1.0	0.7	17.4
1991-2000	13.4	3.8	2.0	1.3	20.5
2001-2008	13.3	3.0	1.0	0.8	18.1

Source: Agro - meteorological observatory, Kanke (Ranchi)

High Intensity Rainfall and Soil Erosion Light textured soils of this region having shallow depths are very prone to erosion in case of high intensity rainfall under the undulating terrain conditions. The trend of change in different levels (25-50 mm, 50-75 mm, 75-100 mm and more than 100 mm) of erosive rainfall events in 24 hours have been studied (Table-3) for different decades. It is observed that the frequency distribution of different intensity ranges of erosive events show an increasing trend in number of events over the decade i.e.15.3 (1961-70) to 20.5 (1991-2000) and decreased slightly (18.1) during the recent years 2001-2008. Soil of Jharkhand is very shallow and lands are undulating with varying slops, intensify the extents of soil erosion. It is apprehended that such increase in number of erosive events may worsen the situation by leaving the top fertile soil barren and unproductive.

Table 4

Monsoon Onset and Withdrawal

Start, End and Duration of Rainy Season at Ranchi

Start of Rainy Season (SMW)				End of Rainy Season (SMW)					Duration of Rainy Season(Week)			
Early	Late	Mean	CV%	Early		Late	Mean	CV%	Max.	Min.	Mean	CV%
23	27	24	4.6	38	52	45	9.8	29	13	21	20.5	

Source: Agro - meteorological observatory, Kanke (Ranchi)

Proper planning and scheduling of cropping activities in rained areas can effectively be done only when the farmers have some idea of normal date of monsoon onset, its withdrawal and length of the rainy season. A perusal of data in Table-4 reveals that the normal weeks (Standard Meteorological week, SMW) of start and end of rainy season, in this region, are 24th SMW (11-17 June) and 44 SMW (29 Oct -4 Nov), respectively. Normal duration of rainy season is 20 weeks (140 days) and the length of rainy season ranged from 13 weeks (91 days) to 29 week (203 days) showing a higher value of variability. This type of uncertainty with before the scientists and farmers, in choosing right crops and regard to the duration of monsoon season puts a major limitation, varieties of appropriate duration.

Conclusion

Temperature Rise and its Impact on Crops The average monthly maximum temperature for the recent years (2001-2006) has been found considerably higher than the average monthly maximum temperature of the decade 1961-1970 (Fig. 1). The maximum rise of 1.21 °C has been noticed in the month of May followed by Feb (0.82 OC), Dec (0.76 OC), April (0.51 OC), March (0.43 OC), Jan (0.3 OC), June (0.15 OC) and November (0.1 OC). In previous few years it has been found that the considerable rise in maximum temperature started from 10th of February which is alarming for Rabi crops. This rise in temperature has been reported to cause sterility in wheat crop. It has been analyzed that the years proceeded by below normal rainfall coupled with its erratic distribution and prolonged dry spells were the worse victims of temperature rise. In case of coincidence of temperature rise with the flowering stage, the available technology "applying irrigation even if the soil moisture is adequate" is being advised to the farmers to escape the sterility in wheat.

The vulnerability and adaptation aspects in climate change have not been given the focus required. A preliminary analysis of climate change impact in India has been made. However, further studies need to be carried out to exactly understand the climate change and human system interaction and the adaptation strategies required to combat these adverse impacts.

Suggestion

Here identified key issues which require serious research in order to understand the agricultural dimension of climate change. It mentioned that further research is required on the understanding of uncertainties about climate-change impacts at a relatively fine-grained geographic and sectoral scale, both harmful and beneficial, which undermines efforts to assess potential benefits from investments in adaptation. It stressed on further research to improve understanding of indirect second and third order impacts: i.e., the effects of temperature or precipitation change, storm behavior change and sea-level rise, through interrelationships among human systems. It also identified that relationships between specific effects in one location and the well-being of other locations, through linkages in inflows/outflows and inter-regional trade and migration flows should be researched to understand the social dimension of climate change. It also stressed on improving understanding of uncertainties about potentials, costs and limits of adaptation in keeping stressful impacts within acceptable limits, especially in developing countries and regions and uncertainties about possible trends in society, economic and technological change with or without climate change. These social dimension issues of climate change are important for understanding the complex vulnerabilities, capacity of victims, decision makers, adaptation and mitigation.

References

Census of India (2011), Provisional Populations Totals-Jharkhand

Critchfield, J. Howard (2010), *General Climatology*, 4th edition, PHI learning private limited, New Delhi.

Garner, Robert (2011), *Environmental Politics: the age of climate change*, Palgrave MacMillan, New York.

Kumar, K. Rupa (2002), *International Journal of Climate,* vol.5, Issue 5, Pages 433-452

Kumar,S.,(2010)"Jharkhand- Greenery Under Threat", *Jharkhand Journal of Development and Management Studies*,Vol.8,No.1(XXX),pp3753-3754

Hingane, L.S (1985), *International Journal of Climate,* vol.5, Issue 5, Pages 521-528

Pittock, A. Barrie (2009), *Climate change: The Science, Impacts and Solutions*, CSIRO Publishing, Australia, pp.1.

Tebtebba foundation (2008), *Guide on climate change and indigenous peoples,* Tebtebba Foundation, Philippines.

35

FREQUENT FLOODS AND ITS IMPACTS
A Case Study Of 4 Villages In Ausgram -1 C D Block, Burdwan District And West Bengal.

Ranjan Kumar Das

Introduction:

Flood has been defined by various workers in various ways. According to Chow (1956), a flood is a relatively high flow which overtakes the natural channel provided for the run off. Rostvedt and others (1968) defined flood as any high stream flow which overtops natural or artificial banks of a stream. Ward (1978) also defined flood as, "It is a body of water which rises to overflow land which is not normally submerged ". In India, a river is said to be in flood when its water level crosses the danger level (DL) at that particular site.

A flood is a great flowing or overflowing of water onto land that is not usually submerged. A flood happens when too much rain, brought by storms and strong winds, falls and cannot be absorbed by the soil. River burst their banks and the water spills onto the land. Strong winds blowing across the sea make huge wave that surge onto the land & flood coastal areas. (Encyclopedia of natural disasters)

Location is one of the major factors which contribute to the frequent flood in that area. These villages are situated in between the floodplain, of river Kunur, Which is the main right hand tributary of river Ajay. These area lies between two small water channels (locally called Kandar) are also flows over the floodplain. Like some flat areas, in the study areas, runoff collects in depressions and cannot drain out, creating a ponding effect. Ponding floodwaters do not move or flow away. Flood waters will remain in the temporary ponds until they infiltrate in to the soil, evaporate or are pumped.

Study Area

Four spatially contiguous villages under Ukta Grampanchayat (G.P.) of Ausgram-1 C.D. Block in west- central part of Barddhaman District are selected as study area. The study area is situated in between of the Ajay River and its right bank tributary Kunur River. The area is mainly near about ½ km from the Kunur River. T he study area is well connected with main Barddhaman town by Barddhaman-Rampurhat rail line (loop-line) with distance of 39 km. only. The other main surrounding towns are Bolpur, 13 km, away in the north direction and Guskara, 6 km., away in the south-east direction from the study area.

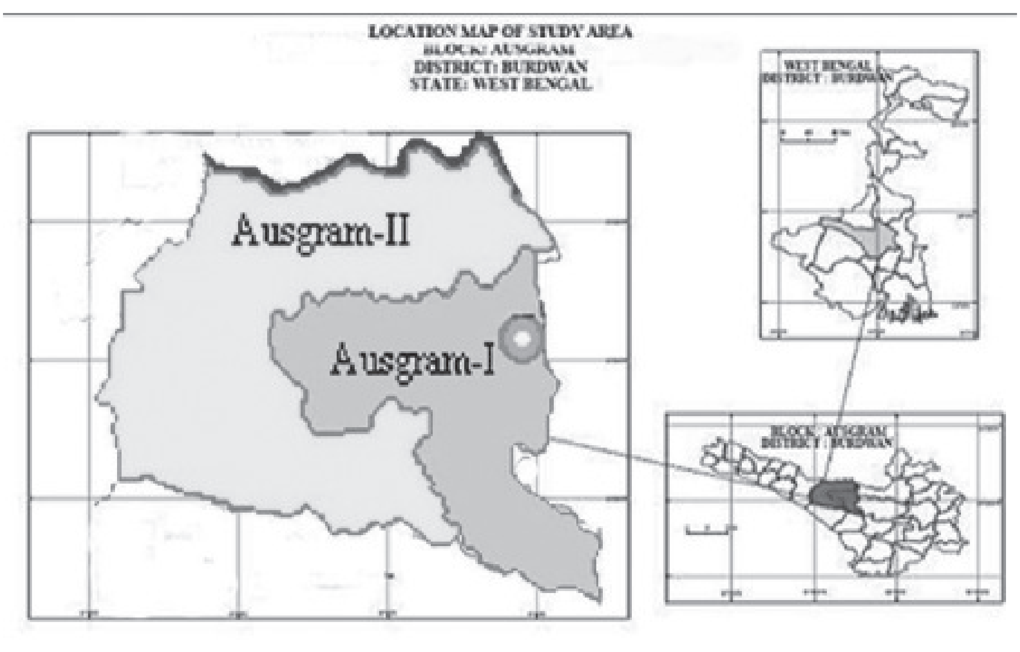
The study area extends from $23^{\circ}\ 14^{\prime}25.584^{\prime\prime}$ N to $23^{\circ}\ 30^{\prime}4.068^{\prime\prime}$ N Latitudes and $87^{0}\ 41^{\prime}55.86^{\prime}$ E to $87^{\circ}\ 52^{\prime}8.8644^{\prime\prime}$E Longitudes, (Topographical sheet number 73M/11 at 1:50,000 scale of survey of India.

The study area has Tropical and subtropical climate regime, the period from March to June is predominantly hot and dry, July to August is hot and humid, September to October is pleasant, and November to February is cool and dry. The hot wave during the summer and cold wave during the winter reflects harshness of the climate in the study area. The temperature ranges up to 46^{o} in summer to 15^{o} during winter. The annual mean precipitation in the study area ranges from 150 to 250 cm.

Total area of this Block is 164.50 km^{2} and topography is more or less plain. The altitude of its origin is about 40 mts above mean sea level. Generally the Block is inclined from the west to east. The important rivers of the Block are Kunur Nadi, Ajay River and two short form channels locally called Kadar. They are flowing from west to east.

Total population of the Block is 106831 (2011, census of India) of which 39576 population (43 percent) belongs to Scheduled Caste category and 14191 population (16 percent) belongs to Scheduled Tribe category And 62 percent of the total population of the Block is literate.

The present study aims to evaluate the frequent flood and its impact of some selected villages of Ausgram Block of Barddhama District. The selected villages are Ukta, Pichkuri, Soara and Parashurampur. The village Ukta is having five cadastral sheets. Total population of the village is 2969 persons (2011). The main worker of the village constitutes 38% of the total population and 16% of the total workers are agricultural laborers and 19% of the workers are cultivators. The village pichkuri is having five cadastral sheets. Total population of the village is 2585 persons (2011). Out of total population 38% are main workers, 15% are agricultural labor, and 80% are cultivator. The village soara is having 4 cadastral sheets. Total population is 545 persons (2011). Out of total population 40% main workers, 15% agricultural labor, and 70% are cultivator. The village parashurampur is having 2 cadastral sheets. Total population is 375.persons (2011). Out of total population 70% are main workers, 50% are agricultural workers, and 20% are cultivators.



Aims And Objectives: -

The main objectives of this present study are as follow:-

1) An over view of occurrence of frequent flood in the study area
2) To determine the effects and extent of the floods on habitations, infrastructure, health, food access, water and sanitation, education, crops and livestock in the study area.
3) To find out the causes behind frequent flood and suggest some remedial measures to mitigate flood problems.

Methodology And Database:-

In order to achieve the above objectives following methodology has been adopted.

Library work: Flood related data has been collected from various offices, such as, Sriniketan Weather station, Guskara Irrigation Department and Census of India 2011, Reference Books, SOI Topographical Map. Besides these relevant literature has been obtained through various websites.

Field Work: In this phase all the spatial data about study area has been collected through interview from villagers, direct field survey and so many over view photocopy.

Post Field Work: After collection the data from primary and secondary field has been processed and analysis in both statistically and cartographically.

Result And Discussion

A significant changing characteristic has noticed from the flood data analysis science the last half of nineteenth century. The major recorded flood years are 1956, 1959, 1970, 1971, 1973, 1978, 1984, 1995, 1999, 2000, 2002, 2005, 2007, 2010, 2012, 2015 and 2016(two times). Among these most devastating flood years are 1978, 1995, 1999, 2000, 2002. Before the Independence of India, in British period, high floods occurred in this area in 1913, 1916, 1938, and 1942 and so on before two century, devastating floods occurred in 1730, 1750, 1816, 1856, and 1885.

The first major flood at this area occurred in 2002. During this flood the rivers reached a height 10 feet above flood stage. The most disastrous flooding event at this area occurred on September 1978. In 1978, the flood wave that inundated the villages came at the dead of night, at 2.30 or 3 a.m., when everyone was fast asleep. The flood wave rose to a height of 5 meters. The village houses stand at most up to 3 meters. The result was a complete inundation of the villagers. The continuous heavy precipitation during 7 days had caused that flooding. At that time all dams, D.V.C., Mython, Muyrakshi, Tilpara were failed to protect the flood.

Table: - 1

Condition Of Dam In West Bengal

DAMS AND BARRAGES	MAXIMUM STORAGE CAPACITY (FEET)	WATER STORAGE AT PRESENT (FEET)	WATER DISCHARGES (THOUSAND QUISEK)
MASANJOR	398	392	22
MAITHON	490	489	35
PANCHET	425	421	60

TENUGHAT	870	845	5
KANSABATI	4402	433	5
BARRAGE			WATER
DISCHARGE(THOUSANDQUICEK)TILPARA			
30DURGAPUR			1 laksh 28 thousands

Sources: Nabannya, 02 August, 2015, up to evening Amanda bazaar partika.

Overview On Impact Of The Floods

The flood affected all the sectors of the economy. Below is a discussion on specific impact of the floods.

Health: Frequent flood extremely damaged the health of those peoples are victimized by flood. Though flood.Water released in a time but it fetched a galaxy of diseases from that men cannot save themselves. First of all, all and sundry prevails an unhygienic atmosphere throughout the rural areas. Gastroiestinal diseases like malaria, diarrhea, dengue, cholera reign in flood area. Water pollution as well as venomous snake bitten incident deserves Mention. Dead domestic animals are thrown into those flooded water and it causes water pollution.

Plate- 1

A view of stagnant water with hyacinth.

Impact on water and sanitation:

The most common water sources for domestic use in the study area are tube wells and protected wells, public taps, pond, scoop Holes Rivers and streams. Major portion of the inhabitants of study area use traditional open field for sanitation. Unsafe water sources and poor sanitary facilities pose a greater risk of water contamination. But the polluted flood water fatally collapsed the sources of water of domestic use and makes them unhygienic. During the flood the victims can't go further for their regular sanitation. That is why they are compelled to do so near their home or surrounding.

Impact on Education: - The school attendance has been reducing due to class rooms, staff houses, and toilets being completely damaged in the affected areas. The communication system for going into the schools being destroyed, the pupils are victimized the most. The culverts and bridges either being flooded or collapsed, neither teachers nor students come into school. The toilets as well as the class rooms are being flooded; the sanitation problem arises as one of the major problems in education. Most of the houses are damaged and educational necessities including books, uniforms are also collapsed.

Impact on Human settlement and shelter: - Most of the houses are built with soil in rural areas. The water of flood damaged those soil made houses easily. Very few brick-built houses are blown off under water. The poor quality building materials such as pole, bamboos, wood, and mud are also destroyed. The inhabitants then use to take shelter upon trees or rail-way platform or a high building of the railway authority. They have to spend sleepless nights. In a tiny room, they live as many as can. The sufferings from surroundings during this flood have no ends.

Impact on Infrastructure*: -* The infrastructure in the study area as like habitations, roads, bridges, schools, health centre become totally collapsed due to flood. The cultivated lands took shelter under water and infrastructure of those lands became plain. Soil made houses were under same result. Geographically there happened a great key change in this study area. The communicative roads which connect this local area to more developed urban areas such as Guskara, Bolpur were stayed under stagnant water of flood during that time. It not only damaged the economical balance but also made a great disturbance of their daily life. This transport problem reaches the pinnacle when a patient died for the lack of treatment due to poor communication during this time.

Plate -2

A view of Road damage due to severe flood

Impact on Agriculture and commercial activities*: -* Rural economy pertirely and entirely depend on agriculture. Most of the inhabitants of my study area earn their livelihood from agriculture and the economy of the Ausgram-1 C D Block is also dominated by agriculture. More than 90% people dependent upon subsistence farming and the economy is based almost entirely on agriculture with a single season rice crop, dependent on the south west monsoon. Floods regularly destroy crops in study area. Losing rice stocks and paddy fields were the most problems for the villagers from floods. Crop loss is mainly through rotting root crops and leaching of fertilizers from the late-planted fields. Cash crops such as rice and vegetables were severely affected. It is most uncommon for some families to completely lose their rice harvest for year. Very few families who are categorized as “wealthy “or “having enough “, the average land area for the paddy field were 25 bighas. They may have some rice stocks to continue feeding the family in case of losses. Those families in the “poor “category owned an average of ½-1 bighas or landless, at the same time having 3 or 4 additional member per household to feed than the wealthy families. So they prefer domestic cattle bringing up, day labor, and hackers, and so on.

Plate 3

A view of crop field under the water

Table2

Rice Sufficiency By Wealth Ranking

Rank	Status
Wealth	Enough to sell (300-400 quintals)
Middle	Enough to eat all year
Poor	Short 6 months
Very poor	Short 6 – 8 months

Source: primary field work

Impact on livestock: - Livestock losses are also a fatal problem caused by flood. When peoples can't able to resist themselves, the resistance of domestic livestock such as, cows, buffalos, goats, sheep, became a serious headak. But they tried at their best to keep them alive by extreme effort as because they (livestock) are the source of their alternative livelihood. Considering that in village one cow or buffalo can buy enough rice to feed four or five people for an entire year, this is a terrible set back in the family's savings. However during flood the livestock is confined on limited grazing land leading to over grazing and potential livestock disease out breaks. There is a high risk of disease outbreak of one or more of the following diseases, Contagion Bovine Pleural Pneumonia (CBP), Hemorrhagic Septica, Blackleg, Anthrax and corridor disease.

1) Impact on Forest: - The study area is totally covered by many various species of trees without agriculture field. Some community forest areas are on the side of river and wasteland. So the flood has direct impact on forest. Loss of forest might cause direct impact on local people's livelihood.

Plate 4

A view of forest area covered by water

Impact on Barren land: - most of the barren land or grass lands were under high risk from flooding, which has negative impact on their livelihood. Because most of the people have livestock and livestock use to graze on barren land.

The benefits of floods:-

Not all floods are bad.

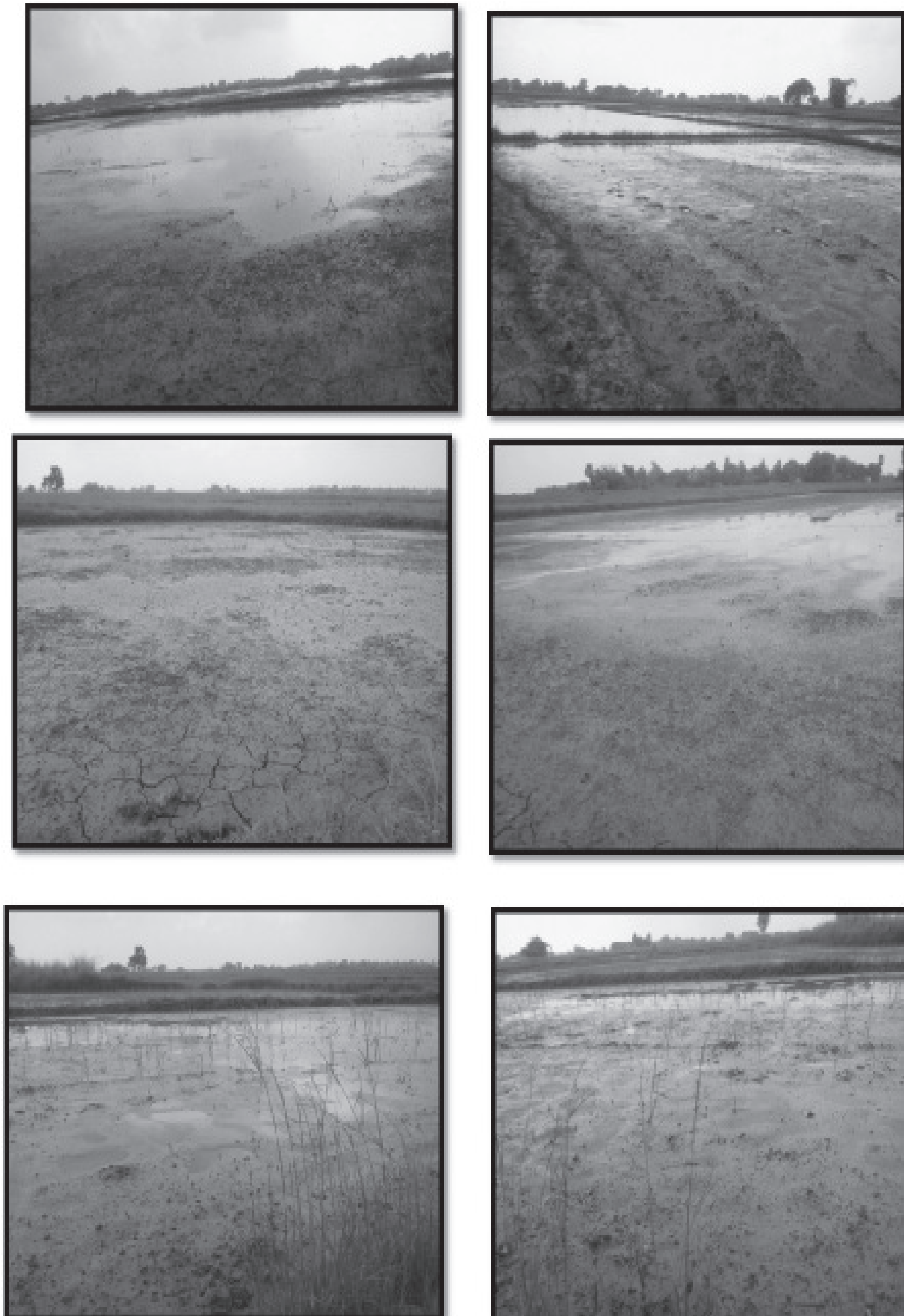
Seasonal flooding can be an important source of nutrients for agricultural land. Flooding is essential to the health of wetland ecological system.

Water supply is an obvious but often overlooked benefit of flooding; as flood water recede, channels, canals and depressions across the flood plain store floodwater for use in the following dry season, especially for irrigation purposes.

Finally, floods serve a number of useful mechanical purposes. They flush stagnant waters and pollutants out of floodwater; and recharge water supplies in dams and underground aquifers; and in some parts of the world, a ck of seasonal flooding is a disaster. Lack of seasonal flooding is a disaster.

Plate: - 5

Some Views Of Paddy Field After Recent Flood



Conclussion

The present study reveals that flood destroyed the livelihoods assets of rural communities and also promoting the poverty and food insecurities in the study area. Financial assets and natural asset (e.g. standing crops, vegetables and livestock) which were the necessary and significant assets for sustainable livelihoods were almost washed off. It can be said that the livelihood of these flood victims has been shifted to several years back of their progress and now they have to work hard and hard for their resilience.

Big farmers who are also affected during flood have recovered very fast as compare to the small farmers. Due to better connection with the Government and also due to some monopolies they were able to set the attention of the Government and other stakeholders very fast.

The D.V.C. was originally constructed by the state Government in to serves as a water supply in irrigation purpose through canal and also use in electricity product. So the Government started to look at channel improvement as the best way to control flooding in this area.

The channel improvement project: The total project encompassed 10 miles of channel improvement. The major features of the project were as follows: ——

1) Enlarging and realigning the present channels.
2) Concrete pavement protection of the stream banks.
3) Relocation of rail road tracks, highways and utilities.
4) Alterations to sewers and drain pipe, bridge pipers and other structures where necessary.

Recommendation

Flooding cannot and should not be eliminating;

——keep flood and people separate or

——live with flooding

Hard and soft solutions are needed to mitigate the impacts,

1) District health offices need to ensure availability of adequate essential emergency drug supply.
2) Promotion of construction of 5000 of adequate sanitary facilities e.g. improved ordinary latrines.
3) Protect well water from contamination, as flood waters often carry toxic materials, including raw sewage, animals waste, oil and chemicals.
4) The Ministry of Education (MoE) needs to upgrade community school and their infrastructure.
5) Elevate the homes, schools, and public buildings above flood level.
6) Use water resistant building materials, such as concrete or ceramic.
7) Provide food security pack for winter cropping.

Besides above general recommendations following some spatial measures should be appropriate for the study area. Such as

1) Flood protection works in the form of embankment / levees were to be designed along the both bank of Kunur River, a major tributary of Ajay River.
2) Afforestation along river banks mainly shrub type's vegetation.
3) Build check dam and reservoirs.
4) Construction of ground water recharge structure, and
5) Retaining ponds, flood channels, and flood walls may help to reduce flooding. However, this measure can be very expensive.

Annexure -1

Questionnaire for the Field Work:

1) Dose the flood occur in your village every year?
2) How many times in a year dose it occur?
3) Has the frequency of flood been increased than the previous year?
4) In which year devastation of the flood were so high?
5) What types of damages has been done?
6) What was the condition of domestic sanitation in the time of flood?
7) What types of problems faced about drinking water in time of flood?
8) What types of pollution have been spread in the time of flood?
9) What diseases have been spread during the flood?
10) Has any health –check up came been organized by any authority during the flood?
11) Has any medical team been send by the Government?
12) What was the condition of school in the time of flood?
13) What was the condition of road & transport in the time of flood?
14) What were the condition of the fishery & fisherman?
15) What were the condition of agriculture & farmers?
16) About how many acres of cultivated land & crops have been damages?
17) How did they manage the daily consumption of food during the flood? (rice, bread etc)
18) How many did they remain water loge in the time of flood?

Acknowledgement:-

I would like to express my special thanks of gratitude to my teacher Prof. (Dr.) Vibhas Chandra Jha, Principal of Vidya Bhavana, Visva Bharati, Santiniketan and Ex- Director of National Atlas & Thematic Mapping Organization (Dept. of Science And Technology, Govt. of India) and Dr G. C. Debnath, Associate professor Department of geography,Vidya Bhavana, Visva Bharati, Santiniketan, as well as my friend Dr. Prolay Mondal, Assistant Professor, Geography Dept., Raiganj University, Raiganj, Uttar Dinajpur who gave me invaluable guidance, keen interest and encouragement for the completion of this work and I came to know about so many new things. I am really thankful to them.

References:-

Bandyopadhyay, S., Sinha, S., Jana, N. C. and Ghosh, D., *“Entropy application to evaluate the stability of landscape in Kunur River Basin, West Bengal, India.*

Basu, S.R. and R.B. Ghosh (eds.) 2004. *Contemporary Environmental Issues of Bengal Basin. Kolkata*

Chakraborty, A., *Suffering with the river: Flood, social transition & local communities in the Ajay River Basin in West Bengal, India.*

District Census Handbook of Barddhaman District, West Bengal: Government of India 2001, 2014.

Dutta, S., *Agricultural Expansion and Its Impact on Environment: A Geographical analysis in Kanksa C.D. Block in Barddhaman district*, West Bengal.

Kale and Gupta Khullar DR (2006). *India :A Comprehensive Geography* ,Kalyani Publication. New. Delhi.

Karki, S. and Pradhan, A.M.S., *Impact of flooding on people’s livelihood: A case study from Kankai watershed.*

Mahalanobish, R. N., *The River Kunur: a standing menace in Burdwan, District*, River Bebav. Control. 1969

Mitra, B., Ecological conditions between natural and managed systems-—Kunur Basin.*J.Indian Group*. Found 1996.

Mitra, B., Expediency of surrogate data in accounting hydrological balance of small river basins: a case study of the Kunur Basin, *Indian J. Landse. Syst. Eeol. Stud*. 2002.

Mitra, N. and M. Mukhopadhyay. (2005) *Flood plain of lower Ajay basin: An Ecological Threat*

Mukhopadhyay, M. and Mukhopadhyay, S. *River Geography* Indian Progressive Publishing Co. (P.) Ltd.

Mukhopadhyay, M. *Bannya O Aamra* (Bengali Book).

Mukhopadhyay, S. "A geo-environmental assessment of flood dynamics in lower Ajay River including sands play problem in Eastern India," *Ethiopian Journal of Environmental Studies and Management,* 2010.

Rapid flood impact assessment report march, 2007. ——Zambia Vulnerability Assessment Committee (ZVAC) Lusaka.

Roy, S. and Mistri, B., *Estimation of peak flood discharge for an ungauged river: A case study of the Kunur River, West Bengal.*

Roy, S. *Spatial variation of floods in the lower Ajay River basin, West Bengal; a Geo-Hydrological Analysis*.

Rudra, K.,(2008) *Banglar Nadikatha*, Sahitya Samsad, Kolkata,.

Saha, S. and Mukhopadhyay. , *Assessment of bank erosion probability: A case study on Kunur River,* concern India.

Sing, S. *Geomorphology* .Prayag Pustak Bhawan Allahabad.

36

Study of Water Quality and Assessment of Heavy Metals Pollution of River Damodar, India, Using Index Analysis Approach

Umesh Kumar Singh and Sneh Pratap Singh

Introduction:

Water is the most important and life saving natural resource, which provides energy to the ecosystem for normal functioning (Pathak et al. 2015). River, glacier, lake, rain water and ground water are the main sources of water, which is used for drinking purpose. Besides drinking purpose, water resources are important for other sectors, like agriculture, industrial activity, hydropower generation, fisheries, livestock production and creational activities, which contributes to its financial value (Tyagi et al. 2013). Among many fresh water resources, river is considered as one of the important natural resources for human development and economic value. Water as well as sediments are the most important components of river ecosystem and considered as indicators of river health. The river sediment is sensitive indicator for aquatic environment contamination (Chauhan and Singh 2010; Raju et al. 2011). The river is considered as one of the most valuable resources of the universe; but increasing severe pollution making them dead day by day. Anthropogenic activities are the main concern for river pollution and it has been noticed that the human impact on the river ecosystem takes place since 200 years. During the 19^{th} and 20^{th} century heavy metals concentration in sediments as well as in water have increased distinctly, which is mainly caused by domestic and industrial activities. Some of the other sources like land development, sewage discharge, runoff and atmospheric deposition contribute heavy metals to the river ecosystem (Zunkel and Krueger 2009). The river sediment is considered as one of the major repositories of heavy metals, hence called as reservoir of heavy metals. Heavy metal pollution of rivers receiving more attention throughout the world in recent years (Chakraborty et al. 2014). Rapid increase in heavy metals concentration of river ecosystem has allowed the investigators to evaluate the toxicity, persistency, bio-availability and change in hydrogeochemistry over the time (Manoj et al. 2012; Raju et al. 2011). The bio-available form of heavy metals can enter into the food chain and produce a range of physiological disorder and diseases. The heavy metals in aquatic ecosystem confined with particulate matters and get settled down, and after a time interval it becomes the part of sediments (Suthar et al. 2009). The confined heavy metals have tendency to remobilise under the influence of environmental conditions like change in temperature, pH and organic matter contents. Thus, it is very important to investigate and monitor the water pollution to analyse and compare the current situation of river. Heavy metal has become the global concern in recent years because it has direct impact on aquatic environment and living beings (Manoj et al. 2012).

Damodar is one of the major peninsular river of India which flows through the states of Jharkhand and West-Bengal with a catchment area of 22,528 km^2 of which around 16,934 km^2 is in Jharkhand and rest in West-Bengal. Like the other rivers (Brahmaputra and Sonbhadra), Damodar is also considered as masculine river and one of the major inter-state river basins in India (Saryu Roy, Save Damodar Campaign article; Banerjee and Gupta 2013). River Damodar passes through some of the important and highly dense industrial belts of Jharkhand and West-Bengal. Some of the important towns like Palamu, Jharia, Ramgarh, Bokaro, Dhanbad, Durgapur and Raniganj, which have large number of industries like coke oven and coke based plants, steel plants, distilleries, paper mills, hydro-power, thermal power plants and mining industries, are situated along the bank of River Damodar (Tiwary and Dhar 1994; Banerjee and Gupta 2011). The main objectives of the study were to investigate the most recent water quality and sediment pollution of River Damodar through index analysis approach.

Materials and Methods

Damodar is a small rain-fed river which originates near Chandwa village of Palamu district and runs through the states of Jharkhand and West-Bengal to a total length of 592 km (11.7 and 8.5% of total area) of the state respectively before joining the lower part of River Ganga at Shyampur 55 km from Howrah (Figure 1). The River Damodar, earlier known as sorrow of West Bengal, extends from 22°45' N to 24°30' N and 84°45' E to 88° 00' E (Singh et al. 2008). Damodar basin lies 610 m above the sea level. As per study, about 1.9 million populations exist along the river basin. Geologically, lower basin of Damodar is quite distinct from upper basin; the upper basin is rich in forest cover and minerals, whereas lower basin is rich in nutrients which make it fertile for agricultural purpose. Damodar basin is not rich in metallic minerals, but it contains large amount of coal reserves, approximately 46% of India's coal reserves lies along the basin. Damodar River have many tributaries, among them Barakar is the main and largest tributary. (Tiwari and Dhar 1994).

Six sampling locations were selected along the course of basin spread across the Jharkhand and West-Bengal, covering an area of about 500 km (Table 1). To study the river health major locations were considered which have loads of industries, domestic wastes, power plants and mines for better understanding of actual impact on its surroundings.

Table 1

Different Sampling Locations Along The River Basin Of Damodar, India

Sample No.	Location	Major Activities
1	Chandwa (Jharkhand)	River Origin
2	Tenughat (Jharkhand)	Hydro-power plant
3	Panchet (Jharkhand)	Hydro-power plant
4	Maithon (West-Bengal)	Thermal and Hydropower plant
5	Dugapur Barrage (West-Bengal)	Steel Plant
6	Rondiah (West-Bengal)	Dam and barrage

Water and sediment samples were collected after the offset of monsoon in the month of November, 2011. River water was collected for estimation of water quality and sediment was used for the study of heavy metals pollution of river. Water samples were collected at the depth of 10-

15 cm from each location of river basin and transferred quickly into pre-cleaned and acid ringed 100 ml polypropylene bottles.

For heavy metals analysis sediment samples were taken at the depth of 5-10 cm and were quickly packed into air tight polythene bag to evade air contact. APHA, 2005 (21st edition) was followed during the estimation of heavy metals in sediments (APHA 2005). The chemicals and reagents used during study were analytical reagent grade quality and Millipore water was used throughout experiment.

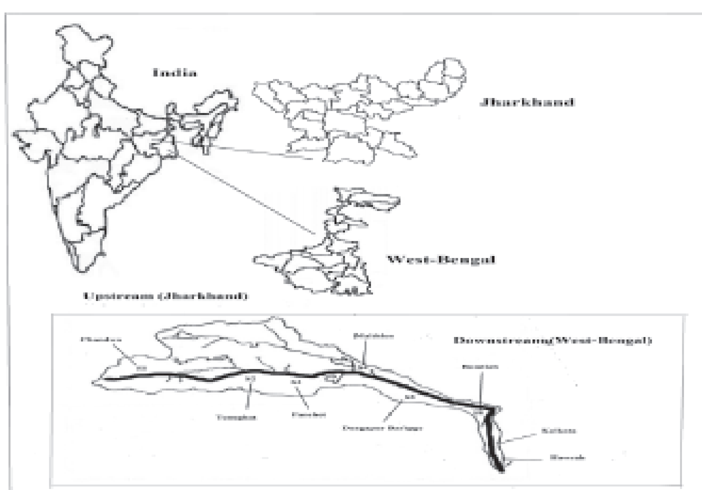
Analysis of Water and Sediments:

To examine the water quality of Damodar River, ten water quality parameters were studied along the river basin which has been shown in Table 5. Some of the water quality parameters like temperature, pH, conductivity and DO were analysed on spot for better results. The other parameters like total suspended solid, alkalinity, total hardness, biological oxygen demand, calcium and magnesium were analysed in laboratory using standard method.

For sediment analysis of River Damodar, nine heavy metals (Fe, Cu, Zn, Mn, Pb, Cd, Cr, Ni and Hg) were analysed during the study using atomic absorption spectrophotometer. Some of the general characteristics of sediments like temperature, pH, and conductivity were also studied. For the analysis of heavy metals in sediments, a sub sample of sediments were taken and dried in hot air oven for 48 hrs at 45^0C. After the 48 hrs of dryness, the sediment samples were ground using mortar and pestle. The sediment samples were sieved using sieve (aperture 125 µm) after the completion of grinding. After sieving, the small fraction of particles were homogenized by grinding with an agate mortar and then kept in test tube for chemical study. The test tubes were marked with all studied location number and precaution was taken to avoid any physical and chemical contamination during all the processes. For heavy metals analysis in sediments hot plate digestion method was carried out using nitric acid, sulphuric acid and perchloric acid (10 part HNO_3 + 1 part H_2SO_4 + 4 part $HClO_4$). All the plastics and glasswares were soaked with 14% HNO_3 for 24 hours. The washing was completed by rinsing the glasswares with Millipore water.

Figure 1

The location of sampling site along River Damodar, India



Statistical Analysis:

Determination of Water Quality Index:

Water quality of Damodar River was estimated by using water quality index. Nine important parameters were chosen for the calculation of water quality index. By using the standards for drinking water quality prescribed by different agencies, the WQI of Damodar River has been calculated (Yogendra and Puttaiah 2007).

The overall water quality index has been calculated by aggregating the quality rating with the unit weight linearly.

$$\boldsymbol{WQI} = “ q_n w_n / “w_n$$

$\boldsymbol{q_n} =$ Quality rating for the nth water quality parameter.

$\boldsymbol{w_n} =$ Unit weight of nth parameters.

Sub index or quality rating ($\boldsymbol{q_n}$) was calculated by following equation.

1. $\boldsymbol{q_n} = 100 [v_n - v_{i0}] / [s_n - v_{i0}]$

$\boldsymbol{q_n} =$ Quality rating for the nth water quality parameter.

$\boldsymbol{v_n} =$ Estimated value of n^{th} parameter at a given sampling station.

$\boldsymbol{s_n} =$ Standard permissible value of n^{th} parameter.

$\boldsymbol{v_{i0}} =$ Ideal value of nth parameter in pure water (i.e. pH and Dissolve oxygen (7.0 and 14.6 mg/L) and 0 for all other parameters.

Unit weight ($\boldsymbol{w_n}$) was calculated by following equation.

2. $\boldsymbol{w_n = k/s_n}$

Where, $\boldsymbol{w_n} =$ Unit weight of nth parameters.

$\boldsymbol{s_n} =$ Standard permissible value of n^{th} parameter.

$\boldsymbol{k} =$ Constant of proportionality and following equation was used to calculate.

$$\boldsymbol{k} = \frac{1}{“ [1 / (1 / Sn = 1, 2, 3...n)]}$$

Determination of Geo-accumulation Index (I_{geo})

The geo-accumulation is a quantitative measure and was determined to analyse the extent of pollution for different metals of sampling locations. It was calculated by using Muller formula, and the equation is known as index of geo-accumulation (I_{geo}) (Muller 1979).

$$(I_{geo}) = \log_2 (Cn / 1.5 \times Bn)$$

Where *Cn* is the measured concentration of the metal '***n***' and *Bn* is the background value of the sediments (shale standard).

Result and Discussion:

The detail results of nine heavy metals in sediments of Damodar River and some basic statistics have been shown in Table 2 and Table 3 respectively. Considering all the studied locations, significant spatial variations in the concentration of heavy metals were observed along the course of river basin.

Table 2

Concentration of metals (mg/kg) in sediment of Damodar River

Parameters	Concentration of Metals in Sediment (mg/kg) Sampling Sites						
	S1	S2	S3	S4	S5	S6	Shale Stand.
Fe (mg/kg)	846.93	1339.91	1811.87	1848.47	2528.75	2083.18	47200
Cu (mg/kg)	22.15	34.5	39.29	54.24	121.93	99.06	45
Mn (mg/kg)	39.92	72.39	78.02	87.86	100.02	88.77	850
Zn (mg/kg)	168.96	418.27	727.49	808.46	955.35	838.63	95
Pb (mg/kg)	2.26	17.89	21.83	23.52	63.9	38.43	20
Cd (mg/kg)	0.025	0.07	0.1	0.16	0.79	0.3	0.3
Cr (mg/kg)	4.4	16.04	24.74	35.71	116.45	64.28	90
Ni (mg/kg)	8.97	18.73	29.31	36.1	51.46	37.81	68
Hg (mg/kg)	BDL	BDL	BDL	BDL	BDL	BDL	-

= (Turekian and Wedepohl 1961), BDL = Below Detection Limit

Table 3

Estimation of basic statistics for the heavy metals

Parameters	Min	Max	Range	Mean	Median	SD	Skewness	Kurtosis
Fe	846.43	2528.75	1681.82	1743.18	1830.17	585.56	-0.388	0.097
Cu	22.15	121.93	99.78	61.86	46.76	39.71	0.829	-1.11
Mn	39.92	100.02	60.1	77.83	82.94	20.87	-1.364	2.345
Zn	168.96	955.35	786.39	562.86	767.97	298.32	-0.993	-0.236
Pb	2.26	63.9	61.64	27.97	22.67	21.07	0.935	1.300
Cd	0.025	0.79	0.765	0.240	0.13	0.285	1.903	3.714
Cr	4.4	116.45	112.05	43.60	30.22	41.10	1.325	1.450
Ni	8.97	51.46	42.49	30.39	32.70	15.01	-0.131	-0.328
Hg	-	-	-	-	-	-	-	-

Confidence Level= 95.0%

Table 4

General characteristics of sediment samples of Damodar River

Sl. No	Parameters	S1	S2	S3	S4	S5	S6	Range	Mean Value
1	Temperature	45	51	58	60	78	62	45-78	59
2	pH	8.53	7.92	8.29	7.58	7.31	6.19	6.19-8.53	7.63
3	Conductivity	0.354	0.327	0.341	0.286	0.259	0.271	0.259-0.354	0.306

The general characteristics of sediment (Table 4) were studied, where the mean value of temperature was 59^{0}C and the pH of sediment ranged from 6.19 to 8.53, mean value of conductivity in sediment samples were 0.306 µS/cm which lies within recommended permissible value. The mean concentration of Fe, Cu, Mn, Zn, Pb, Cd, Cr, Ni and Hg (mg/kg) was 1743.18, 61.86, 77.83, 562.86, 27.97, 0.240, 43.60, 30.39 and BDL respectively. The maximum values of Fe, Cu and Mn were found along the Durgapur region, while the maximum concentration of Zn, Pb and Cd were also observed at sampling location S5 (Durgapur barrage). The studied result revealed that Durgapur barrage has high concentrations of Cr and Ni, whereas Hg was found below detection limit at all studied locations. The mean value of Cu, Zn and Pb were observed more than the shale standard value (Turekian and Wedepohl 1961). The values of heavy metals as per abundance in sediment were in following order (Fe > Zn >Mn> Cu > Cr > Ni >Pb> Cd > Hg). All the heavy metals concentration were found minimum at origin and maximum around Durgapur region, downstream of Damodar basin.

Water quality index (WQI), and Geo-accumulation Index (Igeo) were calculated for better assessment of water and sediment quality of River Damodar.

Table 5

Observed Physiochemical Parameter Value Of Water Body

Sl. No	Parameters	S1	S2	S3	S4	S5	S6	Range	Mean Value
1	Temperature (^{0}C)	17	17	18	17	19	16	16-19	17.3
2	pH	7.3	7.6	7.5	7.4	8.2	7.7	7.3-8.3	7.6
3	Conductivity (µS/cm)	300	410	370	320	510	350	300-510	376.6
4	TSS (mg/L)	5	3	4	1	9	2	2-9	4
5	Dissolve Oxygen (mg/L)	7.9	7.6	7.4	7.5	6.2	7.0	6.2-7.9	7.2
6	Alkalinity (mg/L)	156	178	160	150	120	156	120-178	153.3
7	Total Hardness (mg/L)	172	196	172	160	180	264	160-264	190.6
8	Calcium (mg/L)	116	136	140	135	95	184	95-184	134.3
9	Magnesium (mg/L)	56	60	32	25	85	80	25-85	56.3
10	B.O.D (mg/L)	BDL	2	2.5	2	4	3	2-4	2.25

The mean value of temperature, pH, Conductivity, TSS, Dissolve Oxygen, Alkalinity, Total Hardness, Calcium, Magnesium and BOD were 17.3^{0}C, 7.6, 376.6 µS/cm, 4 mg/L, 7.2 mg/L, 153.3 mg/L, 190.6 mg/L, 134.3 mg/L, 56.3 mg/L and 2.25 mg/L respectively. The observed values of water quality parameters like temperature, pH, and TSS were below the permissible range, whereas the dissolve oxygen value decreased at sampling location (S5). The variation was significantly observed in conductivity along all the studied locations.

Table 6:

Drinking water standard given by different agencies and unit weight. (All values except pH and conductivity in mg/L)

Sl. No.	Parameters	Standards	Recommended Agency	Unit Weight
1	pH	6.5-8.8	ICMR/BIS	0.202
2	Conductivity	300	ICMR	0.0057
3	TSS	500	WHO	0.0034
4	Dissolve Oxygen	5.00	ICMR/BIS	0.344
5	Alkalinity	120	ICMR	0.014
6	Total Hardness	300	ICMR/BIS	0.0057
7	Calcium	75	ICMR/BIS	0.0229
8	Magnesium	30	ICMR/BIS	0.057
9	BOD	5.00	ICMR	0.344

Reference: Thakor et al. 2011

Table 7

Water Quality Index (WQI) of Damodar River, WQI level and water Quality Status

Sampling locations	Water Quality Index	WQI Level	Water Quality Status
Chandwa (S1)	34.851	0-25	Excellent water quality
Tenughat (S2)	54.684	26-50	Good water quality
Panchet (S3)	55.903	51-75	Poor water quality
Maithon (S4)	50.129	76-100	Very poor water quality
Durgapur Barrage (S5)	81.690	> 100	Unsuitable for drinking
Rondiah (S6)	66.333		

Reference: Chaterjee and Raziuddin 2002

The WQI of present river water was calculated by using various physiochemical parameters of different sampling locations. Water Quality Index was estimated with the help of different standards for different parameters provided by the different agencies (Table 6). The water quality index for studied locations of River Damodar and water quality status with respect to WQI value has been given in Table 7. The water quality index of River Damodar for each studied locations were S1-34.851, S2- 54.684, S3-55.903, S4- 50.129, S5- 81.690 and S6- 66.333, which shows poor water quality of water body. Water quality index suggests that the River Damodar has good water quality at its origin (Chandwa, S1), whereas the water quality of River Damodar was very poor at Durgapur barrage (S5).Water Quality Index (WQI) suggests that the water quality is very poor at all studied locations except Chandwa (S1).

Table 8

Geo-accumulation Index (I_{geo}) values of Damodar River sediments

Geo-accumulation Index Values

Sampling Locations	Fe	Cu	Mn	Zn	Pb	Cd	Cr	Ni	Hg
S1 (Chandwa)	-6.38	-1.6	-4.99	0.24	-3.74	-4.17	-4.94	-3.50	BDL
S2 (Tenughat)	-5.72	-0.96	-4.14	1.55	-0.74	-2.69	-3.07	-2.44	BDL
S3 (Panchet)	-5.29	-0.78	-4.03	2.35	-0.459	-2.17	-2.45	-1.8	BDL
S4 (Maithon)	-5.25	-0.31	-3.86	2.50	-0.35	-1.49	-1.92	-1.49	BDL
S5 (Durgapur Barrage)	-4.81	0.85	-3.67	2.75	1.09	0.81	-0.21	-0.98	BDL
S6 (Rondiah)	-5.08	0.55	-3.84	2.55	0.35	-0.58	-1.07	-1.43	BDL

The I_{geo} values of the sediment samples have been presented in Table 8. The I_{geo} values of all studied heavy metals suggested that heavy metals concentrations in sediment were more than prescribed I_{geo} sediment quality in downstream of river. I_{geo} values of Cu, Zn, Pb and Cd were 0.85, 2.75, 1.09 and 0.81 respectively at Durgapur barrage (S5), which indicates that the sediment quality is moderately polluted in Durgapur area. It was observed that, Zn has the highest I_{geo} values as compare to prescribed sediment quality at all sampling locations of River Damodar. Prescribed values of I_{geo} for the measurement of sediment pollution load of the river body have been given in Table 9.

Table 9

Index Classification Of Sediment Quality

Value of I_{geo}	Class	**Sediment Quality** (Reference: Muller 1981)
d” 0	0	Unpolluted
0 - 1	1	Unpolluted to moderately polluted
1 - 2	2	Moderately polluted
2 - 3	3	Moderately to strongly polluted
3 - 4	4	Strongly polluted
4 - 5	5	Strongly to extremely polluted
e” 6	6	Extremely polluted

Heavy metal pollution is the growing concern particularly in the field of aquatic environment. A lot of research has already been done and is still going on for better understanding of their behaviour. Comparison of present study with some recorded heavy metals concentration in other rivers of India and around the world has been presented in Table 10.

Table 10

Heavy Metal Concentrations Recorded In Some Other Rivers

					Parameters				
Rivers	**Fe**	**Cu**	**Mn**	**Zn**	**Pb**	**Cd**	**Cr**	**Ni**	**Hg**
Tsurumi[1*]	-	133.0	-	381.1	40.8	1.0	102.9	36.6	-
Hindon[2**]	233.71	59.32	150.88	58.28	41.19	2.33	101.78	-	-
Chenab[3*]	-	7.3	444.6	30.38	16.3	0.538	-	-	-
Tigris[4*]	- 29.33	265.16	-	34.33	0.736	-	19	-	
Cauvery[5*]	11144	11.2	1763.3	93.1	4.3	1.3	389	27.7	-
Buriganga[6**]	-	184.4	-	502.3	79.8	0.8101.2	-	-	
Yamuna[7*]	39100	307	706.5	557.5	122	18.5	328.5	130	-
Gomti[8*]	2660.9	5.0	148.13	41.47	40.33	2.42	8.15	15.17	-
resent Study[9**]	1743.18	61.86	77.83	562.86	27.97	0.240	43.60	30.39	-

1= (Mohiuddin et al. 2010) 2= (Suthar et al. 2009) 3= (Hanif et al. 2016) 4= (Rabee et al. 2011) 5= (Venkatesha et al. 2012) 6= (Saha and Hossain 2011) 7= (Singh 2001) 8= (Singh et al. 2005) 9= (Present Study); *= ìg/kg; **= mg/kg

Conclusions:

The aim of the present study was to analyse the water quality and sediment pollution level of Damodar River. Study revealed relatively high concentration of heavy metals in sediments mainly in downstream of river. Water Quality Index indicated poor water quality along the urban and industrial belts. The I_{geo} values of studied heavy metals suggested that the sediment quality is moderately polluted by Zn, Cu and Pb in downstream of river. Spatial variation in heavy metals concentration was observed during the study. Industrial discharge is the prime cause of heavy metals in the downstream of river basin.

Acknowledgements

The authors would like to acknowledge the help received from Visva-Bharati University, Santiniketan to carry out research work and technical support throughout the study.

References:

APHA., (2005). Standard methods for the examination of water and waste water. 21st ed. American Public Health Association, Washington. DC, USA.

Banerjee, U.S., Gupta, S., (2011). Statistical Evaluation of Hydrochemical Parameters of the Damodar River Water near Durgapur Industrial Complex, West Bengal, India*. Journal of Industrial Pollution Control. 27 (1),* 51-60.

Banerjee, U.S., Gupta, S., (2013). Impact of industrial waste effluents on River Damodar Adjacent to Durgapur Industrial Complex, West Bengal, India. Environment *Monitoring Assessment. 185,* 2083-2094.

Chakraborty, P., Ramteke, D., Chakraborty, S., Nagender Nath, B., (2014). Changes in metal contamination levels in estuarine sediments around India – An assessment. *Marine Pollution Bulletin. 78*, 15-25.

Chaterjee, C., Raziuddin, M., 2002. Determination of Water Quality Index (WQI) of a Degraded River In Asansol Industrial Area, Raniganj, Burdwan, West-Bengal. *Nature, Environment and Pollution Technology. 1 (2)*, 181-189.

Chauhan, A., Singh, S., (2010). Evaluation of Ganga Water for Drinking Purpose by Water Quality Index at Rishikesh, Uttarakhand, India*. Report And Opinion. 2 (9),* 53-61.

Hanif, N., Eqani, S.A.M.A.S., Ali, S.M., Cincinelli, A., Ali, N., Katsoyiannis, I.A., Tanveer, Z.I., Bokhari, H., (2016). Geo-accumulation and Enrichment of Trace Metals in Sediments and Their Associated Risks in the Chenab River, Pakistan. *Journal of Geochemical Exploration. 165,* 62-70.

Manoj, K., Kumar, B., Padhy, P.K., (2012). Characterisation of Metals in Water and Sediments of Subarnarekha River along the Projects' Sites in Lower Basin, India. *Universal Journal of Environmental Research and Technology. Vol. 2, Issue 5.*

Mohiuddin, K.M., Zakir, H.M., Otomo, K., Sharmin, S., Shikazono, N., (2010). Geochemical Distribution of Trace Metal Pollutants in Water and Sediments of Downstream of an Urban River. *International Journal of Environmental Science and Technology. 7 (1),* 17-28.

Muller, G., (1979). *Heavy Metals in the Sediment of the Rhine-Changes Seity.* Umsch. Wiss. Tech., 79, 778-783.

Muller, G., (1981). *The Heavy Metal Pollution of the Sediments of Neckars and its Tributary: A Stocktaking.* Chem. Zeitung., 105, 157-164.

Pathak, S.K., Prasad, S., Pathak, T., (2015). Determination of Water Quality Index River Bhagirathi in Uttarkashi, Uttarakhand, India. *International Journal of Research-Granthaalayah Social Issues and Environmental Problems. Vol. 3, (Iss.9: SE).*

Rabee, A.M., Al-Fatlawy, Y.F., Najim Abd own, A.H., Nameer, M.,(2011). Using Pollution Load Index (PLI) and Geoaccumulation Index (I-Geo) for the Assessment of Heavy Metals Pollution in Tigris River Sediment in Baghdad Region. *Journal of Al-Nahrain University. Vol.14 (4),* 108-114.

Raju, K., Vijayaraghavan, K., Seshachalam, S., Muthumanickam, J., (2011). Impact of Anthropogenic Input on Physicochemical Parameters and Trace Metals in Marine Surface Sediments of Bay of Bengal off Chennai, India. *Environment Monitoring Assessment. 177*, 95-114.

Roy, S., Article, (*Save Damodar Campaign*) assessed on 12.8.2016.

Saha, P.K., Hossain, M.D., 2011. Assessment of Heavy Metal Contamination and Sediment Quality in the Buriganga River, Bangladesh. *2nd International Conference on Environmental Science and Technology IPCBEE Vol.6.*

Singh, A.K., Mondal, G.C., Kumar, S., Singh, T.B., Tewary, B.K., Sinha, A., 2008. Major Ion Chemistry, Weathering Processes and Water Quality Assessment in Upper Catchment of Damodar River basin, India. *Environmental Geololy. 54*,745-758.

Singh, K.P., Mohan, D., Singh, V.K., Malik, A., 2005. Studies on distribution and fractionation of heavy metals in Gomti river sediments—a tributary of the Ganges, India. *Journal of Hydrology. 312*, 14-27.

Singh, M., 2001. Heavy metal pollution in freshly deposited sediments of the Yamuna River (the Ganges River tributary): A case study from Delhi and Agra urban centres, India. *Environmental Geology. 40 (6),* 664-671.

Suthar, S., Nema, A. K.., Chabukdhara, M., Gupta, S. K., 2009. Assessment of Metals in Water and Sediments of Hindon River, India: Impact of Industrial and Urban Discharges. *Journal of Hazardous Material. 171*, 1088-1095.

Thakor, F.J., Bhor, D.K., Dabhi, H.R., Pandya, S.N., Chauhan, N.B., 2011. Water Quality Index (W.Q.I.) of Pariyej Lake Dist. Kheda – Gujarat. *Current World Environment Vol. 6 (2*), 225-231.

Tiwari, R.K., Dhar, B.B., (1994). Environmental pollution from Coal Mining Activities in Damodar River Basin, India. *Mine Water and the Environment. Vol. 13*, 1-10.

Turekian, K. K., Wedepohl, K. H., 1961. Distribution of the Elements in Some Major Units of the Earth's Crust. *Geol. Soc. Am. Bull., 72*, 175-192.

Tyagi, S., Sharma, B., Singh, P., Dhobal, R., (2013). Water Quality Assessment in Terms of Water Quality Index. *American Journal of Water Resources. Vol. 1, No. 3*, 34-38.

Venkatesha, R.K., Somashekar, R.K., Prakash, K.L., (2012). Heavy metal status of sediment in river Cauvery, Karnataka. *Environment Monitoring Assessment. 184 (1*), 361-73.

Yogendra, K., Puttaiah, E.T., (2007). Determination of water quality Index and Suitablity of an Urban Waterbody in Shimoga Town, Karanataka. *Proceeding of Taal*. The 12th World Lake Conference, 342-346.

Zunkel, C.S., Krueger, S., (2009). Trace Metal Dynamics in Floodplain Soils of the River Elbe: A Review. *Journal of Environmental Quality. 38*, 1349-1362.

37

Application Of Remote Sensing To Analyse Land Capability Of Bankura District

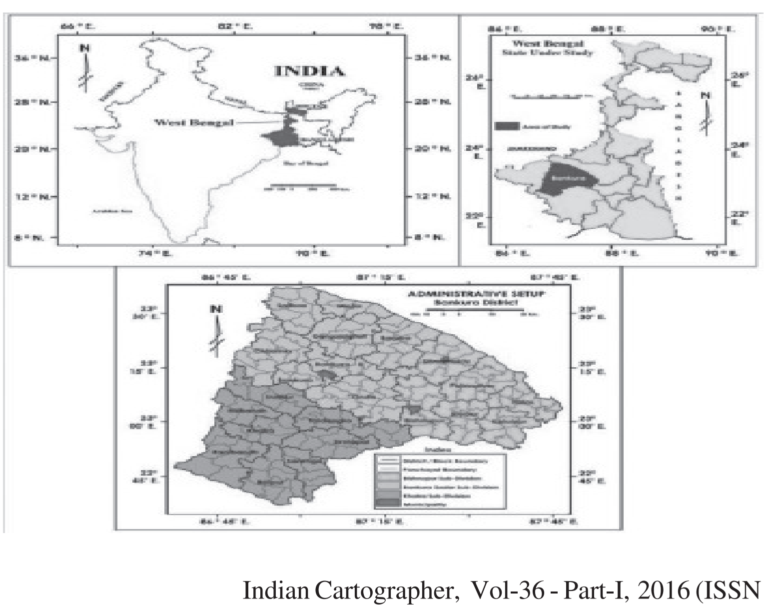
Yogia Dutt, Sohini Neogy** and **Uttam Mukhopadhyay

Introduction

Remote Sensing and GIS are deemed as fundamental tools for the inventory and analysis of natural resources for regional, rural and local planning, management and development at both small as well as large scales in underdeveloped and developing parts of the world (Teotia & Santos, 2010). The integrated use of GIS and Remote Sensing technologies also bestow specific examples involving land, water and soil applications. These technologies also seem to be apposite and economic for land classification (Civco, 1987). The combination of GIS with remotely sensed data helps in assessment of land use which can be matched with land capability (Wilson, 1999). Land capability in one hand aids to find out efficiency of land for specific uses and on the other it assists to prevent improper use of land which leads to deterioration of land quality. This paper aims to signify the application of remote sensing and geographic information system on determining land use land cover, analysing land capability and assessing the effectiveness of parameters taken into consideration for land capability index (in GIS environment) with the actual scenario. Accordingly, land-oriented research (particularly in backward areas) is ensured to formulate policy recommendations for sustainable development.

Figure 1

Location of Study Area



Choice of Study Area

Cultivators and agricultural labourers constitute the main occupation in Bankura (86°36'E-87°46'E; 22°38'N -23°38'N) which account for about 21.1% and 44.2% of the population of the state, respectively, living in villages with more than 15.29% as small and marginal farmers. The agriculture based economy is a typical example of an area having various types of resources but suffering from underdevelopment due to predominance of tribal population which happens to be 10.25% of the total population. The district provides an ample evidence of backwardness in resource richness. In this context, Bankura has been chosen as the study area to showcase the land capability of the region in relation with its existing land use and land cover.

Objectives

The main objectives of the study are:

To identify Land Use and Land Cover in Bankura district

To assess the Land Capability of Bankura district on the basis of six selected parameters

To compare the actual and computed scenario of Land Use Land Cover and Land Capability of the district.

Database

To analyse the pattern of Land Use and Land Cover in Bankura district and to calculate the land capability of the district, various satellite images and some field samples have been used.

Table 1

Data Sources

TYPE OF DATAUSED	YEAR	PATH/ROW	RESOLUTION	NO. OF BANDS	SOURCE
LANDSAT8/OLI	2015	139/44	30m.	7	GLCF
SRTM DEM	2013	-	30m.	-	GLCF
BankuraDistrict map AdministrativeAtlas	2016	-	-	-	

Methodology

***Image Enhancement Technique*:** Generation of LULC map of any area from satellite imagery needs a proper image classification which transforms the FCC into true colour and displays the important LULC features. But any simple image classification method does not provide the accurate land use land cover data. In order to minimise the error, Image Enhancement is quite a popular technique used by geographers. In this method, permutation and combination is done first among the seven bands to get the maximum possible groups of three bands. Standard deviation and Correlation coefficient are then calculated for each band. Finally the Optimum Index Factor is generated by using the formula-

OIF= ÓSD/ÓR

Kappa Statistics: Kappa statistics, a well-known technique for both qualitative and quantitative datasets, helps to find out the level of interrelation between two or more variables. Apart from this, it also discusses about the type of interrelation, i.e. whether the accuracy is actually present or it is occurring only by chance. Kappa Statistics value has a range between 0 and 1. A perfect interrelation should have Kappa value of 1 with zero possibility for chance.

(Observed Accuracy- Chance Agreement) Kappa Statistics =
{(Grand Total)2 - Chance Agreement}

Index Factor: Azzi's method of calculating Index Value is generally used to classify soil on the basis of chemical properties like soil pH, soil organic matter, soil minerals etc.

IV= (100/H) x Y [H= highest value, Y= individual value]

After calculating the Index Value, Effective Index value (EIV) and Proportionate Index value (PIV) are calculated for each point of sample collection and then plotted through GIS software to generate the soil map.

Analytical Hierarchical Process: While dealing with more than one variable, Saaty's Analytical Hierarchical Process is one of the well-known methods to give weightage to the concerned variables according

ANALYTICAL HIERARCHICAL PROCESS (AHP)

Assign Suitability Classes for each attribute
to their importance in a particular circumstance.

AHP= Ó Variables x Weightage

Multi Criteria Decision Making: Using ARCGIS 9.3

Multiple Criteria Decision Making has been run to generate the final land capability map. In this process, the weightage for each variable calculated through AHP is given to the software. On the basis of these values, the software then generates the desired map with the mentioned scoring pattern like five point scoring or ten point scoring.

2. Land Use & Land Cover

Standardisation of Suitability Classes Weight of each attribute Weighted Sum Overlay Suitability Map

Generation of LULC map of Bankura district is the first objective of this study. Generally, this is done by converting the FCC into true colour by identifying features from 4, 3, 2 band combination. Supervised Image Enhancement provides a scope to find out the maximum

Table 2

Calculation for Optimum Index Factor

BAND COMBINATION	OPTIMUM INDEXFACTOR	BAND COMBINATION	OPTIMUM INDEXFACTOR
R,G,B	OIF	R,G,B	OIF
1,2,3	20.66823145	2,3,4	58.96366466
1,2,4	68.67078582	2,3,5	42.71435873
1,2,5	47.45147445	2,3,7	26.93419191
1,2,7	29.23164268	2,4,5	68.53924586
1,3,4	69.99689966	2,4,7	57.98448768
1,3,5	44.71494042	2,5,7	42.26596742
1,3,7	27.37913137	3,4,5	65.73053415
1,4,5	82.0706564	3,4,7	53.18427739
1,4,7	65.96828704	3,5,7	37.56365309
1,5,7	43.17694981	4,5,7	39.78044907

[Source: Computed by Authors]

suitable band combination among the seven bands instead of choosing the common combination of bands. In this study, after conducting the permutation and combination, twenty possible band combinations have been generated and OIF of each combination has been calculated. As the combination of band 1, 4, 5 is showing the maximum OIF value of 82.0706564, it is taken for the Land Use Land Cover classification. 53.06% of areas remain unclassified because of the selection of band combination. In the rest of the area, agricultural fallow and dry fallow land has the maximum coverage of 14% and 16.39% respectively. Apart from those other six categories of Land Use and Land Cover has also been identified. Though image enhancement helps to minimise the error in image classification but a minimum amount of error is always there in the process. So each image classification needs to have an accuracy value more than 90%. Kappa Statistics in this regard has been used to calculate the accuracy of this image classification. The calculation is showing the accuracy value of 0.94 in Kappa Statistics which means the accuracy level is 94% which makes the classification quite acceptable.

Figure 2

Land Use Land Cover (LULC) Map

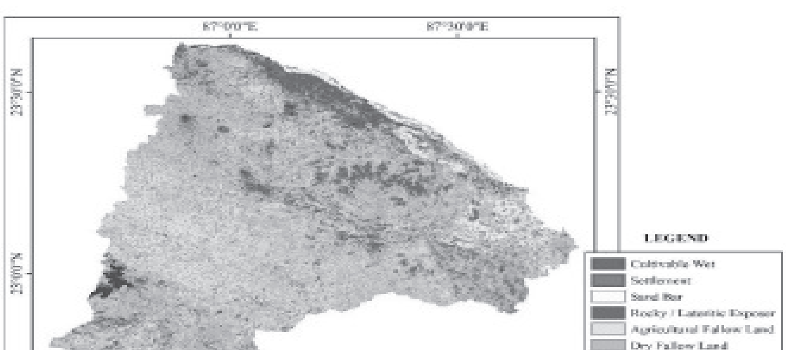


Table 3

Spatial Distribution of LULC Classes

LULC CLASSES	AREA IN SQ. KM.	AREA IN %
Cultivable Wet	329.5377	4.730879635
Settlement	445.1634	6.390814961
Sand Bar	83.5965	1.200120591
Rocky/Lateritic Exposure	222.2658	3.190872385
Agricultural Fallow Land	1683.1116	24.16293611
Dry Fallow Land	1969.1298	28.269045
Water Body/River	69.1164	0.992242676
Agricultural Crop Land	209.493	3.007504657
Dry Bare Land	850.0329	12.20316624
Forest Cover	1104.228	15.85241918

[Source: Computed by Authors]

Table 4

Error Matrix & Kappa Statistics

CLASSIFIED DATA	AGRICULTURAL CROP	WATER BODY/ RIVER	LATERITIC	FOREST	DRY BARE	AGRICULTURAL	DRY FALLO	CULTIVABLE WET	SAND BAR	SETTLEMEN	ROW TOTAL	USER'S ACCURACY
AGRICULTURAL CROP	15710	0	0	0	0	0	0	0	0	0	15710	1
WATER BODY /	0	6015	0	0	0	0	0	0	0	0	6015	1
LATERITIC	0	0	11102	18	0	0	14	33	0	3	11170	0.993912265
FOREST	259	0	2	18540	0	437	0	0	0	0	19238	0.963717642
DRY BARE	0	0	0	0	8390	1	11	0	2	0	8404	0.998334127
AGRICULTURAL	0	0	0	1105	0	9654	290	0	0	0	11049	0.87374423
DRY FALLOW	0	0	16	192	3	159	12640	61	0	88	13159	0.960559313
CULTIVABLE WET	0	0	108	0	0	0	508	4536	0	978	6130	0.739967374
SAND BAR	0	0	0	0	0	0	0	0	2332	0	2332	1
SETTLEMEN	0	26	24	0	0	1	43	541	0	3277	3912	0.837678937
COLUMN	15969	6041	11252	19855	8393	10252	13506	5171	2334	4346	97119	
PRODUCER'S ACCURACY	0.98378108	0.99569608	0.986669	0.93377	0.999643	0.94167	0.93588	0.8772	0.999143	0.754027		
OVERALL ACCURACY	0.94930961											
CHANCE	1210542179											
OBSERVED ACCURACY	8953983324											
KAPPA	0.94184596											

[Source: Computed by Authors]

Discussion

To assess the land capability of Bankura, six parameters have been chosen, namely, Slope, Hydrological Soil Group, Soil physico-chemical Property, Ruggedness Index, Vegetation cover and Drought.

Slope

Slope is regarded as an important element of landform which is formed due to interplay of endogenetic and exogenetic factors. The endogenetic processes fabricate the elevation and orientation of slope elements while the exogenetic process tend to reduce the landscape to base level. In the district of Bankura, very steep slope, as high as 54° is noticeable on the northern part which

happens to be Biharinath and Susunia hills, thereby covering only 0.1% of the total land area. Moderate slope amounting to a maximum of 2° covers an area of approximately 9% which is dispersed all over the map, especially in the western section. Very low and low slope covers the maximum portion of the district (59% and 31% respectively) which is viewed in the entire eastern section of the map. Since gentle slope covers virtually the entire district, it is quite obvious that Bankura should have high land capability owing to this individual attribute. Maximum utilisation of land is possible in this regard as there exists negative relation between slope and land capability.

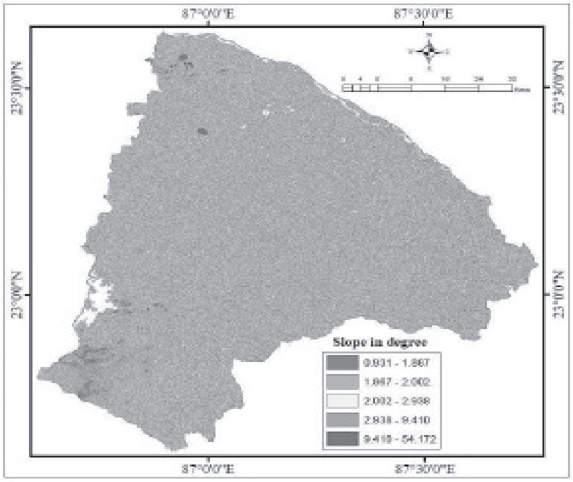
Table 5

Slope of the Study Region

SL. NO.	SLOPE IN DEGREES	AREA IN SQ. KM.
1	0.931- 1.867	3979.65000
2	1.867- 2.002	2078.92000
3	2.002- 2.938	578.85300
4	2.938- 9.410	80.70480
5	9.410- 54.172	8.69670

Figure 3

Slope Map



3.2 Hydrological Soil Group

The Hydrological Soil Group classification relates to soil hydrology specifically concerning runoff, flooding and soil permeability. Soils are classified into hydrological soil groups (HSGs) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting. The HSGs are A, B, C and D. The four groups are defined by Soil Conservation Service (SCS) soil scientists as follows:

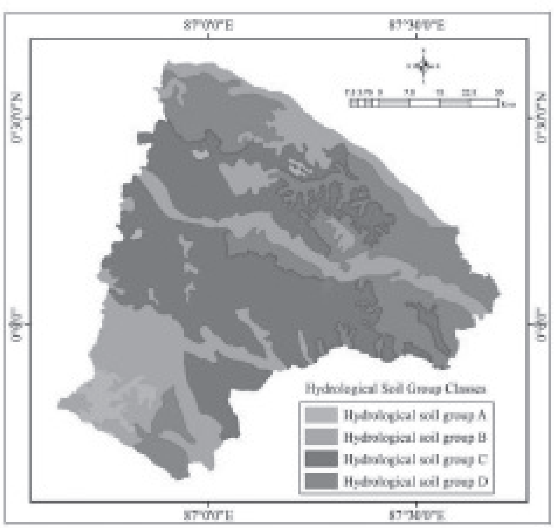
Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15-0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05- 0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0-0.05 in/hr).

Figure 4: Hydrological Soil Group Map



While studying the HSG of Bankura, it has been found that 3% of the total land area pertains to HSG A which indicates that very little land surface has low land capability witnessed in the western section of the district. This is also justifiable with respect to slope wherein high slope juxtaposes with HSG A, thereby signifying that sandy soils pertain to high slope and thus low land capability. 29% of the total district exhibit HSG B which signifies rising land

Table 6

Hydrological Soil Group Map

SL. NO.	HYDROLOGICAL SOIL GROUP (HSG)	AREA IN SQ. KM.
1	*D*	*1856.87000*
2	*C*	*2888.84000*
3	*B*	*2001.96000*
4	*A*	*202.00100*

capability owing to moderate infiltration and low runoff potential which is observed in the western, central and northern part of the map. HSG C & D which covers around 68% (41% and 27% respectively) of the entire area portrays high to very high land capability by virtue of its slow infiltration and high run off rates.

Soil Physico- Chemical Property

Physical & chemical properties of soil are considered of utmost importance while evaluating land capability. Different soil properties such as soil pH, organic matter, available soil nitrogen, phosphorous and potassium have been taken into the purview of study. Azzi's Method (1959) is used to generate Proportionate Index Values (PI) which have been plotted as sampling points in GIS environment. The PI values are the least for the land area in the western region (16% of the total area) where the slope is also very high suggesting that this land possesses least land capability.

Around 28% of the district has low PI value pertaining to low land capability. This can be attributed to the slope factor, i.e. due to high slope, land capability happens to be low. High and very high PI values are detected in the eastern portion of the map, thereby indicating that this region holds high to very high land capability because of very low infiltration and high runoff rates.

Figure 5: Soil Physico- Chemical Property Map

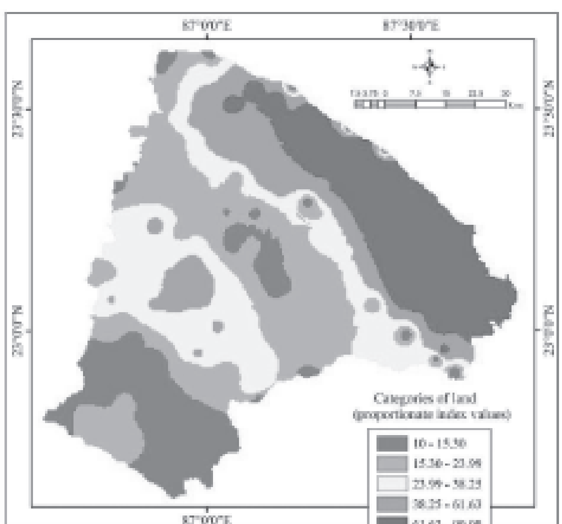


Table 7

Proportionate Index Values of the Study Region

SL. NO.	SOIL PHYSICO- CHEMICAL PROPERTY	AREA IN SQ. KM.
1	10.00- 15.30	1101.12
2	15.30- 23.99	1926.96
3	23.99- 38.25	2064.6
4	38.25- 61.63	757.02
5	61.63- 99.98	1032.3

Ruggedness Index

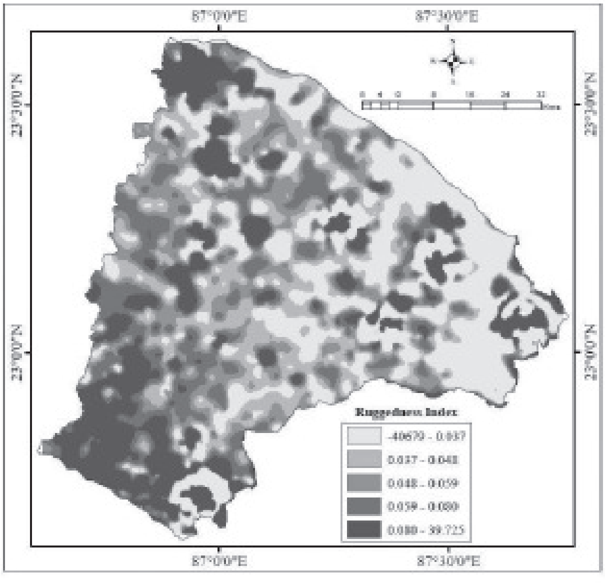
One of the parameters taken into consideration to calculate land capability is Ruggedness Index. RI= (RR x DD)/1000 [RR= Relative Relief, DD= Drainage Density]. With the help of ARC GIS 9.3, the Ruggedness map has been prepared with five classes ranging from very high to very low. The highest value that is 39.725, is found mainly in the South-Western and North-Western part of the district with a very small areal coverage.

Table 8

Ruggedness Index of the Study Region

SL. NO.	RUGGEDNESS INDEX	AREA IN SQ. KM.
1	-40.716- 0.037	457.20
2	0.037- 0.048	5616.63
3	0.048- 0.059	259.20
4	0.059- 0.080	78.30
5	0.080- 39.725	44.10

Figure 6:
Ruggedness Index Map



The second highest ruggedness index value has the maximum spatial coverage of 56.17 sq. km. which is found entirely over the district. Towards east, the ruggedness value gradually decreases as the undulation is minimum in the eastern part of Bankura. As ruggedness value has an inverse relation with the capability of land, highest land capability according to the ruggedness values should be in the eastern part and it should diminish gradually towards North-West and South- Western part of Bankura.

Vegetation Cover

Vegetation cover in any satellite image has the best reflection in Near Infra-Red. To identify vegetation cover or to classify it, that is why needs a clear understanding about the feature space of vegetation in the selected band combination. Using Erdas Imagine most applicable feature space for vegetation has been identified. Pixels having maximum reflectance in Near Infra-Red are showing the vegetation cover. Maximum reflectance in Red band is depicting the area without vegetation cover. The middle part which has moderate reflectance in both of these bands is showing the buffer zone between these two

Figure 7:
NIR & Red Band Feature Space

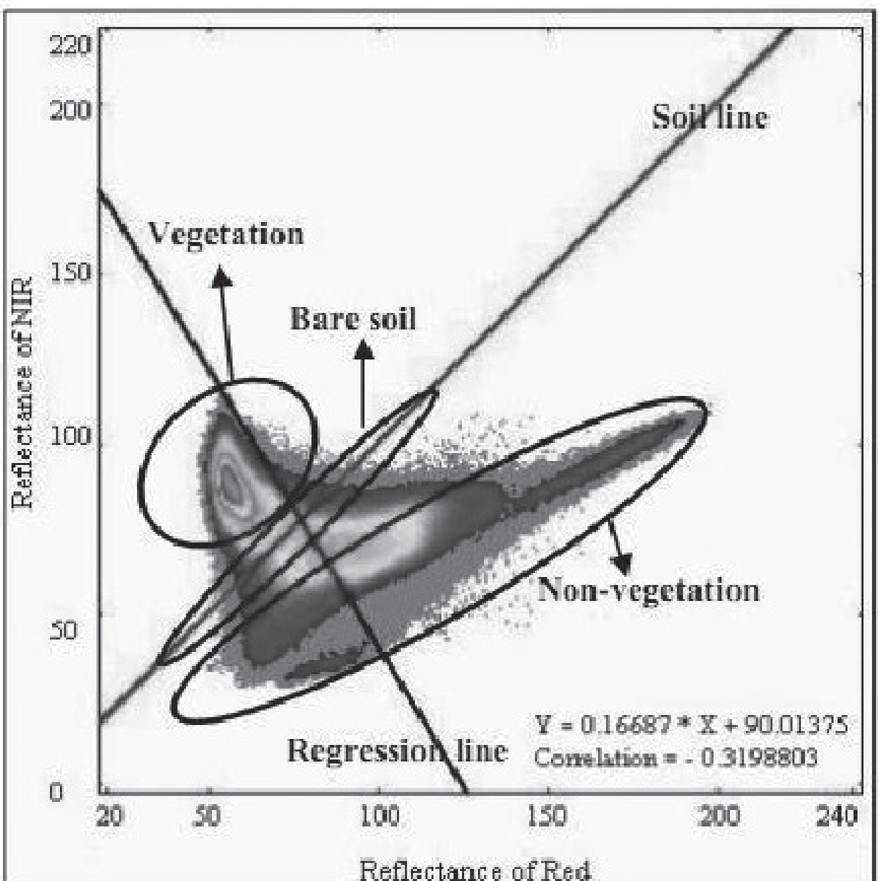


Table 9

Vegetation Cover of the Study Region

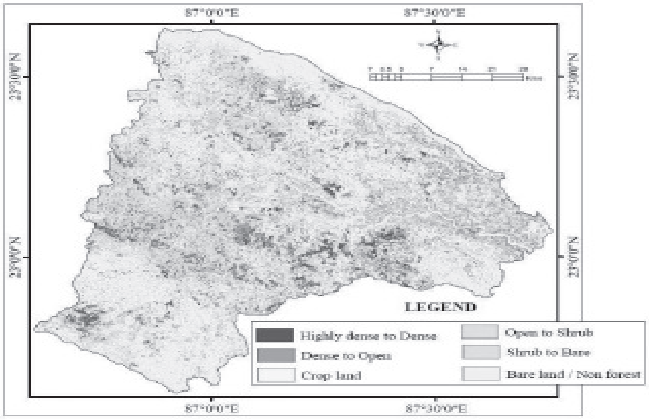
SL. NO.	VEGETATION CLASSES	AREA IN SQ. KM.
1	Highly Dense	485.93
2	Dense To Open	363.915
3	Open To Scrub	622.584
4	Scrub To Bare	1584.53
5	Bare Land/ Non Forest	3908.72

are the two classes

with minimum land coverage. While looking at the probable land potentiality according to the vegetation cover, area with dense vegetation should have the minimum land capability as the growth of vegetation would engulf all the mineral component of soil and the non-forest area should have highest land capability with all its mineral components intact.

Drought

Figure 8: Vegetation Cover Map



As Bankura belongs to the water deficit part of West Bengal, occurrence and severity of

Table 10

Drought Risk of the Study Region

SL. NO.	DROUGHT	AREA IN SQ. KM.
1	No Drought	3771.534
2	Moderately drought Risk	850.033
3	Severely Drought Risk	1969.13
4	Water Body/ River	69.1164
5	Lateritic Exposure	222.266
6	Sand Bar	83.5965

drought is another important parameter to asses land capability. In this paper on the basis of parameters like soil temperature, vegetation index, zones with different drought frequency have been identified. Three zones are there depicting the drought scenario of the district. Two extreme conditions namely no drought prone area and area with severe drought risk are showing maximum spatial coverage of 3771.53 sq. km. and 1969.13 sq. km. respectively. The North- Western part of Bankura belongs to the severe drought prone zone and the zone with minimum occurrence or no occurrence is more or less scattered all over the district. Occurrence of drought has an inverse relation with land capability. Area with minimum drought occurrence has maximum land capability thus having highest weightage and severely drought prone area has minimum land capability and has been weighted accordingly.

Analysis

To compare the actual and computed scenario of land use land cover and land capability of Bankura district, a Land Capability Map has been prepared taking into consideration the above mentioned six variables. These variables have been assigned weightages according to

their importance in land capability. Through integration of Multi Criteria Decision Making (MCDM) and Saaty's Analytical Hierarchical Process (AHP), the final map has been prepared in GIS environment.

In this map, very high land capability appears to be on north eastern section of the district. In reality, this region is occupied by cultivable wet land thereby suggesting that land is being utilised to its fullest in accordance with its computed land capability. High land capability prevails in the western, north western and south western part of the map which mainly consists of dry bare land and dry fallow in actuality. This suggests that these land could further be utilised due to high land potential which is not practised at the present. Moderate land capability happens to be in the areas of agricultural crop land which means that despite having moderate land capability, land is being utilised to the maximum. Little slope and high amount of organic matter and NPK adds to the potentiality of this region. Low land capability exists in the western portion of the map which could be attributed to the presence of high slope and declining soil productivity thus justifying the scenario. The same picture is portrayed by the area having very low land capability which coincides with the areas having maximum slope. The region with lateritic exposure depicts high to moderate land capability. Thus land capability of the region should be enhanced to yield better results as it is capable of doing so. The dry bare land in the southern part of the map should also be utilised since it holds high land capability by virtue of the soil and slope of the region. After comparing the actual and computed scenario of land use land cover and land capability of Bankura District, it is evident that some portions of Bankura have been utilised in accordance with the land capability but this part is limited and most of the district portrays an imbalance between land capability and actual land utilisation.

Conclusion

Land is the most valuable and limited natural resource, which needs to be harnessed according to its potential. The use of land is not only determined by the user but also by the land capability. Land capability is the initial and most important parameter to be measured before utilising any parcel of land. The utmost effort of this study was to examine the land capability of the district. The method adopted is lucid as well as rapid to meet the research goal. Identification of land capability zone scientifically would ultimately lead to maximum and rational utilisation of land. This study has an advantage to help in agricultural planning and guiding for the better land use, in an exacting capability class. Being one of the resources which is facing immense crisis, this method would actually help and suggest a way for sustainable land utilisation.

References

Civco, D. L. (1987). *Knowledge based Classification of Landsat Thematic Mapper Digital Imagery.*Stors.

Ghosh, S. (2012, October). Land Capability Evaluation Based on Soil Parameters in Plateau Fringe

Area of West Bengal, India. *International Journal of Current Reaserch , 4* (10), pp. 287-292.

Liu, J. G., & Mason, P. J. (2009). *Essential Image Processing and GIS forRemote Sensing ISBN 978-470-51032-2.* A John Wiley & Sons, Ltd, Publication.

Ray, R., Mondal, S., & Mondal, S. (2013). Application of Supervised Enhancement Technique for Crop Land Mapping from LANDSAT Digital Data- A Case Study on Bardhaman Block, Bardhaman District, West Bengal, India. *International Journal of Science and Research , 4* (2), pp. 265-273.

Ray, R., Paul, A. K., & Basu, B. (2014, March). OIF Based Indeces Oriented Ecological Classification Using LANDSAT TM Digital Data-A Case Study on Beluchary and Dhulisan Island Groups, Sunderban, West Bengal, India. *International Journal of Remote Sensing Applications , 4* (1).

Teotia, H. S., & Santos, D. (2010). Remote Sensing and GIS Based Land Cover, Soil and Land Capability Information for Resource Management in Semi-arid region of Paraiba, Brazil. 891-893.

Wilson, J. P. (1999). *Local, National and Global Applications of GIS in agriculture.*

38

Climate Change Impact, Vulnerability And Adaptations For People With Disabilities (Pwds)

Diptimayee Behera

Introduction

An estimated 15% of the world's population live with some form of disability (WHO, 2011), yet they are among the most vulnerable and neglected in any type of emergency. Evidence gathered from previous events shows that people with disabilities are disproportionately affected and experience particularly high rates of mortality and morbidity (ACIFD, 2005). The United Nations Convention on the Rights of Persons with Disabilities (UN, CRPD,2006) Article 11 (on situations of risk and humanitarian emergencies) calls upon States Parties to take "all necessary measures to ensure the protection and safety of persons with disabilities in situations of risk, including situations of armed conflict, humanitarian emergencies and the occurrence of natural disasters".

People with visual, hearing and intellectual impairments and severe mental health conditions and those who are socially excluded or living in institutions may be unprepared for events that lead to emergencies, and may not know or understand what is happening. Inappropriate modes of communication for those who may have difficulties in hearing, seeing or understanding can exclude them from receiving critical information about emergencies. In emergency situations, people with disabilities may be less able to escape from hazards, may lose essential assistive devices such as spectacles, hearing and mobility aids and/or medications, or may be left behind when a community is forced to evacuate (ACIFD, 2005). They may also have greater difficulty accessing basic needs, including food, water, shelter, latrines and health-care services (WHO 2005, Oslo, Atlas Alliance Norway 2011).

Need and Significance of the Study:

The study will define in brief the key concepts related to PWDs.
The study will focus on wide range of barriers evident for PWDs.
The research should help to remove the barriers and promote the rights of PWDs.
The paper can expose the possible impact of climate change on PWDs.
The study can assess how much vulnerable climate change is on PWDs.
The study will help to understand what to adopt for disaster risk reduction.
The study can help to understand why it is essential to include disability in disaster risk reduction.
The study will expand and reform the inclusive practices to respond during climate change.

The study will help the policy planners and administrators to redesign training manual.

Objectives of the Study:

The objectives of this study are,

- To focus on the concept and types of peoples with disability.
- To focus on what barriers are evident for peoples with disability.
- To analyse climate change impact on people with disabilities.
- To assess vulnerability of climate change.
- To shade light on necessity of conducting inclusive community.
- To shade light on climate change adaptations.

Research Questions:

The study addressed the following questions,

- Who are the peoples with disability and their types?
- What the physical, environmental, social, cultural, economic barriers are evident?
- Do local, national and global disaster risk management address the needs of PWDs?
- What are the possible impacts of climate change on PWDs?
- How climate change can be vulnerable to PWDs?
- How to be inclusive in vulnerability assessment?
- What adaptation necessary for disaster risk reduction?

Design of the Study:

The researcher has reviewed previously published academic literature, including journal articles, conference proceedings, NGO publication, policy and government documents, best practice manuals and handbooks, press/popular media report on climate change, disaster management, vulnerability, adaptation for differently abled people. To collect concepts, information, and opinion related to this study the researcher was adopted the analytical descriptive approach.

Plan of the Study:

The study has conducted in five main parts,

1. First Part: Definition and classification of basic concepts,
2. Second Part: Some Barrier and Facts Related to People with Disabilities,
3. Third Part: Climate Change Impact on People with Disabilities,
4. Fourth Part: Climate Change Vulnerability on People with Disabilities
5. Fifth Part: Climate Change Adaptations and Risk Reduction for People with Disabilities:

1. First Part: Definition classification of basic concepts:

a) Disability**:** The International Classification of Functioning, Disability and Health (ICF) regards disability – or difficulties in functioning – as neither purely biological nor purely social, but instead the interaction between health conditions and environmental and personal factors (WHO, 2001).

b) People with disabilities**:** The United Nations Convention on the Rights of Persons with Disabilities states that "persons with disabilities include those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others" (UN, 2006). People with disabilities may include, for example, people who use wheelchairs, people who are blind or deaf, people with intellectual impairments or people with mental health conditions, as well as people who experience difficulties in functioning due to a wide range of health conditions such as chronic diseases, infectious diseases, neurological disorders, and as a result of the ageing process (WHO, 2011). The new term 'people with special need' has been started to use parallel with people with disabilities. This may be sub-classified as,

i) Visually Impaired (V.I.): Visually Impaired Means a person with impairment of visual functioning. This may be sub classified as 'person with low vision' and 'total absence of sight'.

ii) Hearing Impaired (H.I.): A person who is not able to hear as well as someone with normal hearing – hearing thresholds of 25 dB or better in both ears – is said to have hearing loss. Hearing loss may be mild, moderate, severe or profound. (WHO, n.d.)

iii) Intellectually Impaired (I.I.): Intellectual impairment affects all aspects of a person's development. They are slower to develop physically, acquire language, and learn to look after themselves and in mastering academic skills. (UNESCO, 2001).

***c) Climate Change*:** This document follows the definition adopted by the Intergovernmental Panel on Climate Change (IPCC), in which "climate change" refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), which defines "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".(IPCC, 2001)

2. Second Part: Some Issues Related to People with Disabilities:

- Climate related reports such as the IPCC and the Human Development Report 2007-08 do not identify people with disabilities as a group requiring particular focus or empowerment in adapting to the changing environment (Wolbring, 2009).
- The proportion of disabled population in India is 26,810,557 (male 14,986,202, female 11,824,355). The percentage of disabled population to the total population is about 2.21% (male 2.41%, female 2.01%) and the decadal growth rate is 22.4% (male 18.9%, female 27.1%) (Census of India, 2011).
- Across the world, people with disabilities face widespread barriers to accessing services such as health, education, employment and transport. These barriers include inadequate policies and standards, lack of provision, lack of accessibility, negative attitudes, inadequate information and communication, inadequate funding, and lack of participation in decisions that directly affect their lives. As a result, people with disabilities have worse health and socioeconomic outcomes than people without disabilities, including poorer health, lower education achievements, less economic and social participation and higher rates of poverty (WHO, 2011).
- Disability is both a cause and consequence of poverty and unemployment, over one in five of the world's poorest people have disabilities, yet international policy-makers and stakeholders have not recognised or prioritised this issue within international development efforts such as the agreements at the World Earth Summits. (WHO, 2011).
- More than 20 per cent of the poorest people worldwide are people with disabilities, and 82 per cent of persons with disabilities in developing countries live below the poverty line (Lewis and Ballard, 2011).

- The impacts of climate change (extreme weather, sea level changes and agriculture productivity changes, leading to food insecurity) will affect the world's poorest people, i.e. people with disabilities. They are some of the most vulnerable to environmental degradation and changes (IPCC, 2007, a).
- The health status of millions of people, including people with disabilities and the prevalence of disability are projected to be affected by climate change through increases in malnutrition; increased deaths, diseases and injury due to extreme weather events; increased burden of diarrhoeal diseases; and the altered distribution of some infectious diseases (IPCC 2007).
- Food insecurity and malnutrition can lead to long term and/or permanent impairments. There are strong links between childhood malnutrition and acquiring impairments. 15·9 per cent of Disability Adjusted Life Years (DALYs) worldwide are attributable to childhood malnutrition (Murray and Lopez, 1997) and malnutrition is estimated to cause about 20 per cent of impairments (World Disasters Report, 2007). People with disabilities face real barriers in accessing food (DFID, 2000).
- People with disabilities living in poverty are facing reduced access to clean water; fertile soils and suitable growing conditions for cropping and livestock; to fuel-wood and other energy sources; to wild foods, medicinal plants and other natural products related to their livelihoods (European Commission, 2007).
- Conflict is a leading cause of physical and psychological disability, and as food and water resources become increasingly insecure, it is anticipated that conflict attributable to climate change will increase (IPCC, 2007).

3. Third Part: Climate Change Impact on People with Disabilities:

3.1. Decreasing food security and resulting malnutrition:

Increases in the frequency of droughts and floods (including from rising sea levels) are projected to cause decreases in local crop production, especially in subsistence sectors at low latitudes, in seasonally dry and tropical regions (IPPC, 2007).

Regional changes are expected to have adverse effects on food production from aquaculture and fisheries (IPPC, 2007). Many of the world's poorest people depend on ocean and inland fish as a significant part of their diet.

Higher food prices due to climate change combined with urbanisation trends will lead to more households being net food consumers; this too will affect (urban) poor people more (Skoufias et.al, 2011).

Malnutrition is estimated to cause approximately 20% of impairments worldwide (DFID, 2000). With increasing malnutrition, we must expect that more children (including those of parents with disabilities) will acquire disabling impairments.

'Fuel poverty' (of firewood and other fuels for cooking) is an increasing cause of malnutrition in many parts of South Asia. It can be difficult to obtain adequate nutrition from uncooked food (Northcott, 2007). As climate change and resource shortages advance it is anticipated that access to cooking fuel will be an increasing concern for vulnerable groups in many parts of the world.

3.2. Decreasing access to clean water, sanitation and hygiene (WASH):

We are aware that many persons with disabilities already face daily hardship in accessing adequate safe water for drinking, sanitation and hygiene. During this century, hundreds of millions of people, especially in the poorest regions, are expected to be exposed to increased water stress due to climate change (IPPC, 2007). PWDs living in urban low-income settlements lack improved water, sanitation, and durable housing, all three are harder to access for them.

Around 390 million people with disabilities worldwide lack access to basic sanitation services, such as toilets and latrines. (WHO, 2011)

Changes in precipitation and temperature lead to changes in runoff and therefore water availability and quality. Increased temperatures will also affect the physical, chemical and biological properties of freshwater lakes and rivers, causing reduced quality. In coastal areas, sea level rises will exacerbate water resource constraints due to increased salinization of groundwater supplies. This is already evident in many countries (IPPC, 2007). All these will make life harder for to the special needs people.

In regions with declining water quality and quantity, it is expected there will be increasing prevalence of water-borne diseases including those causing diarrhoea, with associated dehydration and malnutrition. An estimated 6·8% of DALYs (Disability Adjusted Life Years) worldwide are attributable to unsafe and inadequate water for drinking and sanitation. With decreased clean water, an increase in resulting disability is expected, including in families where disability already exists (Murray and Lopez, 1997).

3.3. Increasing emergencies due to extreme weather events:

Research indicates that weather related disasters are increasing in number and severity. A study in Asia found these emergencies have increased by four times in the past 20 years, and that the number of people affected by them has risen, from an average of 174 million per year to 254 million in the same period (Oxfam Australia, 2007.)

Disasters associated to climate change and their aftermath has a huge impact on persons with disabilities. They are among the most vulnerable in an emergency, sustaining disproportionately higher rates of morbidity and mortality, and at the same time being among those least able to access emergency support. In addition, there is a large tendency for persons with disabilities to be invisible and overlooked in emergency relief operations (Choy, 2009). When the emergency hits they may have difficulty reaching safe areas, become separated from family and friends which is a key to survival and coping, have trouble accessing vital emergency information, or lose assistive devices such as wheelchairs, crutches, prostheses, white canes or hearing aids.

In addition persons with disabilities who also belong to other minority groups based on gender, race, religion or ethnicity may face added disadvantages in having their needs met. Inclusive practice in all relief operations are needed to ensure that response and service delivery is not fragmented but mindful of all sources of vulnerability (Kett & Scherrer, 2009).

3.4. Reducing Access To, Infrastructure, Shelter And Basic Services:

In the world's poorest regions climate change is causing an 'erosion' of services, infrastructure and shelter. This may occur suddenly, due to an extreme weather event, or be slow and insidious.

As climate change places increased pressure on national budgets and resilient livelihood opportunities diminish, there are fewer resources available for affordable and accessible services and infrastructure to the poorest people. This is particularly so for those with a disability who may be more reliant on these.

Accessible basic health and other services may disappear. As an example, the loss of immunisation services will increase the risk of the poorest families, including those of persons with disabilities, contracting preventable disabling diseases (WHO, 2003).

In island and other coastal communities, sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards. This will threaten vital infrastructure, settlements and facilities which support livelihoods (IPPC, 2007). Clearly all these factors impact heavily on persons with disabilities and their families.

3.5. Increasing Displacement / Migration OR Necessary Migration Not Possible Due To Disability:

There are large numbers of climate refugees worldwide and within this group we know there are many persons with disabilities. They are also frequently left behind in a degraded environment, when others in their family or community move on. The situation as social and support networks disappear can be devastating hardship.

An example of a significant people movement is the migration of large numbers of people from the marginal Sahel zone of West Africa to densely populated coastal areas, due to regular crop failures in their home regions (Brauch, 2002).

Most people moving from rural to urban environments have no choice but to settle in slums, where housing and basic services are inadequate. They remain vulnerable to weather related risks, live in substandard and over-crowded housing prone to the spread of disease, have inadequate access to clean water, drainage, sanitation and waste removal, and often have few ongoing livelihood opportunities (Little & Cocklin, 2010).

These conditions are all amplified for persons with disabilities. They may face severe hygiene issues in accessing toilets, increased health consequences of living in a crowded degraded environment, and may have very limited social/support networks and livelihood opportunities as a result of decreased mobility and dislocation.

3.6. Increasing Human Security And Protection Issues (Including Due To Conflicts Resulting From Climate Change):

Poverty, dislocation and the breakdown of social structures are key factors which result in decreasing human security and protection. As the impacts of climate change increase, we must expect that persons with disabilities and their families will face increasing risks.

Conflict is known to be a leading cause of physical and psychological disability (IPCC, 2007). People may be unable to access appropriate interventions and assistive devices for health conditions and impairments which were either pre-existing or caused by the conflict. During conflicts, persons with disabilities are additionally vulnerable due to difficulty moving to a safe place. As a result their condition or impairment becomes a long term disability. During the coming century it is expected that scarce water and food resources caused by climate change, may cause conflict in a number of regions (Borger, 2007). Additionally during a conflict, health and social systems often break down, increasing the hardship for those who may be more reliant on these. Due to their vulnerability, all these issues directly impact persons with disabilities and their families.

Conflict and other emergencies may also increase levels of social exclusion. An example of this was recorded in Sudan, where people with impairments caused by earlier leprosy infection were not allowed by other refugees into the camps – instead being sent to the leprosy village

(Kett & Scherrer, 2009). This example highlights the priority need for awareness rising within relief agencies and community, to ensure services are accessible for everyone.

3.7. Increasing Impairments Leading To Disability:

As indicated earlier, it is anticipated that many factors connected with climate change, will increase the incidence and prevalence of impairments leading to disability. This is due to both disease and injuries. Disabling injuries may result from extreme weather events or conflict.

Malaria is a key example of a disease which may cause disability. Roughly one in ten children will suffer from neurological impairment after suffering cerebral malaria, including epilepsy, learning disability, changes in behaviour, loss of coordination or speech impairments (Jones, 2002).

Warmer temperatures, with increased surface water and humidity, allow increased reproduction of mosquitoes which spread malaria (and other diseases such as dengue and yellow fever). In addition, changing weather conditions facilitate epidemics in areas where malaria was not previously present. The populations in these 'new' areas lack protective immunity and are particularly at risk (IPPC, 2007).

Even by the year 2000, the World Health Organisation had estimated that climate change was responsible for 6% of malaria in some countries (WHO, 2002).

4. Fourth Part: Climate Change Vulnerability on People with Disabilities:

Vulnerability is the characteristics and circumstances of a community, system, or asset that makes it susceptible to the damaging effects of climate change and other hazards. Vulnerability can be determined by the interplay between exposure and sensitivity to a range of interrelated social, economic, political, governance and environmental factors (Oxfam GB, 2010).

PWDs are especially vulnerable during the climate-related force migration evacuation, transit and relocation process with regards to the following:

a) Attaining accessible transportation, including for medical equipment,
b) Access to appropriate housing, including mobile or temporary encampments,
c) Proper of health-care and other medical needs,
d) Accessible information, such as access to American Sign Language (ASL) interpreters or Braille communications,
e) Maintenance of personal support networks,
f) For those with sensory disabilities, communication methods vary by location (for example, ASL is only used in certain countries) and potential translators may become unavailable, so migrants may encounter communication barriers that affect independence, safety and smooth migration and resettlement (UNHCR, 2011).
g) Many countries and populations have resisted or rejected immigrants with disabilities, including disabled members of otherwise-accepted groups, such as conflict refugees or persons fleeing natural disasters.
h) Some governments or populations often argue that PWDs are an unsustainable drain on resources and/or cannot contribute to the economy in a way that compensates for their presence; other times, they are rejected through outright abeles and disability discrimination (Mansha, 2010).
i) PWDs when turned away may then be stuck in unsafe border areas or forced to return home to dangerous conditions and persecution; they may also be separated from family or

caregivers who are able to cross borders and choose to do so. This situation leads PWDs towards death.

j) While disability correlates with vulnerability, not all people with disabilities are equally vulnerable. People with more severe impairments often experience greater vulnerability (WHO, 2011).

k) In some contexts, women with disabilities, children, older people and people with mental health conditions and intellectual impairments experience more discrimination and exclusion than other people with disabilities (WHO, 2011. Handicap International, 2008).

l) Emergencies in particular can increase the vulnerability of people experiencing disability. Statistics following the earthquake and tsunami in Japan in 2011 showed that the fatality rate for people with disabilities who were registered with the government was 2.06% while that for the general population was 1.03% (NHK Fukushi, 2011).

m) People with disabilities can also face higher risks associated with safety, protection and dignity; they may be particularly vulnerable to violence, exploitation and sexual abuse (World Disasters Report, 2007).

Recommendations In Conducting Inclusive Community Vulnerability Assessments:

- Conduct a walk-through in the community together with individuals with different disabilities to identify physical and environmental barriers, and also facilitators undertake participatory community mapping which can help incorporate accessibility of buildings and infrastructure, and safety and accessibility of different evaluation outs.
- Resource and institution mapping which can "identify availability, relevance, importance, and access to key services and resources in and around the community" (including DPOs, rehabilitation providers).
- Include disability in household and other surveys conducted in the community. Household and census surveys are excellent vehicles to add disability modules as they are intended to reach all households. (Handicap International, 2012)

5. Fifth Part: Climate Change Adaptations and Risk Reduction for People with Disabilities:

As an approach, climate change adaptation is a dynamic process and not an end state, given the uncertainty in climate change impacts and the need to support at-risk populations to: address current hazards, increased variability and emerging trends; manage risk and uncertainty; and build their capacity to adapt. (Pettengell, 2010).

Adaptation is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2000). Or,

- Adapting development to gradual changes in average temperature, sea-level and precipitation; and,
- Reducing and managing the risks associated with more frequent, severe and unpredictable extreme weather events (UNISDR, n. d.)

Recommendations for successful Adaptations and Risk Reduction:

- Setting up neighbour-support networks to assist people with mental and physical disabilities in the event of evacuation, relief distribution and other disaster management activities.

- Situating wells and aid distribution points in locations that are accessible to people with restricted mobility.
- Providing fuel-efficient stoves to households with people with restricted mobility.
- Providing livelihood-diversification grants and training to people with disabilities whose traditional livelihood activities are at risk from hazards and/or the effects of climate change.
- Ensuring the physical protection (retrofitting) of health facilities and coordination with health personnel to sustain continuity of services during hazards.
- Developing contingency plans with health facilities to ensure uninterrupted access to medicines during hazards and climate stresses. (Turnbull et.al., 2013)

Conclusion:

On a practical level, the research illustrates the very real and heightened risks that disabled people face during climate change related disasters, including greater risk of death, injury and displacement. Disabled people have been made more vulnerable to natural hazards through historical processes of exclusion and impoverishment. A sound inclusive approach can reduce the problem. It may help in immediate information, shelter, evacuation and relief systems managed. In post disaster situation an appropriate rehabilitation programme should include a combination of Institute Based Rehabilitation (IBR) and Community Based Rehabilitation (CBR) programs. Physiatrists, physiotherapist, occupational therapist should work together to reduce post disaster trauma and mental health related problems. Generally in developing countries such teams often do not exists. Family members, care givers, non-disable peer of disabled people should take extra care for food, treatment, shelter and in other adaptations. In conclusion it may be stated that disabled people are the part of our society. They must be given proper respect, must be treated as a member of our society with same right, must be include in all social functioning. Attitudinal change towards people with disabilities can help to make best possible use of their abilities.

References

ACFID. (2005). Disability-tsunami emergency response summary for, January 2005. Deakin, Australian Council for International Development. adapt. Oxford, UK: Oxfam International.

Borger, J. (2007). 'Climate Change and Conflict', *The Guardian*, 11 May, London.

Brauch, H. (2002). Climate Change and Conflict Prevention. German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Census of India. (2011). Data on Disability. Retrieved from http:// www.disabilityaffairs.gov.in/ upload/ uploadfiles/ files/ disabilityinindia2011data. pdf

Choy, R. (2009). Disasters are always inclusive: Vulnerability in humanitarian crises, *Development Bulletin, Special Issue No. 73,* April 2009, Development Studies Network, ANU, Canberra.

DFID. (2000). Disability, Poverty and Development, Department for International Development.UK. Retrieved from http:// handicap- international. fr/ bibliographie-handicap/ 4 Politique Handicap/ hand_ pauvrete/ DFID_ disability.pdf.

European Commission. (2007). Environmental Integration Handbook for EC Development Cooperation.

Handicap International (2008). Mainstreaming disability into disaster risk reduction: a training manual for trainers and field practitioners. India.

Handicap International. (2012). Disability inclusive community based disaster risk management. A toolkit for practice in South Asia. Retrieved June 16, 2013, Retrieved from http:// www. preventionweb.net/files/ 32279_32279sdpg01light.pdf

IPCC. (2000). 'Glossary of Terms used in the IPCC Fourth Assessment Report WGII'. Geneva,Switzerland. Available at: www. ipcc. ch/ publications_ and_data/ publications _and_ data_glossary.shtml

IPCC. (2001). Impacts, adaptation and vulnerability. Contribution of Working Group II to the 3rd Assessment Report of the IPCC.Geneva, Intergovernmental Panel on Climate Change, 2001.

IPCC. (2007). Fourth Assessment Report. Working Group II. Climate Change 2001: Impacts, Adaption and Vulnerability. Retrieved from http:// www. ipcc.ch/ publications_ and_data/ ar4/ wg2 /en/ contents. Html.

IPCC. (2007a). Climate Change Debate on Sea-Level Rise: Critical Stakes for Poor Countries. Retrieved from http://blogs.cgdev.org/globaldevelopment/2007/02/the-ipcc-debate-on-sea-level-r.php

Jones, I. (2002). Neurological Damage from Malaria. Retrieved from http:// malaria. wellcome. ac. uk/ doc_ WTD 023883. html .

Kett, M., Scherrer, V. (2009). The Impact of Climate Change on People with Disabilities. Report of e-discussion hosted by The Global Partnership for Disability & Development (GPDD) and The World Bank (Human Development Network - Social Protection /Disability & Development Team). Retrieved from http: // www. g p d d online. org/ media/ news/ Impact _ of_ Climate_ Change_ on_ Disability- Report- Final_ 012010.pdf

Lewis, D., K. Ballard. **(**2011). Disability and Climate Change: Understanding vulnerability and resilience in a changing world. CBM, Bensheim, Germany. Retrieved from from www.cbm.org/article/downloads/54741/ Disability_and_Climate_Change.pdf

Little, L., Cocklin, C. (2010). 'The Vulnerability of Urban Slum Dwellers', In *Global Environmental Change and Human Security*, ed. Matthew, R, and Barnett, J., The MIT Press, Massachusetts.

Mansha, M. (2010). Resettlement for disabled refugees. Forced Migration Review, 35:30 31. Refugees Studies Centre, University of Oxford, Oxford. Available Retrieved from www. fmreview.org/ disability-anddisplacement/ mansha-mirza.html

Murray, C., Lopez, A. (1997). Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. The Lancet, Vol 349. Retrieved from http://old.spread.it/Volume/chapt04/add_04/Ref_04006.pdf.

NHK Fukushi Network Shuzaihan. (20111). Higashi nihon daishinsai ni okeru shogaisha no shiboritsu [Death rate among persons with disabilities in the eastern Japan earthquake]. Normalization, November 2011:61–63 (in Japanese) http://www8.cao. go.jp/ shougai/ suishin/ kaikaku/s_kaigi/ k_37/pdf/ref4–1.

Northcott, M. (2007). '*A Moral Climate*', Darton, Longman &Todd Ltd, London.

Oslo, Atlas Alliance Norway (2011). Fact sheet on disability in conflicts and emergencies. Retrieved from http:// www.cbm.org / article/ downloads/ 71140/ Fact _sheet_ Disability_in_ Conflict_and_ Emergencies.

Oxfam Australia (2007). Website, www.oxfam.org.au,

Oxfam GB (2010). Gender, Disaster Risk Reduction, and Climate Change Adaptation: A Learning Companion. *Oxfam Disaster Risk Reduction and Climate Change Adaptation Resources*. Oxford, UK.

Oxfam GB (n.d.) *Rough Guide to Monitoring and Evaluation*. Oxford, UK.

Pettengell, C. (2010) *Climate Change Adaptation: Enabling people living in poverty to*

Skoufias, E., Rabassa, M. & Olivieri, O. (2011). The Poverty Impacts of Climate Change: A Review of the Evidence, *Policy Research Working Paper 5622*. The World Bank.

Turnbull, M., L. Sterrett, C., Hilleboe, A (2013). *Toward Resilience: A Guide to Disaster Risk Reduction and Climate Change Adaptation*. Practical Action Publishing Ltd, The Schumacher Centre, Bourton on Dunsmore, Rugby, Warwickshire CV23 9QZ, UK.

UNESCO. (2001).*Understanding and Responding to Children's Needs in Inclusive Classrooms; A guide for Teachers.* Inclusive Education Division of Basic Education, 7 Place de Fontenoy, 75352 PARIS 07 SP, France. pp. 74-93

UNHCR. (2011). *United Nations High Commissioner for Refugees Working with Persons with Disabilities in Forced Displacement*. Need to Know Guidance UNHCR, (2011) Geneva. Retrieved from www. unhcr.org/ publications/manuals/4ec3c81c9/ w o r k i n g - p e r s o n s - d i s a b i l i t i e s - fo r c e d -displacement.html

United Nations. (2006*). Convention on the Rights of Persons with Disabilities*. Geneva,

WHO. (2001). *International classification of functioning, disability and health*. World Health Organization, Geneva.

WHO. (2002). *World Health Report 2002 – Reducing Risks, Promoting Healthy Life*. World Health Organisation, Geneva. Retrieved from http: // www. who. Int / whr / 2002/ en.

WHO. (2003). *Climate Change and Human Health – Risks and Responses. Summary*, World Health Organisation, Geneva. Retrieved from http:// www. who.int/ global change/ climate/ summary/ en.

WHO. (2005). *Disasters, disability and rehabilitation*. World Health Organization, Geneva. Retrieved from http:// www. who. int / violence_injury_prevention/ other _injury/ disaster_ disability2.

WHO. (2011). *World report on disability*. World Health Organization/World Bank, Geneva.

WHO. (n.d.) *Fact sheet on Deafness and hearing loss.* Retrieved from http:// www. who.int/ mediacentre/ factsheets/ fs300/ en/

WHO. (n.d). *Health Topic on "Disabilities"*. World Health Organization. Retrieved from http://www.who.int/topics/ disabilities/en/11 September 2016.

Wolbring, G (2009) (2009). A Culture of Neglect: Climate Discourse and Disabled People. *M/C Journal, Vol. 12, No. 4* Retrieved from http:// journal.media-culture.org.au/ index. php/ mcjournal/ article/ view/ 173

World Disasters Report (2007). *International Federation of Red Cross and Red Crescent Societies*, Geneva.

39

Application of Geospatial and Field Techniques in Geomorphological Mapping: A Case Study of Himalayan Upper Pindar River Basin

Senjuti Nandy and Vibhash C. Jha

Introduction

Geomorphology as a branch of physical geography deals with the scientific study of origin, evolution, nature, form and mechanism of development of landforms both at and near the earth surface. In other words, it is the science of quantification and analysis of the land surface (Pike, 1995, 2000;Bishop et al., 2012). Generally, it investigates how landforms are formed on the Earth (Shashikant et al., 2014). According to British Society of Geomorphology, the study of Geomorphology includes looking at landscapes to work out how the earth surface processes, such as air, water and ice, can mould the landscape. In every case 'landform' is the dominant term to illustrate the surface terrain of the earth.

For this description of landform evolution, genesis, development and spatial distribution the study of Geomorphological Mapping is a very effective tool to manage the natural landscape for planning and management purpose. Geomorphological maps can be considered graphical inventories of a landscape depicting landforms and surface as well as subsurface materials (Otto and Smith, 2013). Further it plays an essential role in understanding Earth surface processes, geochronology, natural resources, natural hazards and landscape evolution (Blaszczynski, 1997; Bishop and Shroder, 2004a). The aim of geomorphological mapping provides the information about the surface forms, materials, surface processes and age of landforms of a region(Cooke and Doornkamp, 1990). So, Geomorphological maps can act as a preliminary tool for land management and geomorphological and geological risk management, as well as providing baseline data for other applied sectors of environmental research such as landscape ecology, forestry or soil science (Cooke and Doornkamp, 1990; Dramis et al., 2011; Paron and Claessens, 2011; Otto and Smith, 2013). According to Knight et al., 2011; Verstappen, 2011 and Otto and Smith, 2013 basic geomorphological maps may either focus on selected landscape features, for example only depicting the morphology of active processes, or deliver a full view on the landscape composition and its evolution.

Geomorphological mapping has followed considerably different courses of historical development in a variety of countries (Klimaszewski, 1982; Hayden, 1986). Early in the history of geomorphic mapping, production of comprehensive geomorphological maps became a main research priority in Europe (Demek and Embleton, 1978). This is in contrast to the relatively low priority it received in North America and Britain (Evans, 1990). Highly developed artistic skills were used in the production of early landform maps andwere often coupledwith temporally sequential block diagrams of imaginative landscape evolutions (Lobeck, 1924; Raisz,1948; Lobeck, 1958) which were often cited by the Regional Geographers in spite of limited theoretical interpretation of landforms (Bishop et al., 2012). Development of styles and emphasis of mapping has been sequentially emerged from time to time in different countries. Various attempts have been made to discuss geomorphic mapping by Galon (1962), Tricart (1965), Doornkamp (1971), Barsch (1979), Cooke et al. (1982), Verstappen (1983) and Fleisher (1984). Gilewska (1967)provided an interesting perceptive comparison of the approaches used in Hungary, France, Russia and Poland, demonstrating how national trends in geomorphological thinking are apparent in the style of mapping (Cooke and Doornkamp, 1990). Consequently, thematic geomorphologic mapping was emerged for highway engineering design (Brunsden et al., 1975), terrain sensitivity (Rosenfeld, 1977), regional planning (Barsch and Liedtke, 1980), environmental management (Cooke and Doornkamp, 1990), and natural hazards (Seijmonsbergen and de Graaff, 2006). Fookes et al. (2007) recently aggregated many applied geomorphological mapping problems under the general heading of “engineering mapping”.

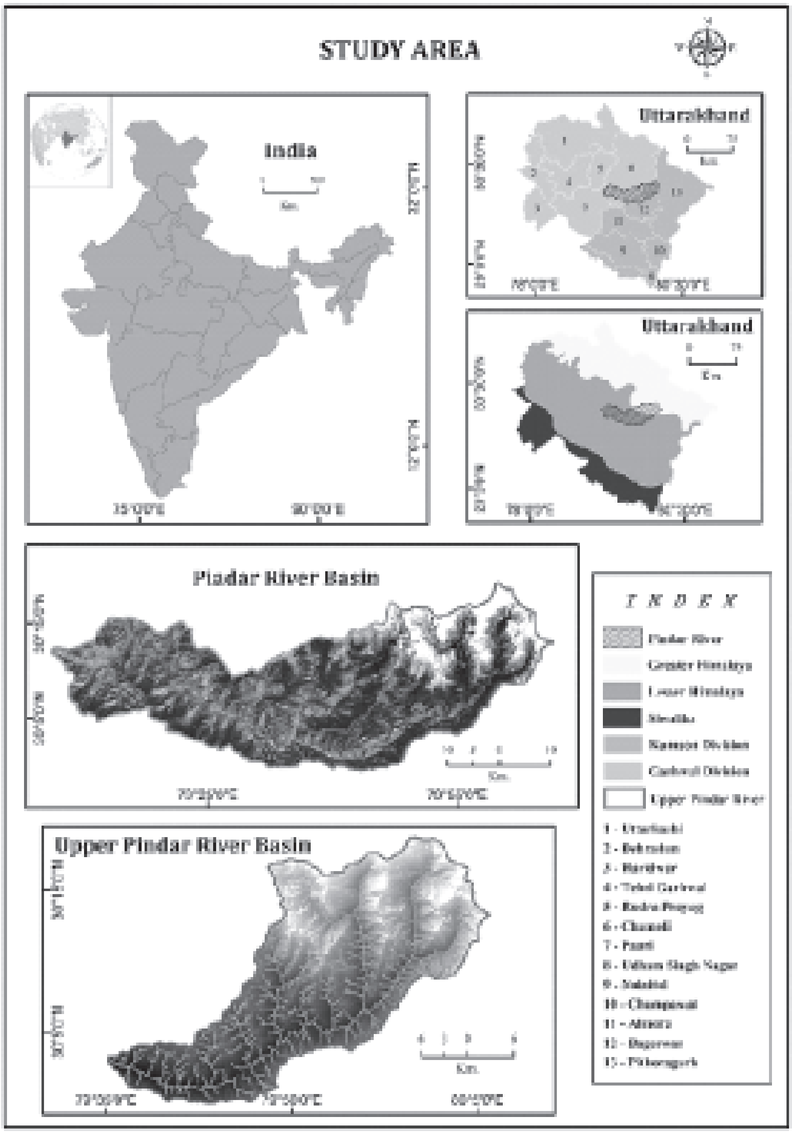
In recent days, both geospatial and field techniques have been used in GIS environment to generate any kind of Geomorphological Mapping. Geospatial technologies can be used to address some conceptual issues such as heterogeneous surface composition with fuzzy-classification membership (Warner and Shank, 1997), indeterminant boundaries and features (Burrough, 1989; Usery, 1996; Burrough et al., 2000; Smith et al., 2000; Deng and Wilson, 2008), hierarchical organization and spatial analysis using object-oriented technology (Ralston, 1994; Brändli, 1996; Schmidt and Dikau, 1999), scale-dependence of properties and patterns using geostatistics (Tate and Wood, 2001), and objective mapping using different analytical approaches (Bishop et al., 2012).Whereas the creation of a field mapping protocol that details the steps of the mapping campaign is important as it allows the organised collection of additional information on landforms and the creation of a database for the data mapped in the field (Knight et al., 2011; Otto and Smith, 2013). Thus, the concept of geospatial and field techniques has been widely used to prepare the Geomorphological Mapping. Here, attempts have been made to generate a detail geomorphological map of Upper Pindar River Basin to show the spatial distribution pattern and calculate the area of each geomorphic unit through the above approaches.

Study Area

The Himalayan Upper Pindar River (30Ú00´05½ N. - 30Ú19´ N. and 79Ú35´06½ E. - 80Ú05´55½ E.) forms a part of Bageshwar (Kapkot Block) and Chamoli (Dewal Block) Districts of both Kumaon and Garhwal division of Uttarakhand, India respectively. It originates from Pindar Glacier of Nanda Devi Range and flows South-West direction upto the confluence with Kail Ganga River at Talor Village. But, the main Pindar River basin is demarcated in the north by the mountain range of Nanda Devi which separate it from the Basin of Rishi Ganga River and joins with the Alaknanda river in the confluence part at Karnaprayag. It occupies a part of Nanda Devi Mountain Range as well as Alaknanda River Basin. The total geographical area under study is about 743.85 km^2. The general elevation of the Himalayan Upper Pindar River Basin ranges from 1290 m. (Talor Village) to 6861 m. (Nanda Kot). Main Right-side tributaries of Upper Pindar River are Sundardhunga Gad, Ghatiya Gad, Baura Gad and Saur Gad & left side tributaries are Kaphni Gad and Kali Gad.

Geologically, the study area consists of the rocks of Pindari Formation of Vaikarta Group (Valdiya, 1999). The Pindari Formationconstituted of gneisses and schists with lenses of calcsilicate rocks is bounded by Trans-Himadri Fault on the northern side and Pindari Thrust on the southern side (Bali et al., 2011).

Figure 1.
Location of the study area

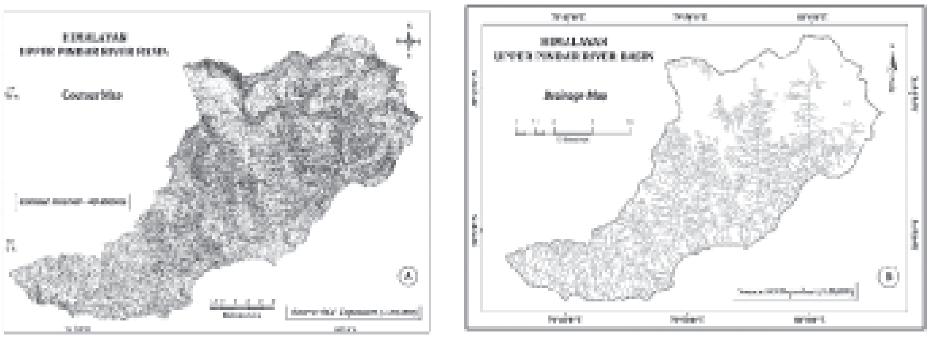


2.0 Database and Methodology

This present paper has been done by both primary and secondary data. Primary data has been collected during field-survey for doubtful areas by identifying each geomorphic unit in their respective location in the field. But, in case of secondary data various types of geospatial maps and data like Contour and Drainage Map of the basin, SOI toposheet of 1: 50,000 scale (1966, 1967 and 1980), Open Series Map of SOI (2009)&IRS P6 (ResourceSat-1) LISS-III Imageries of Bhuban (23rd Nov. 2011) has been used for integral parts of the study area.

Figure 2.

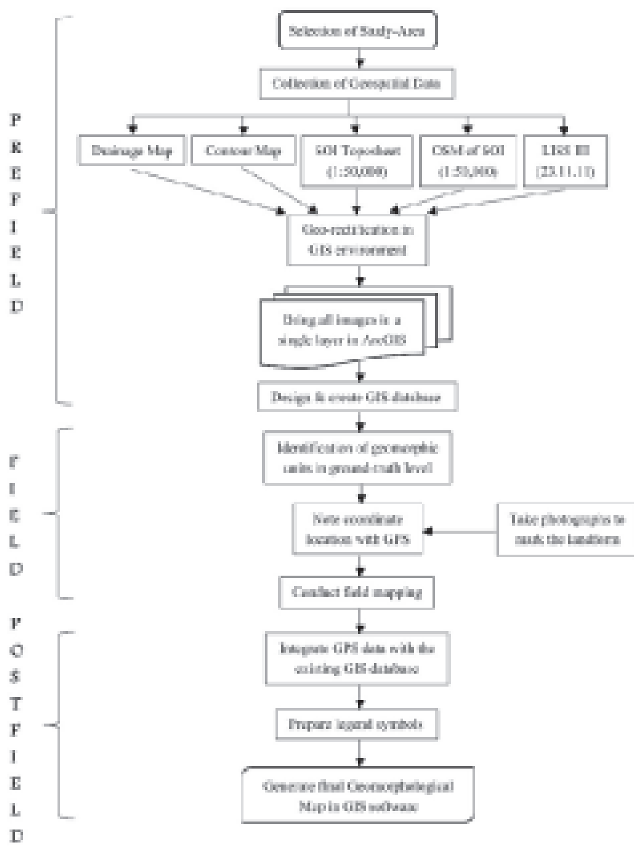
(A)Contour Map (B) Drainage Map of the study area



The entire workflow has been subdivided into three parts, which is shown in the following diagram.

Figure 3

Methodology flow-chart of entire work



Objectives

i. To identify each and every Geomorphic Unit of the selected Study Area.
ii. To specify their location in the entire basin.
iii. To calculate the occupied area of every Geomorphic Unit.
iv. To analyse the genesis of Geomorphic Units in this particular region.

Results and Discussion

The overall landscape of Upper Pindar River Basin is the product of fluvial, glacial and periglacial features along with a series of interactions among structural, denudational and depositional process operating on the underlying terrain. Geospatial and field studies indicate that the geomorphology of the study area is dominated by steep rocky slopes, high ridges, vertical cliffs, deep gorges in the valleys etc.signifying the processes operated in the evolution of the landforms in the considerable geologic periods. Classification of the landforms are made based on geomorphological agent, mechanical processes, scale of relief features etc. (Hartvich and Vilimek 2008). The genesis of landforms isbroadly identified into six geomorphic classes i.e. Structural Origin, Denudational Origin, Fluvial Origin, Glacial Origin, Periglacial Origin and Depositional Origin which are further classified into twenty-seven geomorphic unites in this river basin.

Table 1

Areas in Geomorphic Units of Upper Pindar River Basin

Geomorphic Class	Geomorphic Unit	Area (Km^2)	Area (%)
Structural Origin	Fault Guided Stream	0.81	0.109
	Structural Hill	108.27	14.556
Denudational Origin	Cliff	11.34	1.525
	Denudational Hill	270.32	36.341
	Rocky Slope	25.59	3.440
Fluvial Origin	Braided Bar	0.02	0.003
	Flood Plain	0.99	0.132
	Point Bar	0.25	0.034
	River Gorge	1.12	0.150
	River Terrace	7.29	0.980
	Stream	3.81	0.512
	Water Fall	0.02	0.003
Glacial Origin	Arete Zone	19.42	2.611
	Crevasse Zone	2.40	0.323
	Empty Trough	1.98	0.266
	Glacial Trough	12.27	1.649
	Horn	0.17	0.022
	Ice Field	98.50	13.242
	Ice Wall	0.19	0.026
	Lateral Moraine	1.29	0.173
	Medial Moraine	1.28	0.172
	Terminal Moraine	0.04	0.005
Periglacial Origin	Bare Mountain Slope	167.43	22.508
Depositional Origin	Alluvial Cone	0.26	0.035

	Alluvial Fan	0.22	0.029
	Rock Fall	6.17	0.830
	Scree Deposit	2.41	0.323
Total		**743.85**	**100.000**

A.Structural Origin

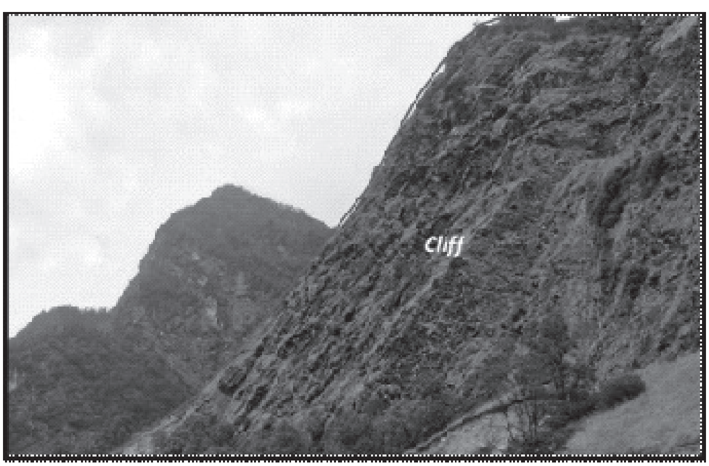
a. Fault Guided Stream: Flow of streams follow the fault-line are called fault guided streams. In this Upper Pindar River basin, fault guided portions of main Pindar River above Dwali, Sundardunga Gad and Mangtoli N have been guided by Dwali-Phurkiya fault (DPF) and Dulam-Khati Fault (DKF) respectively which are lying in North-South direction. It covers 0.81 Km²area contributing 0.109 % of total geographical basin.

b. Structural Hill: Structural hills are representing the geologic structures such as bedding, joint, lineaments etc.inthe study area(Mith and Clark, 2005; Tomar and Singh, 2012).Combine denudational process of erosion, weathering and mass wasting shapes the structural hills depending on the dip of the strata. These hills are linear to arcuate exhibiting definite trends composed of varying lithology (Sudarsana Raju, 2012). In the Upper Pindar River Basin, Structural Hill has covered the area of about 108.27 Km² sharing 14.556 % of the total area. These feature is mainly concentrated in the South-West portion of left bank of the river between the heights 3463 m. to 1284m. They have higher relief, steep slopes and in many places, they are covered by mixed dense forest.

B.Denudational Origin

a. In geographical and geological language, cliff is a vertical or nearly vertical terrain surface found on coasts, in mountainous areas, escarpments and along rivers. Due to high mechanical and chemical weathering and erosion, denudational part of mountain is washed away and relatively less erosional rocky landform is generated with steep or vertical slope. Here, cliff is distributed in all over the catchment in dissected pattern sharing 1.525% (11.34 Km²)of the geographical area. The concentration is highly found near Mrigthuni Gal, Sukhram N and above Phurkia.

Figure 4.
Field photograph of semi-vertical cliff located near Dwali



b. Denudational Hill: Denudational hills are the remnants of massive hills with resistant rock bodies formed by natural dynamic process of differential erosional and weathering. The geomorphic forms of denudational hills occur as exfoliation domes, bornhardts, linear ridges, mesas, low mounds and tors with partial scree or debris covered at the foot slopes (Sudarsana Raju, 2012). Denudational hills occupy lower West portion of right bank of main river between the elevation 1290 m. to 3800 m. On the satellite image, these landforms are identified by dark brownish gray tone with mix green colour due to thick forest cover. It has captured huge 270.32 Km² area sharing the largest portion (36.341 %) of this basin.They are covered mostly by fairly mixed dense jungle with concentration of pine forest.

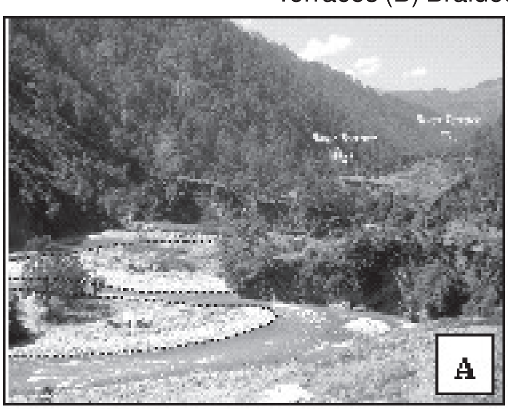
c. Rocky Slope: Moderate to steep slope of mountains covers with rocks or consist of large areas of rock generated by high weathering are called rocky slope. Upper Pindar catchment has the area of 25.59 Km² (3.440 %) rocky slope, noticed in high elevation between 5000 m. to 6500 m. near Mrigthuni Gal, Malla Panchel mountain and Pindar Glacier separated by ice-field area.

C. Fluvial Origin

a. Braided Bar and Point Bar: Bars in the river channel are the slightly elevated portion of sediment of sand and gravel deposited from river loadofriver flow. There are many types of Channel Bars among which braided and point bars are important. Due to lowering of discharge in the middle or old catchment river cannot carry its total load of sediments, so river deposits its sediment load in different places within the channel to maintain the flow upto the mouth. When river sediment is deposited in the middle of the river then it is called Braided Bar or Mid-Channel Bar and when deposited in the side of the river then it is named Point Bar.Upper Pindar River basin occupy only 0.02 Km² and 0.25 Km² of geographical area contributing 0.003 % and 0.034 % in case of braided bar and point bar respectively. All these bars are found near the Garsu, Rain, Odar, Lingri, Maupata etc. villages of lower portion of the catchment.

Figure 5.

Field photographs of river bed deposition (A) Point Bar near Rain Village with two level of River Terraces (B) Braided Bar at Order Village.



b. Flood Plain: It is a flat area of land next to river that stretches from the banks of its channel to the base of the enclosing valley walls and which experiences flooding during the periods of high discharge. Here, only 0.132 % of geographical area near Talor, Rain, Odar, Maupata and Manmatti village of lower section is under this category.

c. River Gorge: Gorge is a very deep and narrow crack between two escarpments of wall-like steep valley side. When active downcutting of valleys through pothole drilling and downward erosion of river in juvenile stage of fluvial cycle of erosion creates 'I'-shaped like features, then gorges are formed.In addition to this, they are generated when there is a significant difference of elevation between the source and mouth of the river. In this catchment, about 1.12 Km^2 area is occupied by gorge contributing 0.150 % of total area. They are commonly found near Malia Doar,source of Baura Gad, Semdagarh Village along river, confluence of Baura Gad with Pindar, confluence of Khapni river with Pindar at Dwali and Phurkia.

d. River Terrace: It is a bench like flat surfaces that extends along each side of a valley that represents a former level of the valley floor and the remnants of former flood plains. They are generally formed due to dissection and downcutting of fluvial sediments of flood plains deposited along the valley floor (Singh, 1998). In this basin, one to three level of terraces are noticed Kheta Village, Talor Village, Khati Village respectively along with unidentified level of terraces near Garsu, Chaur, Maupata, Manmatti, Haraml, Mili etc. covering 0.98 % (7.29 Km^2) of catchment. These terraces od this region are the indicator of various tectonic upliftment and climatic change during Holocene and Late Pleistocene.

e. Stream: They are the channel flow confined within bed and banks. Due to accumulation of water from various rills and gulleys in a single channel, a stream has been formed. They are confined in 3.81 Km^2 area sharing 0.512 % of area. Major streams of this study-area are Pindar River, Khapni Gad, Sundardunga Gad, Baura Gad, Saur Gad, Urna Gad etc.

f. Water Fall: Waterfall or simply falls are caused because of sudden descent or abrupt breaks in the longitudinal course of the rivers due to a host of factors e.g. variation in the relative resistance to rocks, relative difference in topographic reliefs, fall in the sea level and related rejuvenation, earth movements etc.(Singh, 1998). It is a vertical downpouring of enormous volume of water from a significant height in the river course.Only 0.003% area is covered by seven identified waterfalls of this area. Largest height among these is 80 m. noticed near Dwali.

D. Glacial Origin

a. Arete Zone: An arête is a series of close and intervening narrow mountain divide or ridge resembling saw-teeth that separates two parallel valleys mainly of 'U'-shaped. When two or more parallel glacial cirques erode the headward portion of a mountain by freeze-thaw weathering and mass wastingtowards each other then steep sided arêtes' are created.It has captured 19.42 Km^2(2.611 %)of area creating arête zone. Location of it is highly centralized between the confluence of Pindar River and Khapni River above Dwali and left side of Khapni River in upper part where as scattered between Zero Point and the source of Mangtoli N near Burh Gal and Burla Gal.

b. Crevasse Zone: A crevasse is a deep crack or fracture created in surface of glacier. Crevasses form as a result of different rates of movement in different places of valley glacier and resulting stress associated with the shear stress generated when two semi-rigid blocks have differential movement(Wikipedia, 2017).In the river basin, Crevasses are found in zones near Mrigthuni Gal in North-West corner, Mangtoli Gal and in between Sal Chhanguj Glacier and Khapni Glacier sharing 0.323% (2.40 Km^2) of total area.

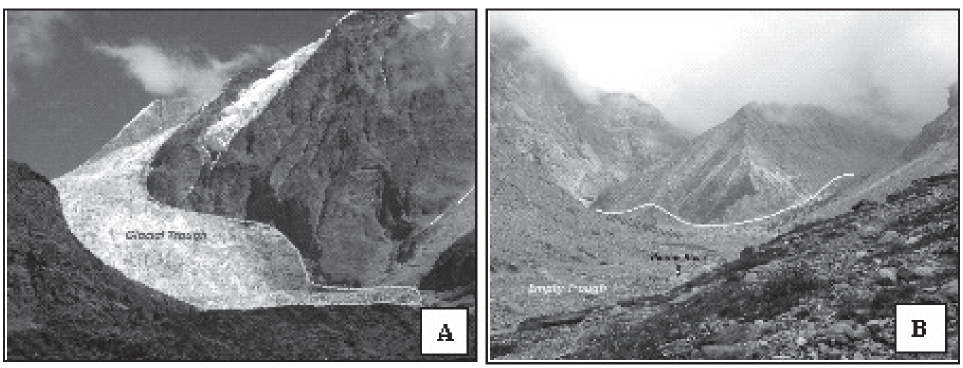
c. Trough: Glacial troughsare long, U-shaped valleys with a tendency to have flat valley floors and steep side-wallsthat were carved out by glaciers.In this area height, of the trough decreases from 150 m.- 300 m. in the base of trough to 100 m. in the valley head. Trough is of two types-

i. Glacial Trough: They are found in Mrigthuni Gal near Mangtoli Gal in North-West section, Burh Gal near Bauljuri mountain in Middle-North portion, Pindar Glacier and Sal Chhanguj Glacier near Zero Point in North-East corner &Khapni in the South-East portion near source of Khapni river. Contributing 1.649 %of total area, this unit covers about 12.27 Km^2.

ii. **Empty Trough:** The empty troughs are common below the Mrigthuni Gal near Mangtoli Gal in North-West corner and Pindar Glacier and Sal Chhanguj Glacier near Zero Point in North-East corner upto the locality namely Sundardunga and Phurkia respectively. Most of these troughs are covered by ground and ablation moraines overlain by frost-scattered and other mechanically weathered materials sliding down from the adjoining trough walls (Mukherjee, 1994). Floors of troughs are shaped by turbulent ice-melted streams by steep-sided 'V'-shaped valleys. This class has occupied 1.98 Km^2 (0.266 %) of basin.

Figure 6.

(A) Glacial Trough of Pindar Glacier at Zero Point (B) Empty Trough of Pindar River near Kupi Dhaura.



d. Horn: Horns are pyramidical peaks usually non-erodible part of Mountain ranges. A horn is created when glaciers erode three or more arêtes and forms respective cirques all around the sharp-edged peak. A number of horns are identified in this area namely Cheper Choti, Lamchhir in North-South frontier, Nandabhanar in the East, Changuj in North-East corner, Nanda Khat, Panwali Doar, Mangtoli in North and Tharkot and others in North-West corner with an elevation ranges from 4300 m. to 6800 m. It has occupied 0.17 Km^2 which shares 0.022 % area of total land.

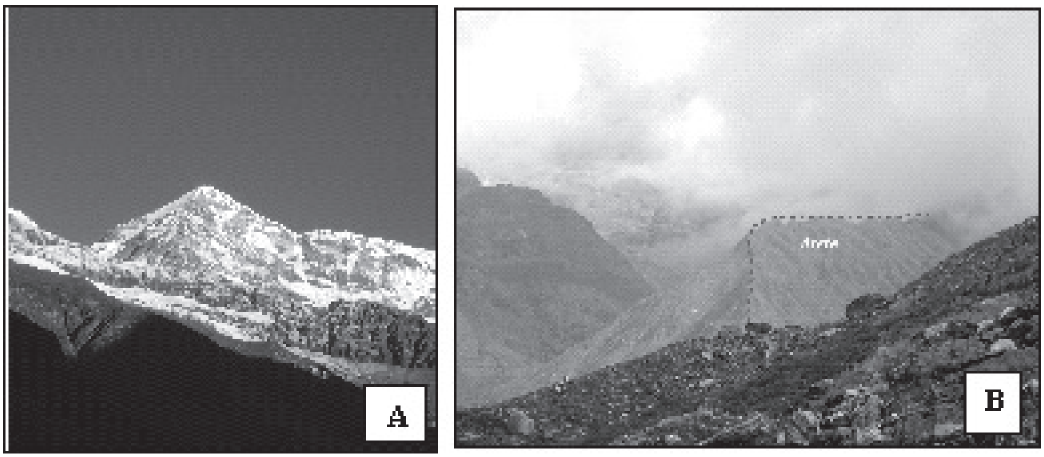
e. Ice Field: Literally, an ice field is an area with < 50,000 km^2 of ice often noticed in the cold climate and higher altitudes of the world forming the supply zones of the glaciers. Location of this unit is confined in the whole northern portion of the study area above the elevation of about 4500 m. in an average, these areas are the highest part of Pindar Basin.Cheper Choti, Lamchhir, Laspa Dhura, Dang Thyal, Nanda Kot, Nandabhanar, Nandakhani, Changuj, Nanda Khat, Panwali Doar,Mangtoli, Mrigthuni, Tharkot etc. mountain peaks with slope angle between 35p to 65p , Sundardunga Khal and Pindari Kanda (Traill's Pass) all are located within ice field contributing 98.50 Km^2 area.

f. Ice Wall: According to the Flat Earth Society, the Ice Wall is a 150-foot-tall (46 m) wall made with ice that encloses the perimeter of a flat, circular earth (Wikipedia, 2017). Only 0.026

% of area of this study-area is covered with ice-wall located near Traill's Pass, Pindar Glacier, Nandakhani, Sal Chhanguj Glacier and Lamchhir.

Figure 7.

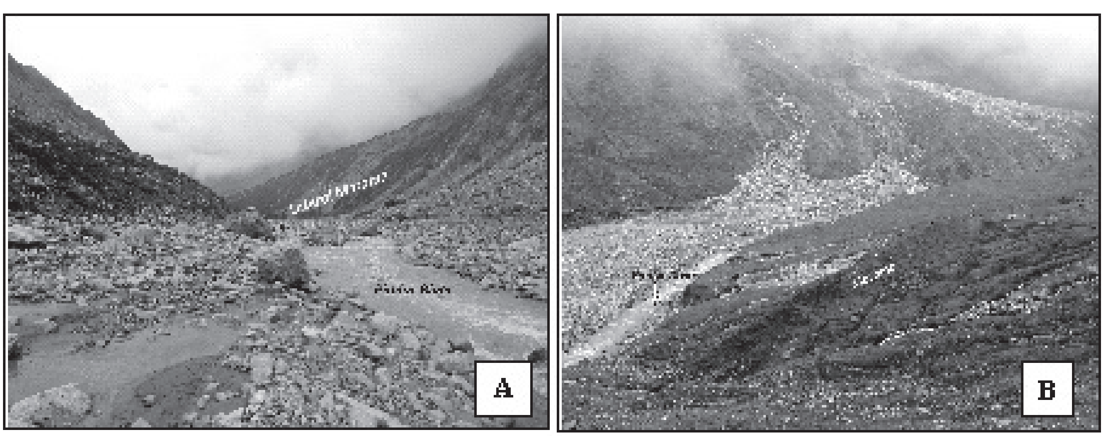
(A) Pyramidical Shape of Panwali Doar mountain (B) Arete near Zero Point.



g. Moraine: These are glacial debris transported and eventually deposited in the ablation zone (Mukherjee, 1994). Formation of moraines are caused by 'accumulation of unconsolidated glacial debris' of eroded rocks, cobbles, pebbles, granules, sand etc. by abrasion and plucking during the transportation of glaciers through glacial trough. Three types of moraines are found in this region-

Figure 8.

(A) Field photograph of the left Lateral Moraine located about 1.5Km. downstream of Pindar source (B) Left Lateral Moraine at 5 Km. upstream of Pindar River from Phurkia.



i. Lateral Moraine: When glacial debris are accumulated like a ridge along the sides of any glacier then lateral moraine is formed. About 1.29 Km^2 area is covered by this type of moraine in Pindar valley. They are very much significant along both sides of Pindar Glacier, Sal Chhanguj Glacier, Khapni Glacier and Mrigthuni Gal.

ii. Medial Moraine: Two inner lateral moraines are merged together along the internal margins of two glaciers at their confluence creates medial moraine. In Mrigthuni Gal, Buar Gal and near confluence of Pindar Glacier andSal Chhanguj Glacier various number of medial moraines are recognised covering 0.172 % of geographical area.

B Terminal Moraine: Accumulation of debris of glacial eroded material at the snout of glacier after ablation of ice are called terminal or end moraine.In the study-area beneath th Buar Gal only the terminal moraine is identified that has occupied 0.04 Km^2 sharing 0.005 % of catchment.

E. Periglacial Origin

a. **Bare Mountain Slope:**This geomorphic unit is distributed below the ice-field sharing 22.512 % (167.45 Km^2) of area. This landform shows typical mechanical weathering of wind abrasion and frost scattering with hardly any regolith formation due to extreme coldness and often creates talus debris beneath it. Landform acts as trough wall near Mrigthuni Gal, Buar Gal, Pindar Glacier and Sal Chhanguj Glacier and valley wall of Sukhram N, Mangtoli N, Pindar River, Khapni River and Baura Gad. Slopes of this features are varying from 30p to 65p .

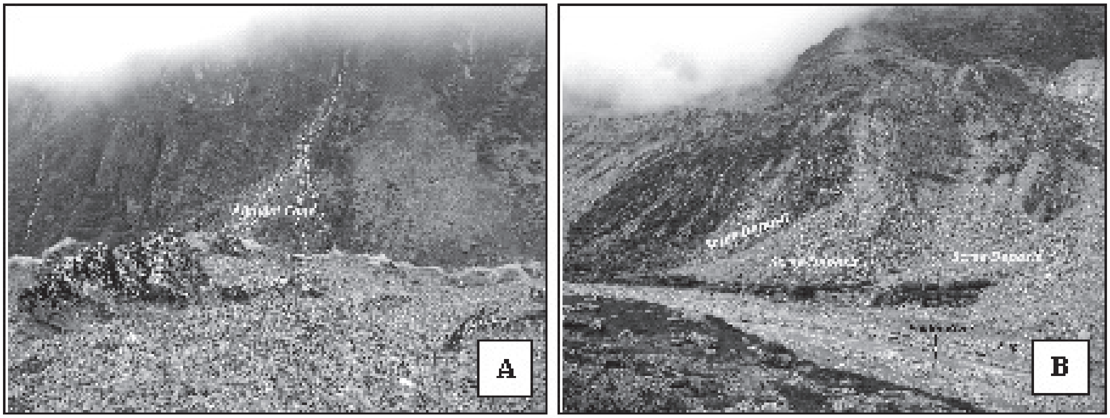
Figure 9.

Field photograph of Bare Mountains Slope located north of Phurkia village.

F. Depositional Origin

a. Alluvial Cone and fan: Due to abruptly decrease of channel gradient, both the transportation capacity and velocity of water flow of streams suddenly drops at the foothill zones where river enters in the plain from mountain topography. and accumulates materials at the base of the foothill. As a result, the transported sediments of coarser to finer material are deposited from the apex to the outer margin respectively creating both alluvial cones and fans. The only difference between them is that the cone exhibits more conical shape and tends to be steeper. In case of alluvial fan the gradient is about 5p to 10p whereas the slope of alluvial cone is > 15p upto 35p .0.26 Km^2 (0.035 %) and 0.22 Km^2 (0.029 %) areas are covered in case of alluvial cone and alluvial fan respectively. They are identified along both sides of Khapni river, near Rata Kharak, Phurkia, at Kupi Dhaura etc.

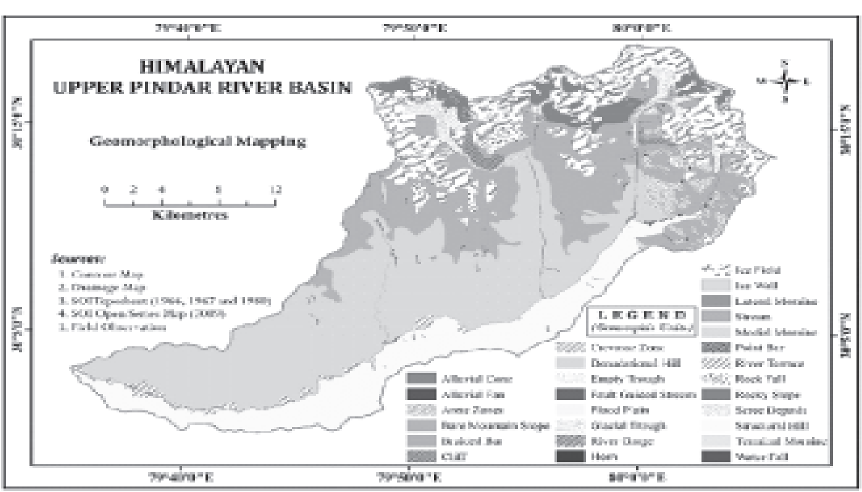
Figure 10.
(A) Alluvial Cone at north of Phurkia (B) Scree Deposit near Zero Point along Pindar River.



b. Rock Fall: Rock falls are relatively small landslides confined to removal of individual and superficial blocks from a cliff base (Selby, 1982). It is happened due to granular and block disintegration of rocks for the process of mechanical and chemical weathering mainly oxidation. Abundant rock falls have been occurred in this study area near Mangtoli Gal, Nagg Kund (Bhairav Kund), Cheper Choti, Rata Kharak and Salgwar sharing 6.17 Km² of total basin. It covers 0.830 % of total.

c. Scree Deposit: Due to physical and chemical weathering and erosion acting on a rock free face,broken rock fragments, loose cobbles, pebbles, granules, finer sand, silt etc. slides down through the cracks of the mountain and deposits beneath the slope in conical concave upward shape forming Scree Deposit at the base of the gully. They are abundantly found at the source of Pindar River,Sukhram N, Mrigthuni N and at Khapni Glaciercontributing 0.323 % of total geographical area.

Figure 11.
Geomorphological Map of the study area



6.0 Conclusion

Geomorphological Mapping would be helpful for identifying of each geomorphic unit and demarcating spatial distribution pattern of them that express the geomorphic evolution and ongoing process operating in any geographical region. So, there should be always a necessity of geomorphic mapping to understand the landform characteristics in terms of geomorphic, geologic and tectonic point of view. From the above discussion of geomorphic units, it can be concluded that the Upper Pindar River Basin has went through glacial, periglacial as well as fluvial cycle of erosion experiencing most of the geomorphic process. Detail study in this field of this region can able to improvepolicy making regarding scientific land use planning and construction purpose and create a path of sustainable environmental development in the Himalayan region.

References:

Bali, R., Agarwal, K.K., Patil, S.K., Ali, S.N., Rastogi, S.K. and Krishna, K., 2011.*Record of Neotectonic Activity in the Pindari Glacier valley: Study based on Glacio-geomorphic and AMS Fabric evidences.*Earth Science India, 4(I): 1-14.

Barsch, D. and Liedtke, H., 1980.*Principles, scientific value and practical applicability of the geomorphological map of the Federal Republic of Germany at the scale of 1:25000 (gmk 25) and 1:100000 (gmk 100).* Zeitschrift für Geomorphologie, 36, pp.296–313.

Barsch, D., (ed.), 1979.*The geomorphological approach to environment*. Geojournal, 3, pp. 329-416.

Bishop, M.P., James, L.A., Shroder Jr., J.F. and Stephen, J.W., 2012.*Geospatial technologies and digital geomorphological mapping: Concepts, issues and research.* Geomorphology, Elsevier, 137, pp.5-26.

Bishop, M.P., Shroder Jr., J.F. (Eds.), 2004a.*Geographic Information Science and Mountain Geomorphology.* Springer-Praxis, Chichester.

Blaszczynski, J.S., 1997.*Landform characterization with geographic information systems.* Photogrammetric Engineering and Remote Sensing, 63 (2): 183–191.

Brunsden, D., Doornkamp, J.C., Fookes, P.G., Jones, D. and Kelly, J.M.H., 1975.*Large scale geomorphological mapping and highway engineering design.* The Quarterly Journal of Engineering Geology, 8, pp.227–253.

Burrough, P., 1989.*Fuzzy mathematical methods for soil survey and land evaluation.* Journal of Soil Science 40, pp.477–492.

Burrough, P., Van Gaans, P., MacMillan, R., 2000.*High-resolution landform classification using fuzzy k-means.* Fuzzy Sets and Systems, 113 (1): 37–52.

Cooke, R.U. and Doornkamp, J.C., 1990.*Geomorphology in Environmental Management (2nd ed.).* Clarendon Press, Oxford, pp.19-63.

Cooke, R.U., Brunsden, D., Doornkamp, J.C. and Jones, D.K.C., 1982.*Urban Geomorphology in Drylands.* Clarendon Press, Oxford.

Demek, J. and Embleton, C., 1978.*Guide to Medium Scale Geomorphological Mapping.* Schweizerbarts, Stuttgart.

Deng, Y., Wilson, J.P., 2008.*Multi-scale and multi-criteria mapping of mountain peaks as fuzzy entities.* International Journal of Geographical Information Science, 22, pp.205–218.

Doornkamp, J.C., 1971.*Geomorphological mapping, in S. H. Ominde (ed.), Studies in East African Geography and Development.* Heinemann, London and Nairobi, pp.9-28.

Dramis, F., Guida, D. and Cestari, A., 2011.*Nature and Aims of Geomorphological Mapping. In Geomorphological Mapping: methods and applications.* Smith MJ, Paron P, Griffiths J (eds.). Elsevier, London, pp.39-74.

Evans, I.S., 1990. In: Goudie (Ed.), *Cartographic Techniques in Geomorphology*. pp.97–108.

Fleisher, P.J., 1984.*Maps in applied geomorphology, in J. E. Costa and P. J. Fleisher (eds.), Developments and Applications of Geomorphology.* Springer-Verlag, Berlin, pp.171-202.

Fookes, P.G., Lee, E.M., Griffiths, J.S. (Eds.), 2007.*Engineering Geomorphology: Theory and Practice.* CRC Press, New York.

Galon, R., 1962.*Instruction to the Detailed Geomorphological Map of the Polish Lowland.* Polish Acad. of Science, Geogr. Inst. Of Geomorphology and Hydrography of the Polish Lowland at Torun.

Gilewska, S., 1967.*Different methods of showing the relief on the detailed geomorphological maps.* Zeit. Fur Geom., 11, pp.481-490.

Hartvich, F. and Vilimek, V., 2008.*Selected landforms and their significance in the analysis of the slope origin in the Losenice river valley, Sumaya Mts.*Acta Geodynamic Geomater, 5(151): 275-296.

Hayden, R.S., 1986. In: Short, Blair (Eds.). *Geomorphological Mapping*. pp.637–656.

https://en.wikipedia.org/wiki/Crevasse and https://en.wikipedia.org/wiki/Ice_wall, 2017.*Wikipedia, The Free Encyclopaedia.* Wikimedia Foundation, Inc.

Klimaszewski, M., 1982.*Detailed geomorphological maps*. ITC Journal, 3, pp.265–271.

Knight, J., Mitchell, W. and Rose, J., 2011. Geomorphological Field Mapping. In*Geomorphological Mapping: methods and applications.* Smith MJ, Paron P, Griffiths J (eds.). Elsevier, London, pp.151-188.

Lobeck, A.K. (Ed.), 1924.*Block Diagrams.* John Wiley and Sons, New York.

Lobeck, A.K. (Ed.), 1958.*Block Diagrams and Other Graphic Methods used in Geology and Geography.* Emerson Trussel Book Co, Amherst, MA.

Mith M.J. and Clark C.D., 2005.*Methods for the Visualization of Digital Elevation Models for Landform Mapping, Earth Surface Processes and Landforms*. 30, pp.885–900.

Mukherjee, B., 1994.*Gangotri – Kedarnath – Badrinath Area: A Study in Glacial Geomorphology.* Unpublished Ph.D. Thesis, Department of Geography, Visva-Bharati, Santiniketan.

Otto, J.C. and Smith, M.J., 2013. Geomorphological Techniques. *Geomorphological mapping.* Chap. 2., Sec. 6., British Society of Geomorphology.

Paron, P. and Claessens, L., 2011. Makers and users of geomorphological maps. In *Geomorphological Mapping: methods and applications*. Smith MJ, Paron P, Griffiths J (eds.). Elsevier, London, pp.75-106.

Pike, R.J., 1995. Geomorphometry - progress, practice and prospect. Zeitschrift für Geomorphologie, 101 (7): 221–238.

Pike, R.J., 2000.*Geomorphometry - diversity in quantitative surface analysis.* Progress in Physical Geography, 24 (1): 1–20.

Rosenfeld, C.L., 1977.*Terrain sensitivity of the townsite at Resolute Bay, N.W.T.* Association of Pacific Coast Geographers Yearbook, 39, pp.77–87.

Seijmonsbergen, A.C. and de Graaff, L.W.S., 2006.*Geomorphological mapping and geophysical profiling for the evaluation of natural hazards in an alpine catchment.* Natural Hazards and Earth System Sciences, 6, 185–193.

Selby, M.J., 1982.*Hill Slope Materials and Processes.* Oxford University Press, Oxford.

Shashikant, Singh, P. and Doi, R.D., 2014.*Geomorpholgical Mapping of Remote Area Using RS & GIS Technology of Doda Catchment.* Current Trends in Technology and Science, 3 (3): 176-180.

Singh, S., 1998. *Geomorphology.* Prayag Pustak Bhawan, Allahabad, India.

Smith, G.R., Woodard, J.C., Heywood, D.I. and Gibbard, P.L., 2000.*Interpreting Pleistocene glacial features from SPOT HRV data using fuzzy techniques.* Computers and Geosciences, 26, pp.479–490.

Sudarsana Raju, G., 2012.*Delineation of groundwater prospects zones in and around Kadiri, Anathapur District, Andhra Pradesh, India.* International Journal of Geomatics and Geosciences, 2 (3): 759-769.

Tate, J.N., Wood, J., 2001. In: Tate, Atkinson (Eds.), *Fractals and Scale Dependencies in Topography.* pp.35–52.

Tomar, A.S. and Singh, U.C., 2012.*Geomorphological Mapping Using Remote Sensing and GIS: A Tool for Land Use Planning Around Shivpuri City, M.P., India.*IOSR Journal of Computer Engineering (IOSRJCE), 5 (1): 28-30.

Tricart, J., 1965.*Eìtude expeìrimentale du proble@me de la gelavition.* Biul. Peryglacjalny, 4, pp.285-318.

Usery, E.L., 1996. In: Burrough, Frank (Eds.), *A Conceptual Framework and Fuzzy Set Implementation for Geographic Features.* pp.71–85.

Valdiya, K. S., 1999.*Lithological sub-divisions and tectonics of the 'Central Crystalline Zone' of Kumaon Himalaya.* Proceedings of the Seminar on Geodynamics of Himalayan Region, Abstr., NGRI, Hyderabad, pp.204–205.

Verstappen, H. Th., 1966.*The role of landform classification in integrated surveys.* Actes du le Symposium International de Photo-Interpretation, Paris, pp.VI.35-VI.39.

Warner, T., Shank, M., 1997.*An evaluation of the potential for fuzzy classification of multispectral data using artificial neural networks.* Photogrammetric Engineering and Remote Sensing 63 (11): 1285–1294.

Climate Change Scenario Of West Bengal, India: A Geo-Environmental Assessment

Bhaskar Das and Reshma Chakraborty

Introduction

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. According to United Nations Framework Convention on Climate Change (UNFCCC), 'climate change' is 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. Climate change is major threat to sustainable development in any region which is now considered as most well-defined pathways through which global environmental changes.Increase in aerosols (atmospheric pollutants) due to emission of greenhouse gases(GHG) such as Carbon Dioxide (Co_2) due to burning of fossil fuels,chlorofluorocarbons (CFCs), hydro-fluorocarbons(HFCs), hydro-chlorofluorocarbons (HCFCs), per-fluoro-carbons (PFCs) etc., depletion of Ozone layerand UV-B filtered radiation,eruption of volcanoes, deforestation in the form of forest firesand loss of wet lands are causal factors for weather extremes. It can be triggered through El Niño-Southern Oscillation phenomena in a region. This climate changes include changes in regional climate characteristics, including temperature, humidity, rainfall, evaporation, wind rose, and severe weather events.Climate change models, driven by a variety of socio economic scenarios project that the global average temperature may rise by 1.8 to 4.0°C by 2100 .(WBAPCC,2012).Climate change and its variability which leading to global warming has the potential to undermine human development across many countries including India and many even lead to a reversal of present development progress. Overall in India, it is predicted that, physical impact of climate change will be seen as (i) an increase in the average surface temperature by 2-4 degrees C, (ii) changes in monsoon and non-monsoon rainfall (both distribution and frequency) (iii) decreasing number of rainy days by more than 15 days, (iv) increase in the intensity of rain by 1-4mm/day and (v) increase in the frequency and intensity of cyclonic storms (Ranuzzi et al,2012).

1. Climate assessment of West Bengal

Climatic variability and global warming in India which effects are projected to impact millions of lives due to the submergence of low-lying islands and coastal lands to the melting of glaciers in the Indian Himalayas, threatening the volumetric flow rate of perennial rivers of India. West Bengal,one of the Eastern region's state of India spatially situated between N 21°30' & 27° 30' and E 85° 30' & 89°45' with the Tropic of Cancer runs across the middle of Nadia, Burdwan, northern parts of Bankura and Purulia districts. Geographically West Bengal is the only state in India which extends from the snowy peaks of the world's highest mountain, the Himalayan Range in the north to the Bay of Bengal in the southern part and is covered by the active delta of the Sundarbans Mangrove forest. The greater part consists of detrital and alluvial plains, The total area of the state is 88,752 sq Km having a dense population of more than 80 million people with population density of 1029 (NIDM Report, 2011).

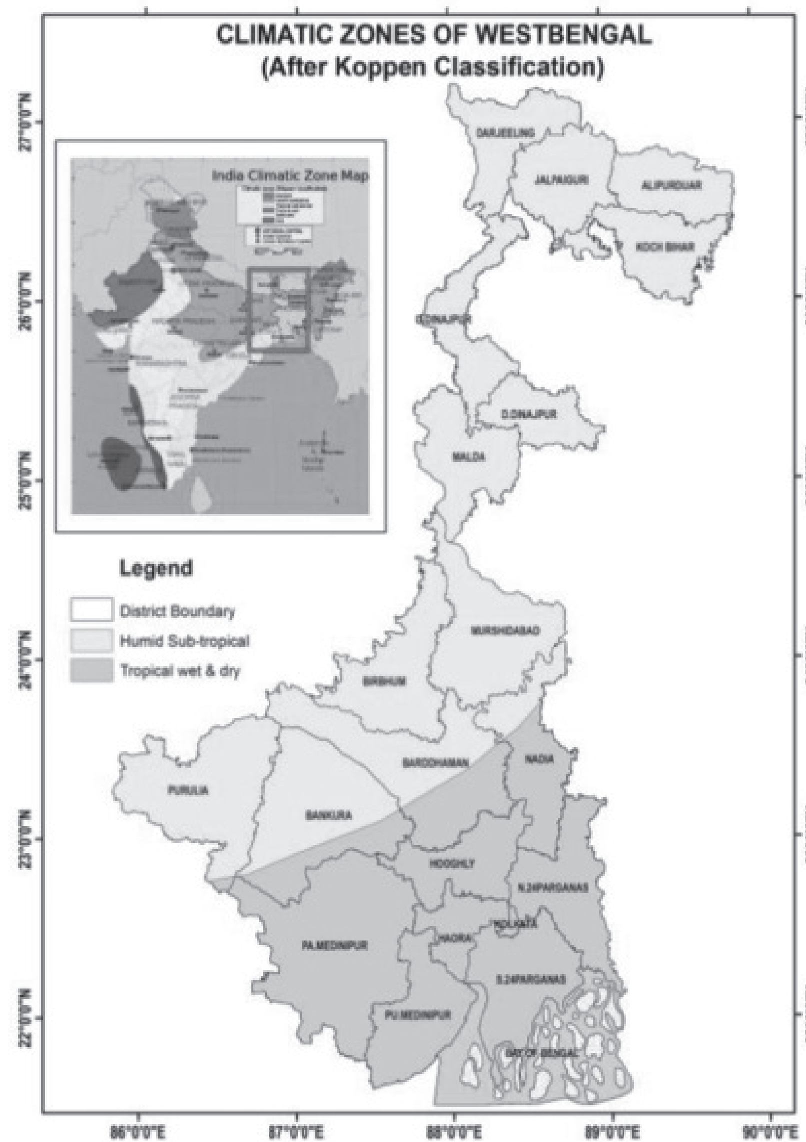


Fig-1: Climatic Zones of West Bengal, (Source- IMD, Pune)

The climate of West Bengal is tropical and humid in nature except in the northern hilly region which is close to the Himalayas. The temperature in the mainland normally varies between 24°C to 40°C during summer and 7°C to 26°C during the winter. The average rainfall in the state is about 1750 mm with considerable variation among the districts ranging between 1234 mm in Birbhum to 4136 mm in Jalpaiguri (WBSAPCC, 2013).According to State Forest Report West Bengal (2007), the coastal areas of the state experience fierce cyclonic storms during pre-monsoon and postmonsoon seasons. Violent thunderstorms and hailstorms are very common weather phenomena during the pre-monsoon month while droughts of different intensity and floods are common during monsoon.The distribution of precipitation parameters like temperature, humidity, cloudiness; wind direction and speed also register marked regional and seasonal variation round the year. All the above variations of weather and climatic conditions are well reflected in the natural vegetation of the land, which includes numerous varieties beginning with mangrove swamps along the littoral belt to purely temperate flora over the Himalayas (State Forest Report West Bengal, 2007).

The year may be conveniently divided into the following four principal seasons:

(1) Cold weather season, December-February, (2) Hot weather season, March-May.(3) South-West monsoon season, June- September.(4) Retreating South-West monsoon season, October-November. Due to large variation in frequency and intensity of rain-inducing disturbances (monsoon with monsoon trough, cyclonic storms, lows & depressions, thunderstorms, western disturbances, etc.) as well as post monsoon circulations over different parts of the state rainfall occurrences exhibit large spatial variability (State Forest Report West Bengal, 2007).

2. Aim and Objectives

The broader objective of this study is to prepare a comprehensive and informative database through

- v Identification of the key concerns due to climate changescenario.
- v In-depth observed differences and changes in climatic parameters.
- v Preparation of climate projections in the future aspect.
- v Impacts of climate change under the threat of global warming.

3.Scope of the work

v Multi-criteria evaluation of climatic parameter of West Bengal through assessment and cartographical works.

v Several users such as at the national and international organizations policy makers, researchers, middle level policy makers and local levels consultants of the state, relief agencies and environmental planner and water managers are interested in reliable information for effective climate management adaptation.

4. Methodology

A number of qualitative and quantitative methods are used to address the different tasks identified during carrying out this assessent. These are:

a) Review of the research literature.

b) The study has been carried out through high resolution referenced satellite data with thematic map, for which a number of hazard and vulnerability attributes will be collected from secondary sources and limited ground checks.

c) Policy papers of Government of India and Government of West Bengal including the climate change reports, environment anddisaster management plans to find out the differences and change assessment of weather component and related climatic phenomena.

d) In depth study of prevention phase and remedial strategies where activities such as early warning/ forecasting, monitoring are taken up just before or on long term basis.

5. Identification of the key concerns due to climate change

i. Global Warming

Global Warming is an overall warming of the planet Earth, based on average temperature over the entire surface. It is defined as the increase of the average temperature on Earth. Green house gases are increasing in the atmosphere leading to global warming and carbon is one of the main GHGs. The simplest way to understand the difference is: “Global Warming is the Cause and Climate Change is the Result”. About 30 per cent of sunlight is scattered back into space by the outer atmosphere, but the rest 70% passes down through the atmosphere to warm the earth’s surface. The main greenhouse gases in the Earth’s atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, chlorofluorocarbons (CFCs), and ozone. Greenhouse gases (GHG) are gases in an atmosphere that absorb and emit radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect ADB Technical Assistance Consultant’s Report (2012). This phenomena increases the vulnerability of the people by

a) Affecting biotic and abiotic health and livelihood,
b) Maximum water stresses for both potable drinking water and water for irrigation process.
c) Decrease in food grain production
d) Increase in frequency/impacts of extreme weather events

ii. Rise in Sea Level

Ascend in sea level directly threatens the mangrove ecosystems as well as aquatic ecosystem and diminishes their ability to cope with changes. Ambient temperatures higher than 35°C will affect mangroves by reducing the rate of leaf formation, ultimately causing the population to weaken. If temperatures rise above 35°C, there will be acute thermal stress affecting the development of roots and seeds. At temperatures of 38-40°C, photosynthesis will stop, killing the mangrove population (Mc Leod et al,2006). An indirect effect of increasing temperature and CO2 will be felt because of the degradation of coral reefs, which provide shelter to mangroves from ocean wave activities.

Oceanic uptake of carbon dioxide (CO_2) resulted in acidification of oceans warming of 0.850^0 C increased during 1882-2012 and sea level rose by 0.19 m during1901-2010 (SCCI, 2015). The Sundarbans (UNESCO World Heritage site) has plays a natural “Green Barrier”for the state of West Bengal and Orisha against cyclones and tidal surges. The sea levels rise creates unstable balance between freshwater aquifers and sea water in coastal areas of West Bengal.

iii. Extreme climate events

Every year, about 80-90 Tropical Cyclone form over the oceanic regions of India, out of which,about 45 Tropical Cyclone develop into severe cyclonic storms and cause damages over theland falling areas of the various coastal regions (Landsea, 2007).Extreme climate events include heat waves in Rarh Bengal, cold snaps Darjeeling Himalayan Region, tropical cyclones in Coastal belt, storm surges, floods in Gangetic plain region, droughts in western district seen plays the key concern for climatic hazards in West Bengal. Extreme climate events can have a serious impact on the environment and society, including loss of life, property and livelihoods. In recent years, the occurrence of extremeclimate events and the associated damage has become highly visible. The Bay of Bengal has experienced more than 75% of the total world-wide Tropical Cyclone (TCs) causing human death of5000 or more in last 300 years.It can be seen that 1387 cyclonicdisturbances out of which, 1081 (78%) formed over the Bay of Bengal (SCCI,2015)

iv. Drought

Rising of temperatures and scanty rainfall over a period causes an discrepancy of the hydrological cycle hence created longer-lasting droughts. Water-related climate change impacts are being experienced in the form of more severe and more frequent droughts mainly in the Rarh Bengal districts in West Bengal like Purulia, Purba and Paschim Medinipur, Bankura Part of Birbhum and Part of Burdwan district. These districts are already experiencing water deficits due to diminished precipitation and recurrent of agricultural and climatic drought.

v. Snow melting

Glaciers play an important role in climate and weather regulation as well as region's economy. They are important for maintaining ecosystem integrity and in feeding rivers, thus providing water for agriculture and drinking purposes. Apart from the monsoon rain fed rivers (Ajay, Mayurakshi, Damodar etc.) of South Bengal districts, entire North Bengal rivers (Ganga, Tista, Torsa etc.) relies heavily on the Himalayan Rivers for its irrigation as well as communication system. The hydrological characteristics of Himalayan watersheds have already undergone significant changes as a result of climate change and anthropogenic activities. This has resulted in increased variability in rainfall and surface water runoff, more frequent hydrological disasters, and the pollution of lakes. The increase in temperature resulting in more rainfall instead of snow is a direct consequence of Himalayan glacial melt. A reduced water flow from the melting glaciers changes the watershed distribution and the ecological parameters of rivers causing the temperature of river waters to rise (Ranuzzi, A, et al, 2012)

vi. Environmental Refugees

Climate change is likely to lead to increase the number of climate refugees. The term Environmental Refugees has been coined for those populations and predictions who are displaced by environmental events/ disasters which are directly linked with climate change. The Sundarban region in West Bengal linking 7000 people have already been is placed and by 2030, it is anticipated that over 70000 people from this area will be exposed to the risk of losing their homes and livelihood due to sea level rise, increasing cyclone intensity and flooding. These environmental refugees are forced to reside colonies where poor sanitation and limited water supply can lead to the spread of diseases and further health implication (Seth,2014). The population living in South and South-East Asia on the coastline extending from the east coast of India to Myanmar have been buffeting by annual cyclones from the Bay of Bengal and ever increasing tidal floods.Notably, from last two decades deadly cyclones have been routine example like Cyclone Sidr of 2007, Nargis of 2008, Aila of 2009, and Laila of 2010 (WBAPCC,2012).

vii.Depletion of Biodiversity

The fourth IPCC Report (2007) states that by the end of this century climate change will be the main cause of biodiversity loss. If there is an increase of the average global temperature by 1.5-2.5 ° C, then approximately twenty to thirty percent of known plants and animal species will be threatened by extinction. Climate change will increase the pressure on land degradation and habitat loss, as well as genetic erosion which is already intensifying because of the growing uniformity in agricultural systems across the world. By mid-century, most species could lose half of their geographical range and size because of habitat fragmentation.(FAO Report, 2010). West Bengal is enriched with flora and fauna networked by number of perennial and rain fed r rivers including hills and the sea with abundant natural resources.

viii.Depletion of Water resources

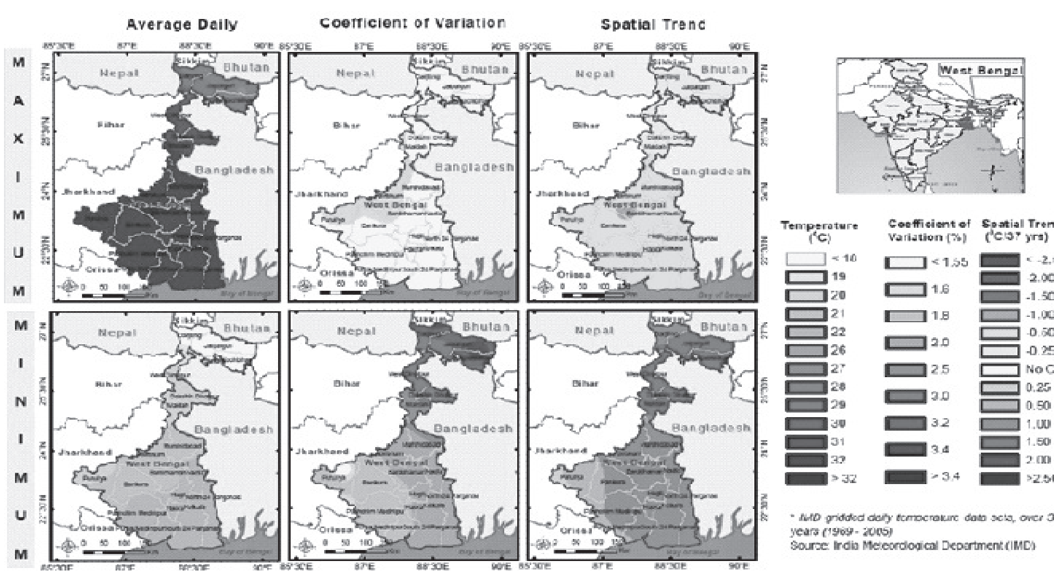
Increasing temperature, varying precipitation patterns, and an increasing frequency of extreme weather events are expected to be the main reasons for reducing regional water availability and impacting hydrological cycles of evaporation and precipitation. Recently, scientists have said that climate change may bring unsustainable demands on the world's groundwater supply for agriculture, industry and drinking water. As precipitation becomes less frequent due to climate change, lake and reservoir levels will drop and people will increasingly turn to groundwater for the water needs. This will pose serious issues as groundwater recharges at a much slower rate (UPI Science News, 2012). The drought prone districts of West Bengal where acute problem of Ground water and fluoride contaminated drinking water, over extraction of irrigation in plain region of West Bengal ultimate reduces the surface and sub-surface water resources hence key concern.

6. Observed Differences and Changes in Climatic Parameters

A. Temperature

A research work by Johny,S.(2012) estimates that rise in mean surface temperature will not only affect the post-monsoon and winter weather, but it is likely to lead to a 70% decline in summer rainfall by 2050 A project report by WBAPCC for the time period 1969-2005 (37 years) shows the maximum temperatures are decreasing across the state whereas the minimum temperatures are increasing (Fig-2) The maximum temperature has become less than 0.5% with respect to starting of the observation period (1970s) in the New Alluvial zone, the Laterite Zone and the Saline Coastal Zone, while minimum temperatures are increasing rest of the state the minimum temperature has increased by 0.5ºC. In the Hilly, Terai and the Old Alluvial zone, the temperatures have increased by 1.5ºC and New Alluvial Zone and the Coastal Zone's minimum temperatures have increased by 1ºC (WBAPCC,2012).

Fig-2:
Observed changes in minimum and maximum temperatures in West Bengal, (Source: WBAPCC,2012)



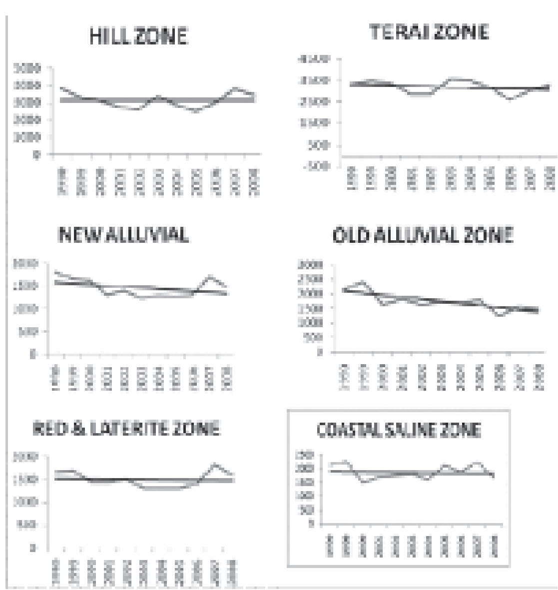
B.Precipitation:

A recent report of the IMD (Status of Climate in India, 2010) indicates that there are distinctive changes in observed pattern of rainfall between 1901 and 2003 between the northern (Darjeeling, Jalpaiguri Cooch Behar, Uttar Dinajpur and DakshinDinajpur, and Malda) and southern regions of West Bengal (rest of the districts from Malda downwards). In winter and pre monsoon seasons the rain fall has decreased in the southern region by -14.5 mm and -6.7 mm respectively between 1901-2003. In the northern region an increase in rain fall in the pre-monsoon season by +10.5 mm has been observed during the same period, whereas a decrease in rain fall by -1.7 mm in the winter season has been observed. In the monsoon season the increase in rain fall in the southern region is about 91 mm and in the southern region the increase is around 57 mm. Post monsoon season continues to show an increase in rainfall by 25 mm in southern region, but a drastic decrease in rain fall is observed in the northern region (-5mm). (WBAPCC,2012).

In the monsoon period, the same analysis carried over for 1901-2003, indicates that the June rain fall has decreased by an amount of -3.1% in northern part of Bengal and by -0.9% in the southern part of Bengal. There is no change observed in the July precipitation in the southern region, but in July there is a perceptible increase in rainfall by 4.5% in the northern region. In August there is an overall decrease by -0.2% and -0.1% in southern and northern parts of West Bengal respectively. In September, though southern West Bengal shows an increasing trend (+2.5%), the northern part of Bengal shows a decrease in rain fall by -1.1%. (WBAPCC,2012).

An analysis of total annual rain fall for a recent time slice, between 1990 and 2008, for the 6 agro climatic zones in West Bengal, carried out using the rainfall statistics published in the district handbooks, indicate that there is an overall decrease in the total rain in 2008 with respect to 1990 in the Terai zone, New Alluvial zone, Old Alluvial zone, Red and Laterite zone,and the Saline Coastal zone except for the hill zone (Figure-3). All zones except Hill zone have experienced a decrease in rain fall and the decrease is of the order of -8.8%, -20.0%, -33.3%, -2.7%, and -2.1% respectively. No change in total precipitation in the Hill region, may be due to the net increase in rain fall in this region (WBAPCC,2012).

Fig-3: Trends of annual rain fall in different agro-climatic zones between 1990 and 2008, (Source: WB Statistical Handbook, 2009)



B. Monsoon Wind:

In India, global warming is mainly contributed by the winter and post-monsoon seasons, which have increased by 0.80°C and 0.82°C in the last hundred years, respectively (Ranuzzi, A,2012). Estimates of disruption of established precipitation patterns show that the rise in mean surface temperature will not only affect the post-monsoon and winter weather, but it is likely to lead to a 70% decline in summer rainfall by 2050 (Stanly, Johny, 2012). The uncertainty of pre-monsoon and monsoon temperatures also indicate a warming trend. In India, the commencement of onset of monsoon starts from Andaman & Nicobar Islands from last week of May. The arrival date of onset of monsoon in subsequently in other parts of India follows, as the monsoon progresses towards the north as S-E monsoon wind. The maximum delay in onset of monsoon over Andaman & Nicobar Islands has been observed to be 11 days in the period 1941 – 1970 and the delay has been maximum by 7 days between 1971 – 2000. The mean withdrawal dates are found to be later than the existing normal, in both the 30 years slot of 1941 – 1970 and 1971 – 2000, by about one to one and a half week. More than 80% of annual precipitation occurs during monsoon and that too erratically in respect of time and space causing drought like situations in summer and flood during monsoons. (WBAPCC,2012).

C. Cyclones and Storm surges:

Long term observations by WBAPCC (2012) between 1900-2008 show an increasing trend of tropical cyclonic storms (48-63 kts or 88-117 kmph) as well as formation of severe cyclonic storms (64-90 kts or 118-167 kmph) in the Bay of Bengal during the period 1900-2008. Storm surges form when heavy winds produced by tropical cyclones generate the disturbances in the ocean. As these surges propagate into the shallow regions, they amplify and produce large variations of sea level at the coast. The height of the storm surge depends on wind speed, the shape of the coastline, and variations in the water depth along the coastline. Height also depends on phase of the tide. If a surge occurs during high tide, the storm surge will be higher than if it occurs during low tide. Category 5 tropical cyclones can produce storm surges in excess of 6m (20 feet). Because the storm surge occurs ahead of the eye of the storm, the surge will reach coastal areas long before the cyclone makes landfall.

D. Mean Sea Level rise:

The average sea level rise has been 1.3 mm per year along the Indian coast, however, tide gauge observations at the diamond harbour port indicate a sea level rise of 5.7 mm, which can be attributed to subsidence in the region at the rate of 4mm per year (INCCA, 2010),. In the past 25 years, sea level has raised at a rate almost double the global average. The sea level rise is also affecting the availability of sediment, directly impeding the establishment of new groves.

Projections of major components of climate

To find out the future aspect of the variation and changes in temperatures, precipitation rates, and the intensity of tropical storms over the Indian Ocean Climate projections for 2050s and 2100 have been derived from Change in mid century (2021-2050) and end of the century (2071-2098) with respect to 1970s (1961-1990)of climatic parameter the WBAPCC (2012) as carried out PRECIS (Providing Regional Climate for Impact Studies) Model by Indian Institute of Tropical Meteorology, Pune. with latest IPCC Assessment suggestions.

A. Temperature: The trend analysis of climatic variables can help in construction of future climate scenario, maximum temperature shows decreasing trend, while the minimum temperature shows increasing trend. The mean temperature of the study area shows an increasing trend over years. The annual rainfall of the zone slightly increases over years (Banerjee, S et al.,2015). The extreme weather events (mainly rainfall fluctuation) increases in more recent years. In 2050s, the average daily maximum and minimum temperatures are both projected to rise by 2.2°C in 2050s and by 2100, the temperatures are likely to rise by 3.6 to greater than 5°C with respect to the base line i.e 1960-1990 . (WBAPCC, 2012).

Fig-4:
Projected changes in average rainfall during Winter, pre-monsoon, Monsoon and post monsoon season in West Bengal 2050s (upper panel) and in 2100 (lower panel) (Source-WBAPCC,2012)

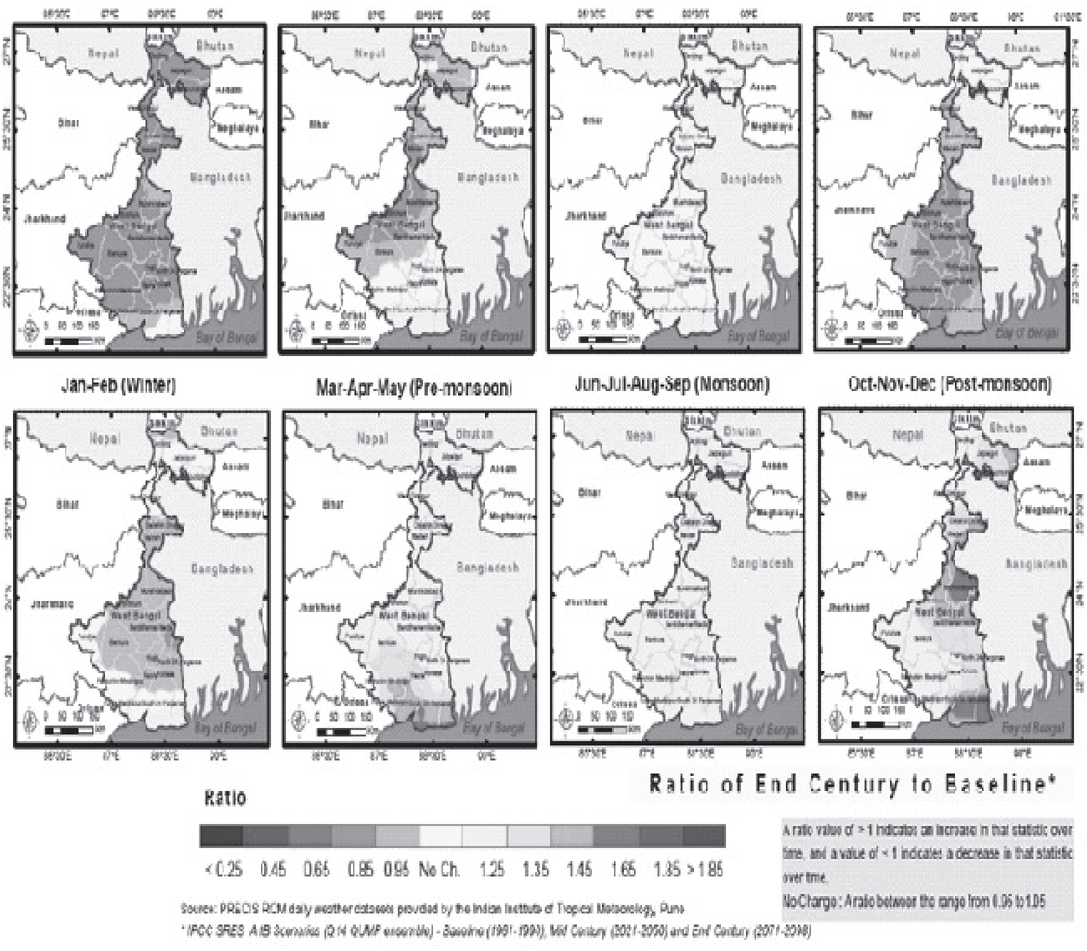
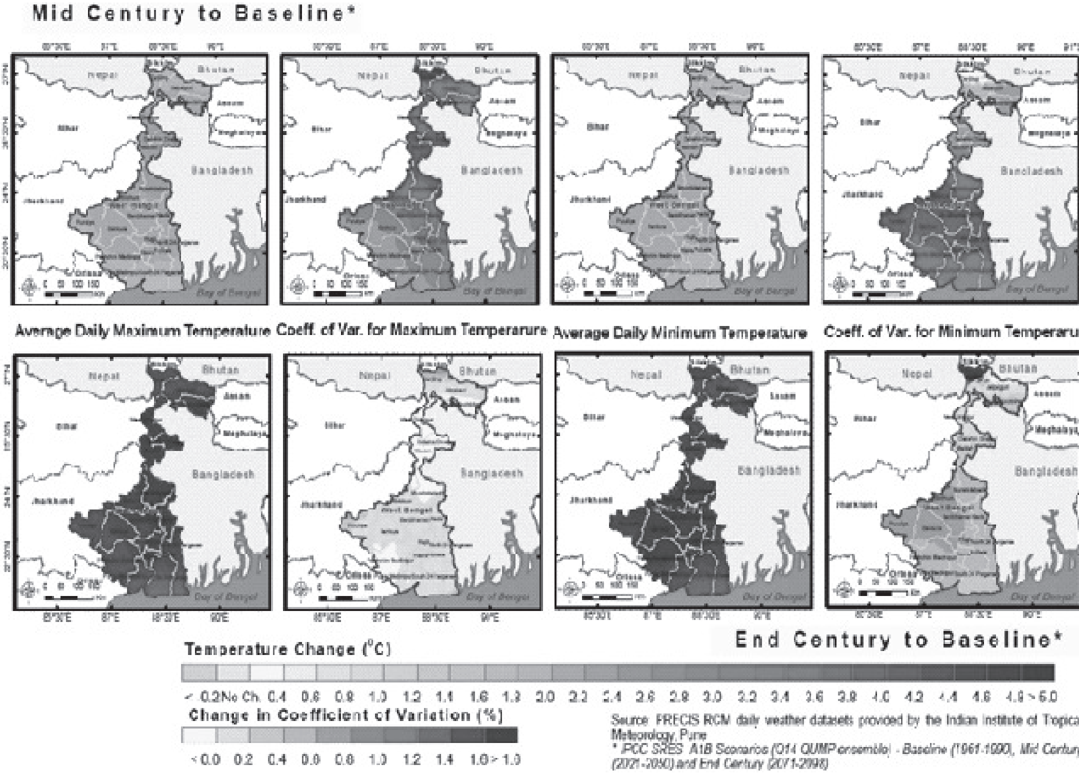


Fig-5:
Projected changes in average temperature during Winter, pre-monsoon, Monsoon and post monsoon season in West Bengal 2050s (upper panel) and in 2100 (lower panel) (Source-WBAPCC,2012)



B. Rainfall: Projections of rain fall in West Bengal for mid centuries 2050s (Fig-5), indicates that there is no change in monsoon (June-July-August-September) rain fall in the entire West Bengal region in the mid century, except, an increase is indicated in the southern Sundarbans region of the South 24 Parganas and in Eastern part of Purulia. In the winters (October-November-December), however, the scenario changes, the rainfall decreases in most parts of southern Bengal, no change is seen in eastern parts of Purulia and in Coochbihar and Jalpaiguri. A slight increase in rainfall is projected for the northern tip of Darjeeling during the same period (WBAPCC, 2012). .

Projections for January and February show an overall decrease in rain fall in the entire WB, except no change is projected in rain fall in the Sundarban region. In summers, the rain fall is likely to decrease northwards in WB starting from Bankura, Purulia, Burdwan, with no change in Paschim Medinipur, Hoogly, Howrah, and North 24 Parganas, and an increase in summer rainfall in the south 24 Parganas and Uttar Medinipur. The rain fall however increase in the entire WB region by the end of the century, except in January -February period, when the rain fall is likely to decrease in the entire alluvial region from DakshinDinajpur in the North to Bankura, Howrah, Kolkata, and northern parts of Northern 24 Parganas and PaschimDinajpur in the South. (WBAPCC, 2012).

C. Sea level rise: A significant fraction of sea level rise is due to thermal expansion of a warmed ocean (as much as 0.3 to 0.8 m over the past century, according to the 2007 IPCC report). Geographic patterns of sea level rise are due mainly to changes in the distribution of heat and salinity in the ocean, resulting in changes in ocean circulation. The 2004 Indian National Communication to the UNFCCC states that sea level rise is highest in the Gulf of Kutch (Gujarat) and on the coast of West Bengal (UNFCCC, 2004). Model-based projections of global average sea level rise at the end of the 21st century (2090–2099) made for a number of climate scenarios indicate that the sea globallymay rise from a minimum of 0.21 m minimum to a maximum of 0.48 m by the end of the century at the rate of 0.4mm/yr in the A1B scenario (IPCC, 2007). In the absence of availability of regional projections, global projections can be used as a first approximation of sea-level rise along the Indian coasts in the next few decades as well as towards the end of century.

D. Climatic Events: Changes in tropical storm and hurricane frequency and intensity are often masked by large natural variability, possible future changes in heat waves and found that in a future climate, heat waves are expected to be more intense, longer-lasting and more frequent(UNFCCC, 2004). The cyclonic storm tracks seem to shift more southwards over the Indian Subcontinent, with very few hits along the West Bengal coastal area. Overall, the frequency of cyclones hitting the Indian coast seems to decrease in the future, however, at the end of the century scenario, the number of cyclonic events during post monsoon period seems to be increasing by around 10-15 cyclonic events with respect to 1970s (INCCA, 2010). According to the Indian Meteorological Department (IMD), the most destructive element associatedwith an intense cyclone is storm surgewhich is leading to inundations as well as coastline washouts. For the two stations considered in the head Bay, namely, Sagar and Kolkata, increase in 100-year return levels of storm surges for the future scenario were found to be less than 5 % (INCCA, 2010).

E. Agricultural Growing Periods : Western regions of West Bengal already face water scarcity. Productive agricultural regions in the North Bengal Districts depend on the snowmelt to replenish regional water supplies through perennial river sytem. Climate models predict an earlier snowmelt, which could have a significant effect on Projected Impact of Climate Change on Selected Crops in India, (Using Ricardian Model). Agricultural production, especially if the levels of moisture in the soils are reduced during the growing season. Himalayan glaciers collect water during the monsoon season and release it during the dry season, providing irrigation water for agriculture activities.

If the rate of glacial melt increases, flooding is likely to occur in the river valleys fed by the glaciers. Later, as the river flows decrease to below previous rates, many people may be left without sufficient drinking water or water for irrigating crops. Decreasing trends in evapotranspiration during recent decades are evident in records, even though such records are sparse. This is likely due to decreased sunshine duration related to increases in air pollution, atmospheric aerosols, and increases in cloud cover (UNFCCC, 2004).

7. Impacts of climate change under the threat of global warming

The CRED report (2014) states that there ‘there is increasingly conclusive evidence which confirms that global climate change will have an impact on the occurrence and magnitude of extreme events. These impacts are envisaged to increase human vulnerability to natural disasters, thus emphasizing the need for improved measures of preparedness in every part of the world.

From above scenario it could be said that climate change, with present developmental trends, will not express itself in through slow shifts in average conditions, but it will manifest at an unprecedented rate with increased variability of climatic parameters, frequency of extreme climatic events, long term implications and possibility of abrupt changes and elicited largely through anthropogenic activities in different regions of West Bengal. Some other area where direct and indirect impacts of such of climate variability has been observed is as follows-

a) Industrialisation: The high influxes of demographical activities to urban areas, increase in consumption patterns and unplanned urban and industrial development have led to the problem of air pollution. After innovation of series of technologies regarding the utilisation in natural resources and industrialization in the 19th century resulted in extensive deforestation, further conversion of agricultural lands, changes in land use pattern, mining, quarrying, energy generation and utilization, introduction of urban heat islands, industrial effluents, solid waste generation, air and water pollution. The biggest environmental stories of the last several years in industrial areas have been energy security and climate change. For the sake of economic development and mitigating the increased greenhouse gases, The West Bengal Pollution Control Board has been working effectively to facilitate the proper environment management practices in the industries in West Bengal Area (Samim, S. K. 2011), These entire changing scenario of has been took place after second five-year plan implementation in the parts of western districts (for ex.Mrjia, Uluberia, Ranigunj, Kulti, Barnpur, Haldia etc.) of West Bengal.

There are large numbers of industries within West Bengal. All these industries are emitting harmful gases into the atmosphere and as a matter of fact, this emission is leading to tremendous amount of air pollution in major cities like Kolkata, Asansol, Durgapur and Raniganj. The extent of this pollution is so high, as to raise some serious environmental concerns. The thermal powers plants are at risk due to the change in climate since their efficiency and performance depend on air density, ambient temperature and hydro-meteorological parameters. Also, these power plants are vulnerable to potential damages due to unusual violent phenomena caused by climate changes such as floods and hurricanes (Makky, M .2013). There are 16 thermal power stations in west Bengal (Wikipedia of WBPDCL) which continuously generate Carbon, CHG, NO_2,and other toxic gases leading to massive air pollution causes fatal impact on human health of surrounding area of thermal power station and agricultural area in terms of crop productivity.

b) Transportation: The development of transportation facilities through vehicle explosion cause increased fossil fuel utilisation, land use changes, heat generation and air pollution. The carbon from fossil fuel stored in the energy source is released to the atmosphere in the form of carbon dioxide which indicates our carbon footprint. The more severe is the footprint, the more impact will be there on weather and climate (Kunhikrishnan, E.2014). The total effect of improved and huge development of transportation system has brought about many subsequent and radical changes in terms of air pollution, aerosol and emission of carbon to their surrounding society specifically the district head quarter area as urban heat island. According to the Ministry of Urban Development, in Kolkata, almost 54 % use public transport, four per cent auto, and the rest other modes. Nearly 65 % of the Kolkata's vehicular population and nearly 99 % of commercial vehicles are diesel-run, huge fleet of taxis and autos run on diesel or adulterated diesel. Kolkata with a little less than 2,000 kilometers of road, hardly 6% of its total area and Kolkata's air pollution is heading for disaster with an annual average of respirable suspended particulate matter level exceeding the national standards in 2007 by 1.4 % Narain (2009). Due to immense pressure of transportation vehicles and expansion of roadways need massive deforestation which bringing more frequent intense rainfall may exacerbate the landslides across the mountains of Darjeeling Himalayan Region.

c) Water Resources: The impact of climate change on water resources will affect human well-being to various digress, depending on how West Bengal State Water Resource Conservation Policy and its implementation is going on. Generally in Corporation and Municipal area of this states have better water management system due to pipeline water supply system and how they will be dealing with consequence of climate change, at the same time rural areas of Western most districts are more dependent on seasonal rain fall will be more acute during summer season due to scanty rainfall, high temperature and poor ground water recharge. The totals for the surface water resources is 51.01BCM, ground water resources is 34.21 BCM and Trans boundary water is 1759.27 BCM The present 14% of area under forest cover needs to ideally expand to 30% of the total area. Assuming that West Bengal will be able to achieve this target by 2051, the water demand for the forest sector is also likely to increase. The demand in the energy and industry sector is shown to be rising from 5.9% in 2001 to 49.7% in 2051, mainly due to the perceived increase in Industry in the state (WBPCB, 2009).

The census carried out in 2001 and the investigations of SWID (SWID, 2001), has revealed that 91.4% of rural households and 41.2% of urban households rely on underground water in West Bengal. Therefore increase in the surface temperature will lead to a rise in the snowline and increasing the risk of floods in Jalpaiguri, Koch Bihar, North and South Dinaj Pur, Malda, Murshidabad district) during the monsoon season.

d) River deltas, coastal areas, and mangroves: Climatic uncertainty and high anthropogenic pressure resulting from climate change is exacerbating the already high pressures on Sunderbans regions. Changes in temperature and CO_2 levels, changed rainfall patterns, frequency of storms, and rise in sea level directly threaten the mangrove ecosystems and diminish their ability to cope with changes. If temperatures rise above 35°C, there will be acute thermal stress affecting the development of roots and seeds. At temperatures of 38-40°C, photosynthesis will stop, killing the mangrove population. (Mc Leod, E.2006). Increase in intensity of extreme events such as cyclonic storms has been observed. On 25th May, 2009 a devastating cyclonic storm, Aila, caused havoc particularly in the coastal districts of the State. Vast areas in North and South 24-Parganas were inundated under saline water, causing large damage to agriculture of the Sundarbans (WBAPCC, 2012). Climate change is causing a rise in the sea level. Kolkata being located just barely above the mean sea level is vulnerable. The city's major industries and logistical infrastructure are in danger of being severely disturbed or even flooded. Certain studies have reported that the average sea level rise in Diamond Harbour, near the city of Kolkata, stands at 5.74 mm per year as against 1.0-2.0 mm per year elsewhere. While the number of cyclones may not be significantly increasing, the intensity of cyclone will undoubtedly increase, with possible impact of storm surges becoming very high (Unnikrishnan, A.S,et al (2015). The polluted air is also affecting the health of the mangrove forests (the Sundarbans) as the soot blocks the pores of the leaves affecting growth. If the mangroves get affected the entire aquatic ecosystem gets affected in result. Some of the soot also gets deposited in the Bay of Bengal contributing to the increase in sea surface temperature. Black carbon also hastens the process of climate change as it leads to the melting of snow when it gets deposited on glaciers (Chatterjee, A,2016)

e) Agricultural Productivity: Looking at the climatic uncertainty, the vulnerability assessment of the local economy of West Bengal has primarily concentrated on three aspects –

agriculture production or Crop production, pisciculture and livestock. Though there is an inter-annual variability, the total precipitation across the state has a decreasing trend across all its agro-climatic zones, except for the hill region. Increasing variability of onset of monsoon and monsoon precipitation has become very erratic hence Aman seedbeds, summer vegetables, jute, betel vine, flowers, etc. were damaged and the entire farming community had to incur irreparable loss since few decades. In 2009-10, however, there was shortage of rainfall, and a drought like situation was created, again leading to reduction in productivity of most of the crops. The minimum temperatures are increasing leading to increase in winter temperatures that have begun to remain considerably above normal causing uncongenial situation for cultivation of most of the rabi crops. Increasingly the duration of high temperatures during summer is extending, and in spite of adequate rainfall, it is leading to reduced production of late-sown Boro paddy. Though the area under the crop was slightly more than the previous year, the yield was reduced by 14 %, resulting in 11.5 % reduction in production of Boro rice (WBAPCC, 2012). The productivity of potato in the entire Indo-Gangetic plain, of which West Bengal is a part, is likely to decrease by 2 to 19% and 9 to 55 % in the year 2020 and 2050, respectively since, the winters are already milder and further rise in winter temperatures would adversely affect the productivity (Singh,H.P.,2011).

Global warming will have a dramatic impact on already weakened soils. This trend will, in turn, worsen desertification and increase the prevalence of poverty, forced migration and vulnerability to conflicts in affected areas. Conversely, concerted efforts to combat desertification by reclaiming degraded land, combating soil loss and restoring vegetation can help curb greenhouse gas emissions, strengthen the resilience of affected countries and build their capacity to adapt to climate change (Palkhiwala,K.,2008).

e) Biodiversity: West Bengal is very rich in flora and fauna flanked by number of rivers, hills and the sea with abundant natural resources. Climate change affects biodiversity in many ways like changes in distribution and abundance, the timing of seasonal events and habitat use and, changes in the composition of plant and animal communities. Habitats and ecosystems are also likely to change character by, for example, showing altered water regimes, increased rates of decomposition in bogs and higher growth rates in forests (SCCI,2015) .These climatic disasters, therefore, make the livelihood of the people more susceptible, especially in India as they are already vulnerable to the conventional problems like poverty and food insecurity etc. It is argued that India is particularly vulnerable to predicted climate changes because of its high population density, low adaptive capacity, several unique and valuable ecosystems (coral reef, large deltaic region with rich biodiversity) and vast low-altitude agricultural activities (Roy, 2007). The Sundarbans (UNESCO world heritage site) contains 85 per cent of all mangrove habitats in India display high biodiversity as well as the occurrence of endangered and highly threatened 300 species of flora and about 425 species of wildlife, including the Gangetic Dolphin with only population of critically endangered Royal Bengal Tigers. (Mahadevia,2014). Biodiversity of any given area being a function of precipitation, temperature, soils, altitude etc. West Bengal particularly in Hill region of North Bengal is considered very rich in biodiversity where recorded forest is 11,879 sq.km i.e. 13.38% of geographical area of state, reserved forest is 7,054 sq.km. protected forest is 3,772 sq.km.,unclassed state forest is 1,053 sq.km., forest cover outside the recorded forest area is 15.52%, Vegetation cover is 27% which includes village, orchards/groves, tea gardens and horticulture plantations with rare animal like Elephant, Tiger, Leopard, Monkeys, Gaur, Wild Boar, Crocodile, Rhino, Snakes etc. are major concern in climate change aspect (Das,2013). Even with a conservative temperature increase of 1–2°C, most ecosystems and landscapes will be impacted through changes in species composition, productivity and biodiversity. Impacts to forest based villages of West Bengal which are naturally heavily dependent on forest resources will be immeasurable.

f) Human Systems: India's per capita demand is growing at a fast pace, 3.2 % per year (2000-2005).projects India's primary energy demand to more than double by 2030 in a reference scenario (i.e., no policies to slow demand); this projection is attributable largely to a projected annual growth rate for GDP of 6.3 %. India will become the world's third-largest carbon dioxide emitter by 2030, although per-capita emissions will still be comparatively low (Paris: International Energy Agency, 2007). The impacts of climate change are likely to be felt first and foremost in the agricultural sector and associated water availability, with many people affected by lower food productivity (e.g., hunger, malnutrition, and its consequences for education and productive economic life). (The NIC Report, 2009).

Climate change impacts on health include an expected increase in communicable diseases, such as malaria. Malaria is projected to move to higher latitudes and altitudes in India (Ulisses, C. et al ,2007*).* The changing climate is affecting the basic requirements for maintaining health clean air and water, sufficient food and adequate shelter. Many of the major killers are highly climate sensitive as regards temperature and rainfall, including cholera and the diarrhea diseases, as well as diseases including malaria, dengue and other infections carried by vectors. Over the last three years 2008-2010, the incidence rate and the mortality rate of these diseases are found to be more or less constant. Among the different districts the annual incidence rate of Acute Diarrhoea in Dakshin Dinajpur, Cooch Behar and Malda is found around 50/lakh population with an indication of constant persistent of the disease in this region (WBAPCC, 2012).

Some suggestive remedial measures

v **Application of GIS in climate study**

GIS creates a new framework for studying global climate change by allowing users to inventory and display large, complex spatial data sets. They can also analyze the potential interplay between various factors, getting us closer to a true understanding of how our dynamic climate may change in the coming decades and centuries (Matt Artz,2008),.

Two general types of data are useful in studying climate change: observations of past climatic parameter and future predict patterns and trends of this climatic parameter that could impact our long-term fate. Proper application and in-depth examining and cross-referencing past and future climate data under Geographical Information System environments preparing some models like Community Climate System Model (CCSM), Carbon Nation model can help identify ultimate changes of climate scenario of West Bengal. The result of all this collection and research is vast stores of data describing conditions at particular locations on this state.

v **Adaptation to climate change**

ü Sea level rise at Sundarban region could displace a large number of climatic migrated population along the coastal zone which needs proper plan for rehabilitation and remedial dealings;

ü There is a need to develop of strong database of climatic factors affecting climatic parameters and also understanding their interplay with long term weather changes.

ü Hazards and disaster in the form of landslides, air pollution, drought, cyclone, flood management needs to be improved including more cyclone shelters, flood shelters, embankments, artificial water recharge structures etc. and terrain based alternative measures.

ü Huge afforestation through social forestry, protection and conservation of existing mangrove plantation at Sundarbans area aiming to develop dense coastal greenbelt

ü Raising of community based mass awareness against Climate Change and strengthen institutional capacity to adapt extreme events and policy formulation and its effective implementation.

ü Continuous monitoring and application of Early Warning System (EWS) at the city / town or coastal area target beneficiary level as well as village or ponchayat level. Usually the information and warning comes through radio, miking by Ponchayat, newspaper and television and website.

v **Implementation of Sustainable development concept**

The implementation of concept of sustainable development which leads human beings to new resource consumption strategies which are:

ü Preservation and Conservation or reduction of excessive resource utilization,

ü Application of resource based technology for recycling and reuse of environmental materials and

ü Maximum use of renewable resources like solar energy rather than non-renewable resources such as oil and coal.

Acknowledgements

Authors sincerely acknowledge the kind assistance, rendered in the form of data,aps, and all kinds of secondary information by the officials and personnel of the team of West Bengal State Action Plan on Climate Change ,Indian Meteorological Department, Indian Meteorological Deptt., GoI,National Remote Sensing Centre (NRSC), Dept. of Space, GoI, Deptt. of Science & Technology, GoWB, Forest Deptt., GoWB, Biodiversity Board, GoWB, Irrigation & Waterways Deptt., GoWB, Public Health Engineering Deptt., GoWB, Sunderban Biosphere Reserve Wing of Forest Deptt., GoWB, West Bengal Pollution Control Board, Dept of Geography, Visva-Bharati.

Reference

ADB Technical Assistance Consultant's Report (2012),*Nepal: Strengthening Capacity for Managing Climate Change and the Environment,* Ministry of Environment, Science and Technology,Government of Nepal

Attri, S.D and Tyagi Ajit (2010), *Climate profile of India*, India Meteorological Department, Ministry of Earth Sciences, New Delhi.

Banerjee, S et al.(2015), Indian Journal of Hill Farming, Vol. 28(2),81-84

Chatterjee, A.(2016),*Pollution in northern India affecting West Bengal*, http://economictimes.indiatimes.com/articleshow/51206883.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Climate change and desertification, WMO Bulletin (2016).

Das,Kalyan (2013),*Man –Elephant Conflicts in North Bengal Draft Report*. Wildlife (Headquarters) West Bengal

Dhar, Sujana et al.,(2009),International Journal of Civil and Environmental Engineering,1:3.

Frea, S. (2014), *The human impact of climate change in India*. Oxfan India Centre For Legislative Research and Advocacy

Indian Network for Climate Change Assessment Report (INCCA),(2010), Govt. of India.

IPCC,(2007(1)), *The Physical Science Basis*. Working Group I Fourth Assessment Report.

www.upi.com/Science_News/2012/03/06/Researchers-Climate-change-will-stress-water-supplies/UPI-73681331067383

Intergovernmental Panel on Climate Change Report, (2007), Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the ,Cambridge University Press 2007.

India's First National Communication to the Framework Convention on Climate Change (UNFCCC, 2004) http://unfccc.int/resource/docs/natc/indnc1.pdf.

International Energy Agency, World Energy Outlook 2007: China and India Insights (Paris: International Energy Agency 2007).

Kunhikrishnan, E.(2014),*Impact of Human Activities on Weather and Climate* , National Children's Science Congress Activity Guidebook.

Landsea, 2007, http://www.aoml.noaa.gov/hrd/tcfaq

Mahadevia, K.et al(2014),*Climate Change–Impact on The Sundarbans: A Case Study*, International Scientific Journal Environmental Science http://environment.scientific-journal.com

Makky, M (2013), *Potential Risks of Climate Change on Thermal Power Plants*, https://www.researchgate.net/publication/236174007_Potential_Risks_of_Climate_Change_on_Thermal_Power_Plants.

Matt Artz,(2008),GIS Best Practices, GIS fro climate change, ESRI.

Mc Leod, E., Salm, RV. (2006). *Managing mangroves for resilience to climate change*, IUCN Resilience Science Group Working Paper Series – No 2. Page 50.

National Disaster Risk Reduction Portal,(2011).

Narain (2009),*West Bengal choking on air pollution*, http://www.business-standard.com/article/economy-policy/west-bengal-choking-on-air-pollution-109030300083_1.html

National Intelligence Council (NIC) Report (2009), *India: The Impact of Climate Change to 2030* Joint Global Change Research Institute and Battelle Memorial Institute, Pacific Northwest Division

Palkhiwala,K.(2008), World Day to Combat Desertification, West Bengal

Ranuzzi, A. and Richa Srivastava (2012*), Impact of Climate Change on Agriculture and Food Security*, ICRIER Policy Series,No-16.

Roy, J (2007), *Climate Change in the South Asian Context with a Special Focus on India: A Review.* AEI Newsletter, 3 .

Statistics related to Climate Change in India (SCCI,2015), Ministry of Statistics and ProgrammeImplementation,Central Statistics Office, New Delhi

Singh, H.P. (2011), http://www.niam.res.in/pdfs/DDG_Hort_lecture.pdf

State Forest Report West Bengal (2007), Government of West Bengal, Government of India.

Stanly, Johny (2012), *Climate Change and Economy: In search of fine balance*, http://zeenews.india.com/EarthDay/story.aspx?aid=617794.

Samim, S. K. (2011),International Journal of Artificial Intelligence and Computational Research, 3(1),27-32

The National Intelligence Council Commissioned Research Report (2009), *India: The Impact of Climate Change to 2030*, Joint Global Change Research Institute and Battelle Memorial Institute, Pacific Northwest Division

Unnikrishnan, A.S,et al (2015),Current Science, VOL. 108 (5)

Ulisses, C. et al (2007*), Human health," in Climate Change 2007: Impacts, Adaptation and Vulnerability,* Fourth Assessment Report of the IPCC, Cambridge University Press.

West Bengal Pollution Control Board Report (2009),*Water Resources and its Quality in West Bengal*, Status of Environment Report.

West Bengal State Action Plan on Climate Change (WBAPCC, 2012) Report. Government of West Bengal, Government of India.

Geomorphosites and Geotourism : A Case Study of the Mawsmai Limestone Caves, Meghalaya, India.

Sucheta Mukherjee, Gopinath Patra, Somit Mandal and V.C. Jha

Introduction:

Geomorphosites have always been held in wonder and awe by human kind and are referred to as " geomorphosites are those landforms that in time have acquired, a certain value , naming here scientific,cultural,aesthetic,ecological&economic.This features must be a landform which we can attribute a certain value & must be a geomorphological resource which can be used by the society (Panizza, 2001).

Normally any geomorphosite is regarded due to its uniqueness from its immediate landform which surrounds it and is always a result of natural processes over a long period of time . Some are located upon difficult and inaccessible terrain, some are accessible for a certain season while some require adequate safety measures to be viewed.Nonetheless, they are readily appreciated by mankind for ecological,aesthetic values andrelevance,social or economic benefits or cultural reasons.

The word geomorphosite is basically composed of two words "geomorpho" from geomorphology and "site" meaning a particular location.It can be assumed thus that unique geomorphological features at a particular location which later is interpreted by man upon ecological, aesthetic ,social and economic lines for his benefit.

Geotourism is recently gaining popularity as it includes tour of those areas which showcase the physical uniqueness of certain terrain .For example the Mawsmai caves in Meghalaya,India are actually underground cave carved out by action of rainwater through a limestone terrain.

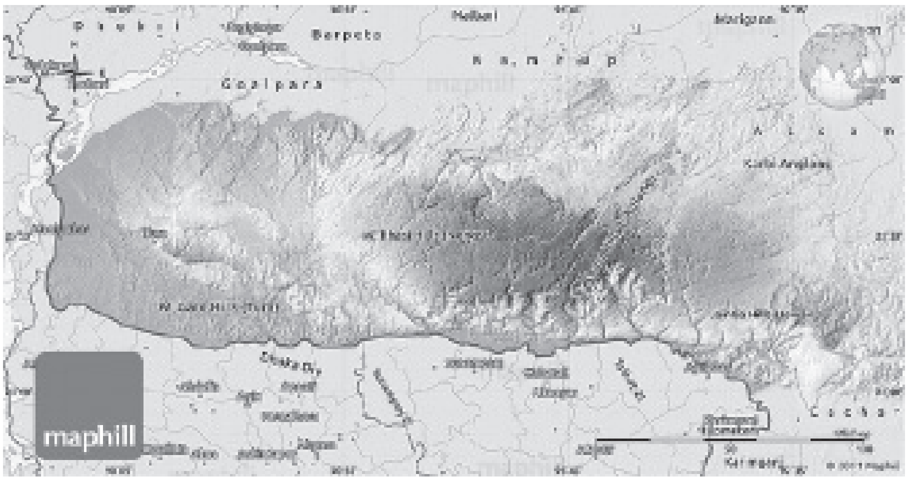
Tourists chiefly visit the place and take a tour through the caves to witness the landform features created as a result of rainwater action on calcium carbonate terrain.The caves are by themselves unique and exhibhit a distinct character in limestone landforms which is not the same as that of the overall geomorphology of the surrounding region so far known to man.

Location of the study area:

The Mawsmai caves ,in Meghalaya is situated in the East Khasi hill district at a distance of 6 km. from Sohra (Cherrapunjee) and about 62 km. away from Shillong,the capital of Meghalaya.It is situated at 25° 18' and 00" N latitude and 91°42'00"E longitude.

Situated in the tropical latitudinal zone it receives ample rainfall during the rainy season and ample sunlight . This has supported lush foliage and as a result secretion of humic acid from decaying of foliage as well as carbonic acid which together play a significant role in decomposition of rock masses.

Situated in the south eastern part of Meghalaya, the length of the Mawsmai caves is approximately 250 metres.It is segregated into two parts i) the old part which is spacious and contains large chambers about 25 metres wide,25metres high and 75 metres in length and has visibility during daytime.ii) new part has a large swallow hole which allows sunlight through the foliage above of the forest .This part is narrow and one has to almost bend down to pass through.The caves are closed during the monsoons.



Source: Maphill

Geological background of the study area:

The Mawsmai caves are situated in the south eastern part of Meghalaya Plateau. Geologically the Meghalaya Plateau was formed in the Archeanperiod.The rocks of Archean and Dharwars are found here.These rock formations contain valuable deposits of coal,limestone ,uranium.

Meghalaya situated south of Assam is characterised by the Paleocene and Eocene formations which together constitute the Jaintia series made up mainly of sandstones,limestonesandshales and exhibhit a thickness of over 4,000 feet.The bottom most beds of the Jaintia series composed of limestone and sandstones is known as the Therria stage is over 300 feet in thickness. Although this stage does not contain any characteristic fossil, the presence of typical foraminifers of Ranikotage,in the overlying limestone beds, is suggestive of its Paleoceneage.TheTherria stage is followed upwards by limestone beds with intervening horizons made up of sandstones and these together constitute the Sylhetstage.There are ,in all,three important limestone horizons in the Sylhetstage,which range in thickness from 200 feet to 900 feet and the two intercalcated sandstone horizons are rather thin(60 to 80 feetin thickness).The lower sandstone horizon contains seams of coal,which are workable in some parts of the ShillongPlateau.The three limestone remains contain characteristic remains of foraminifera (Nummulitesthalicus, Miscellaneamiscella,Discocy clinaranikotensis, Alveolina, Nummulite beaumonti, Assilinapappillata, Orbitolites complanatus,etc.)and are considered equivalent to the Ranikot,Laki and Kirthar series of Sind Baluchistan.The Sylhetstage, thus ranges in age from Lower to Middle – Eocene and is overlain by the Kopili stage, which is composed mainly of alternating horizons of shales and sandstones. The Kopili stage contains remains of foraminifera (Nummulites, Discocyclina, etc.) of Upper – Eocene age.(.Mukherjee,P.K.,1986 pg 376)

Morphogenesis

The development of the landforms of the study area has been analysed with the help of geology,climate and the geomorphic processes. The entire study area is composed of chiefly limestone and gypsum .The impact of climate is also very significant in the morphological development and origin of major and micro landforms in this region . An attempt has been made to trace out the plausible stages in the genesis of the major and micro limestone features.

1. Pleistocene period limestone deposition completed.
2. The impact of underground water action was also evident in the chemical processes of major landforms.
3. In due course of time the chemical effectively changed the morphology of the area resulting in limestone features.
4. The process of development of micro features are still active in the area where both the erosional and edepositional mechanisms are operating and resulting in development of microfeatures and modification of major landforms. Infact morphoclomatic mechanisms are very active in recent times.
5. Due to change in spatial pattern of rainfall and temperature the genesis is also affected.It may be called as imp act of climate change in the limestone topography in particular and the landscape of the entire area in general.

The climatic & geomorphic process which has influenced the landforms of the study area:

"Tropical monsoon climate is found over those regions where there is a complete reversal of winds. On shore summer winds blowing from over tropical oceans are generators of abundant precipitation,while the off shore winds from over land make the weather dry during winter.The most clearly defined monsoon climates are located in the coastal areas of the eastern and southern Asia. The following Asian countries have monsoon type of climate :India,Burma,Bangladesh,Indo-China, Southern China and the Phillipines. Besides,the monsoon circulation also affects Taiwan,Japan and Korea where ,because of their middle latitude location between the continent and the ocean,seasonal contrast of temperatures results in seasonal reversal of winds.It may be noted that surface relief,direction of coastline and the extension of the monsoon into middle latitudes cause a number of subtypes of the monsoon climate found over this most extensive continent." (Lal,D.S.Climatology,pg.314pub.Chaitanya Publishing House 2002,Allahabad)

The geomorphic processes operating over any region are always a product of climatic influence upon that particular region. The Eastern part of India is characterised by a wet tropical monsoon climate and receives rainfall from the approaching monsoons as well as the retreating monsoons due to its unique physical alignment of the Himalayas in the North and the Garo, Khasi and Jaintia Hills in the Meghalaya Plateau.The presence of the ArrakanYoma and PeguYoma ranges to the east of the Meghalaya Plateau are a major deciding factor in the deflection of monsoon winds back into the subcontinent. This ensures rainfall with the retreating monsoons as well. There is a major onslaught of rainwater upon the landforms in this region.As a result chemical weathering is dominant.

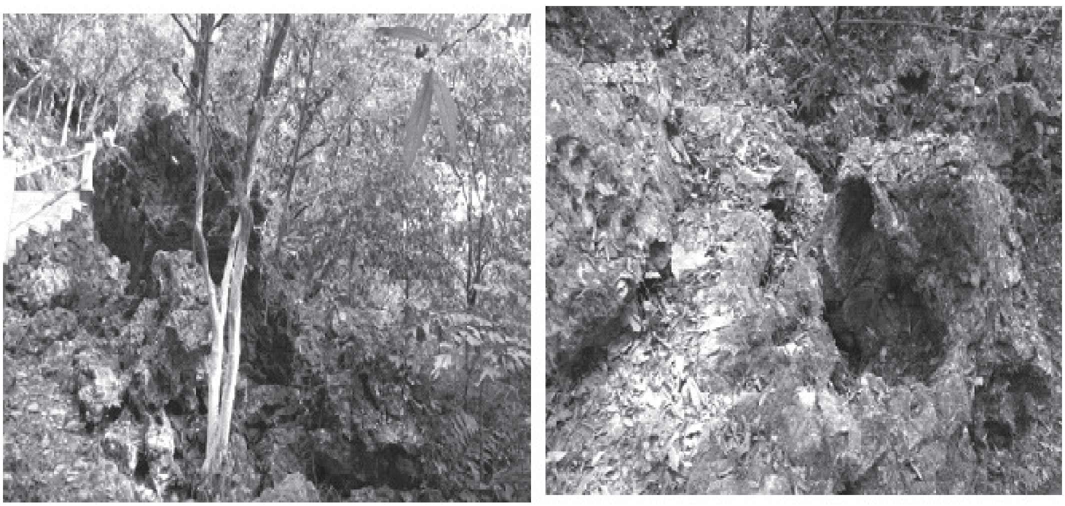
Plate 1:
Decay of rock mass due to rain action. Near Mawsmai Limestone caves, Meghalaya.

Source: Authors

"Temperature,precipitation, biologicativity,and amount and seasonality of runoff are all climatic factors that affect the intensity of karst processes" (Bloom, 2003) and also limestone regions it can be understood.

Infiltration of rainwater through limestone surface is easy where layers have been exposed due to denudation. This has aided the percolation of rainwater and forming swallow holes as in typical karst topography.These caves have their origin in solution cavities which gradualy enlarge enough for people to enter.Rainwater slowly flows down in the form of drips, clinging as droplets to the sides of such solution holes and carve out expansive limestone caves as in the case of the Mawsmai Caves ,Meghalaya while at the same time carving out its own underground path.This type of underground regional drainage is referred to as ***holokarst*** in karst topography.Here it maybe referred to as underground limestone caves.The process of forming limestone caves involves the hydrolysis of CaCO"(Calcium carbonate) by downward slow flow of water over such terrain.The solubility is controlled partially by addition or loss of carbon di oxide(CO,) gas and excess of water. Changes in temperature,mixing of different chemically induced water and biologic processes together promote solution or deposition(Bloom,Arthur,L.2003).The tropical regions are usually regions where intensive ***biochemical weathering***take place due to the presence of lush foliage.Their decay result in release of humic acid from the decomposing masses and together with the presence of carbon di oxide as released by the foliage when sunlight is absent,dissolution of limestone surface is easy and quick. This results in an intense pitted surface and micro organisms habituating these miniscule cavities.They create a biochemical environment that may promote solution and gradually these cavities are further enlarged ,finally leading to breakdown of the rock mass as the pits get interlinked and collapse.Some of these micro organisms inhabit the (epithilic) upper layer or the surface and penetrate to about 1mm.Those that colonize in the cavities (chasmolithic) and within the outer layer to about a millimetre (endolithic) of limestone in tropical regions.(Viles,1987. Bloom,2003)

Plate 2:
An intense pitted surface with cavities and inhabited by algal cover.Due to biochemical influence these cavities are further enlarged ,finally leading to breakdown of the rock mass as the pits get interlinked and they collapse. MawsmaiCaves,Meghalaya



Source : Authors

Water dissolves about twice as much atmospheric CO_2 at 10°C than water at 30°C and much more at 0°C .Thus in this region the tropical climate due to its latitude makes water more readily active in dissolving soluble elements from rock surfaces.The presence of lush foliage and occurrence of heavy rains in the region hence aids the dissolution of CO_2 with rainwater.Though CO_2 is less soluble in warmer water yet its greater presence may encourage dissolution.***Temperature*** plays a significant role in shaping landforms.

The effect of ***pressure*** due to CO_2 is yet another factor as it presses down in cavities and air filled cells of the rocks.The cavities filled with percolating rainwater release pressure on the cavity walls .The percolating rainwater when they enter larger cavities release this pressure and this leads to dripping effect leading to formation of stalactites or dripstones and correspondingly stalagmites and other minor features within caves .

Another factor which can be considered is the ***rate of flow*** rainwater and its mixing with $CaCO_3$ water already present in the caves cavities.The rainwater due to its rapid downpour does not stay upon surface for long and is not saturated with mineral salts and CO_2 of the surficial soil. "If such undersaturatedwater,normally with low dissolved CO_2 partial pressure, enters a karst terrane and mixes with saturated groundwater,the extreme difference in their composition greatly enhances the mixing effect.This process may especially be important in enlarging caves beneath plateaus that normally drain outward to a surface river but become back flooded when the river is in flood".***(Bloom,2003,pg.151)***The Mawsmai Caves are closed during the rainy seasons from July to October.

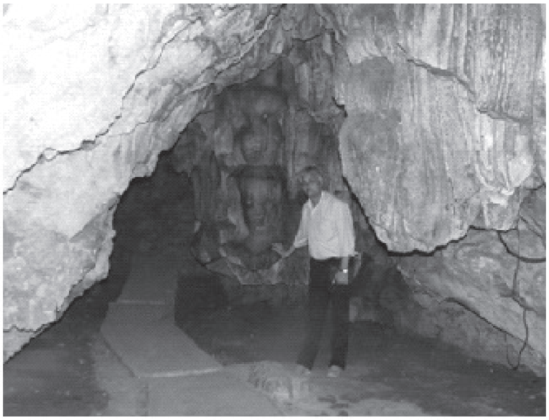


Plate : 3The formation of a calcite pillar an the eroding away of softer limestone to create passage way about 160 meters high. The caves date back to Eocene period.Source : authors

Plate 4: The Mawsmai caves in Meghalaya exhibhit many minor limestone features like clefts and pinnacles ,globulites ,corniches as seen here. Source : authors

The formation of the Mawsmai Caves can thus be attributed to not only surface related process but the active percolation of rainwater through a limestone mass .Beginning with solution,enlargementalong bedding planes and joints,open conduits developed (Bloom,2003.pg.163)and facilitated the flow of water .

Methodology: Field based for identification of landforms, laboratory based for chemical analysis of collected rock samples from site.The area was identified on SOI toposheetsnumbers and the caves identified and delineated for study and investigations.

Results and Discussions: Limestone mining for the cement industry is a major threat to the Caves of Meghalaya,causing a major collapse of the KremMawmluh cave, the seventh longest cave in the state of Cherrapunjee. The caves are of considerable ecological importanceand home to rare species of bats.The caves are closed during the monsoons as they are flooded and open for tourists after water recedes in the winter months and summer. The process of solutional disintegration is rapid during the monsoons and with rain water flowing in underground streams are recharged.The limestone caves here exhibit many major and minor features which are all carved by the process of running water and the seepage of threads of water through micro cavities initiate the process of solutionalerosion.The percolation of water this way further accentuates the formation of limestone features like minor stalactites,small indentations and involutions, slow mass movement ,piping or tunnelling caused by the percolating waters and transportation of eroded materials.Collapse of overhead masses of limestone rocks which have gradually weakened their adhesive capacity due to disintegration of individual grains of the main rock mass also takes place due to gradual eroding away by percolating water. Here gypsum being also chiefly present it should be kept in mind that- “Gypsum becomes increasingly soluble upto 37°C .It is deposited as warm water cools sufficiently and when evaporation leads to supersaturation “(Huggett 2007,p.189).Dolomite also behaves similar to limestone yet does not dissolve so readily as limestone and in places where there are dolomite the rate of solution is slower than those areas characterised by purely limestone as limestone readily succumbs to carbonation.The concept of ‘normal cycle of erosion’ advocate by Davis was applied in the karst areas by J.W. Beede (1911) and J.Cvijic (1918). According to them, the evolution of landscape in the limestone regions is a special and transitory phase marking the mature stage of the normal cycle in regions where the structure was especially favorable to solution. The basis of such a view arises from the fact that even in limestone regions the cycle starts with surface drainage which also ends with surface drainage. In other words, the karst cycle of erosion may be said to begin with the transfer of surface drainage to underground routes and end with its reappearance on the surface.

The requirements for development of limestone topography can be ennumerated as :

1.Presence of water should be adequate in the form of rainfall.

2.Limestone rocks should contain about 75% calcium carbonate (CaCo3)

3. The limestone pavement should be thick ,hard and tenacious and have a network of joints or surface drainage lines along which water will flow

4.There should be a zone of aeration and entrenched valleys above facilitate downward percolation of rainwater.

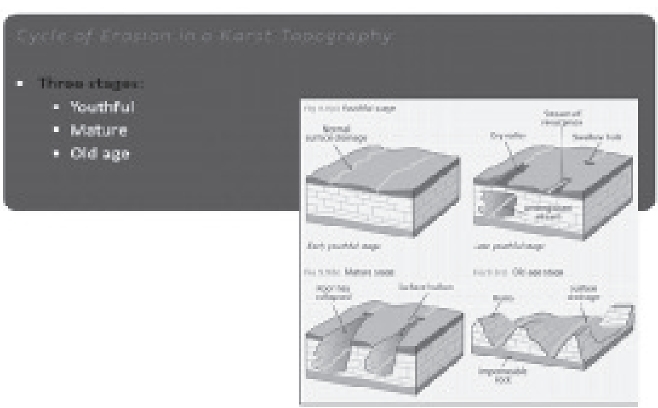
5.Adequate vegetation cover which upon decay will provide sufficient humic acid

There are two ways in which a karst cycle may commence:

(i) through uplift above vase level of a limestone terrain on which fluvial erosion had been in progress, and

(ii) through uplift of an area of clastic rocks beneath which are limestone above the new base level.In either event, the cycle begins with surface drainage lines but the transformation to underground drainage proceeds by percolation and enlargement of swallow holes.

There are normally three stages in the cycle of erosion within a limestone topography,Youthful,mature and old stage .



“The shape of underground caves is directed by lithology,by pattern of joints ,fractures ,and faults ,and by cave breakdown and evaporite weathering”. (Huggett,2007 p. 211)The formation of underground caves not only takes place due to solution but also because of opening of cave conduits which are gradually enlarged with the solutional nature of the lithology.Gradually the primary cave conduit gathers water through seepage ,percolation or flow through capillaries and the secondary conduits give rise to a maze of channels which coalesce to the primary channel.Caves normally have a channel of flowing water passing through them and sometimes a pool is found in the shallowest part of the cave floor inside .

Below is a list of twentylimestone caves in Meghalaya,India and based on field data besides the Mawsmai Caves, by the authors.Most of them are **vadose caves**i.e.they lie above the water table in the unsaturated vadose zone with an exception of KremKotSati where one has to swim to enter.

1. **KremLiatPrah is** 30,957 m (101,600 ft)long situated in theJaintia Hillsin the Shnongrim Ridge.. Composed of Limestonechiefly.It is a huge trunk passage called the Aircraft Hangar. It is the longest cave in the Indian Subcontinent.
2. **Krem KotSati** is also called theUmlawan Cave Systemmeasuring about21,530 m (70,640 ft) situated near Lumshnong village, in the JaintiaHills.It is comprised of chiefly limestone and has 24 entrances, both horizontal and vertical. One needs to swim to enter the caves.This is an example of “phreatic cave which lies below the water table where the cavities and the caverns are permanently filled with water”.(Huggett,2007 p. 211)
3. **KremTynghengDiengjem**is 21,250 m (69,720 ft)in length and situated near Sammasi village in the JaintiaHills.Made up of limestone it has many side passages which are narrow.
4. **Krem Umthloo-SynrangLabbitSynrang-Pamiang**is 18,181 m (59,650 ft) long and situated near Chiehruphi village, on NH 44, in the JaintiaHills.Made up of limestone the dendritic pattern of stream cave passage speaks about the nature of water percolation. There are many entrances the most notable being the”Titanic Hall” chamber with coloured formations in orange, red, black, grey, blue, green and white.
5. **KremChympePielKhlieng Poukis** 12,434 m (40,790 ft) in lengthand extends from village Khaddum to Sielkan, in the JaintiaHills.Composed chiefly of limestone it also has an underground active river and is also called a river cave. There are 50 natural mini dam like structures which enclose water and gours, about 6–8 metres (20–26 ft) high. A large colony of bats inhabit the cave and hence is ecologically sensitive.
6. **Krem ShriehTangnub**is 8,862 m (29,070 ft) long and situated in the Tangnub village, in the JaintiaHills.Composed of limestone has a very large vertical entrance shaft of 97 metres (318 ft) .Its depth leads to formation many stream passage and many passages which have fossil remains of flora.
7. **Krem Tyngheng** is 8,671 m (28,450 ft) long and situated in the Jaintia Hills made up of limestone.It is a small cave and one has to lie down to enter.
8. **KremMawkhyrdop**also called KremMawmluhis 7,194 m (23,600 ft) long and situated in the JaintiaHills.Composed of limestone it is filled with water almost like a cenote and one has to wade in.Theceiling is 2.5 feet (0.76 m) high, and there are formations of stalactite, stalagmite, and rock fossils. Also large number of bats inhabit the cave.
9. **KremLymput**near Nongjri6,641 m (21,790 ft) is long and situated in the Nongjri village, of the KhasiHills.Composed of chiefly limestone with traces of dolomite and gypsum its chief attraction is from a small entrance that leads to 1 kilometre (0.62 mile) passage called ‘Way

to Heaven," and further to a large cavity called the Mughal Room which are more than 25 metres (82 ft) wide, 25 metres (82 ft) high, and 75 metres (246 ft) long).

10. **Krem Rongdangngai**situated near MondilKol in the Jaintia Hills are about 5,831 m (19,130 ft) in length and composed of dolomite and limestone.This is a realatively new cave and in primary stages of formation.
11. **KremShyrongLabbitfound near** ShyiengKhliehvillage with a length of 5,715 m (18,750 ft) in the Jaintia Hills is composed of limestone.
12. **TetengkilBalwakol is about** 5,681 m (18,640 ft)in length found nearNengkhong village in the GaroHills.Composed of gypsum ,dolomite and chiefly limestone there are two doline like features which act as circular entrances of 1 metre (3 ft 3 in) diameter expanding to walking height passages with dendritic river flow.
13. **KremUmsynrang is** 5,612 m (18,410 ft)in length found in the Jaintia Hills and composed of limestone .
14. **Siju Cavenear**Siju–DobhakholSiju village, is about 4,772 m (15,660 ft)long in the Garo Hills and made up of limestone. It is in found along the steep ,vertical side of the Simsang River.Also known as "bat cave". It has a large number of stalagmites and stalactites. The cave has been extensively researched and is well known.
15. **KremRisangis about** 4,565 m (14,980 ft) long and found in the Jaintia Hills made up of limestone.
16. **KremSynrangNgap is approximately** 4,172 m (13,690 ft) long situated in the JaintiaHills.Composed of chiefly limestone. The interior is made up of calcite tunnels to reach a major junction which lead to an inlet tunnel converging to a smaller section of passages beyond which are potholed galleries within thecavern.The floor is embedded with pearl-like sandstone pebbles .
17. **KremSynrangLabbitis** 3,933 m (12,900 ft) in length in the Jaintia Hills composed chiefly of limestone .
18. **KremWahRyngo** situated near Khongrang village is 3,416 m (11,210 ft) in length situated in the Jaintia Hills and composed of limestone.
19. **Kremlawe is** 3,398 m (11,150 ft) in length situated in the Shnongrim-Tangnub Ridge, in JaintiaHills.It is composed of limestone and is filled with daylight. It has a very wide pothole entrance and a number of attractive fossil passages.
20. **KremMawshun** is 3,339 m (10,950 ft) in length situated near church Lelad, in the KhasiHills.It is composed of mainly limestone and has a dendritic master river cave. It has many passages situated at higher level than the cavern floor.

The following are the list of karst landforms, macro and minor features have identified in the study area on the basis of field work extensively :

Macro features: Cave forms which are created as a result of weathering, runningwater and wind are called speleogens which are found in abundance here like potholes, scallops, rockpendants, besides ceiling cavities,passages,conduits ,ponores,spongelike rock faces.oyster shell shaped hollows,stalactites,stalagmites ,calcite columns or pillars,drapery like stalactites where water flows down in thin sheets over the surface of rocks and the calcium carbonate gradually accumulates,cauliflower shaped moist form of calcite ,colloidal forms and globular forms.

Micro features :Gours like features,cave pearls or pisoliths on the floor where sandstone pebbles are embedded,runnels,flutes or lapies,karren,solutionpits,crystal linings found in cave pools,Rimstonepools,clints,grikes,solution pipes and solution notches,pinnacles and clefts,sheet runoffs which produce flat solution facets.

Conclusion: The region around the Mawsmai caves are not only ecologically fragile but also prone to rapid degradation due to nature of terrain.The interior of the cave is a delight for every tourist,geomorphologist,geologist or speleologists who shall witnessa myriad features all carved out by running water as a result of heavy rainfall in the region and with controlled tourism is a potential geo tourism as well as eco tourism site .

References :

1. Bharadwaj.,Dr.K(2009) .An Introduction to Physical Geography,Discovery Publishing House Pvt.Ltd.New Delhi, pp249 -252
2. Bloom, Arthur, L.(2003) Geomorphology: A systematic Analysis of Late Cenozoic Landforms Third Edition Copy right Pearson Education ,Inc.1998,U.S.A. Indian Reprint 2003 pp123 - 125
3. Daly 2013, pgs.71,40 & 123...
4. Dikshit,KamalRamprit,Dikshit , Jutta K.,2 North-East India: Land, People and Economy.Pub; Springer Science & Business Media. pp. 124–.ISBN 978-94-007-7055-3.013.
5. Huggett.,Richard John (2007), Fundamentals of Geomorphology ,Second Edition, Routledge Fundamentals of Physical Geography, 2007, pub:Routledge,Oxford.pp 189,211.
6. Kaur, Preetinder (9 April 2014). “Subject Matter: Speleology:Explorers' delight”. The Tribune India7.Lal,D.S. 2002 Climatology,pg.314 pub.Chaitanya Publishing House ,Allahabad
8 Mukherjee,P.K., A Textbook of Geology,1986 pub:World Press Private Limited,Calcuttapg 376.
9. Peake,Stephen and Smith, Joe(2003),Climate Change:From Science to Sustainability,The Oxford University Press.pp 37 – 68
10. Swinnerton,A.C.,1932,Origin of limestone caverns:Geological Society of America Bull.v.43,pp 663 -693

ANALYSIS OF RELIEF CHARACTERISTICS USING DIGITAL ELEVATION MODEL: A CASE STUDY OF DUMKA UPLAND, JHARKHAND, INDIA

Sayan Choudhary and V.C.Jha

ABSTRACT

Morphometric analysis based on geospatial technology has several advantages over manual methods based on topographical maps. It is fast and it has less scope for error. Secondly, it is much easier to acquire geospatial data than topographical maps. In some places of the world, topographical maps are often kept restricted. The scale and the standard of these maps also vary from one country to another. On the other hand, there are various authoritative sources that provide free geospatial data on global and regional scales. Hence, it is much easier to work on global and regional scales using geospatial data. The present paper demonstrates the analysis of relief characteristics using digital elevation model (DEM) in Dumka Upland. It is a part of the Chotanagpur Highland. It lies between latitude 23^0 59$^/$ N- 24^0 40$^/$ N and longitude 86^{0}55$^/$ E - 87^{0}45$^/$ E. Administratively, it belongs to the state of Jharkhand, India.

KEYWORDS: Relief analysis; DEM; Dumka; Jharkhand

INTRODUCTION

Relief is defined as the difference of elevation over a predetermined area. The term ‘relief’ can be used in relative as well as in absolute sense. In relative sense it refers to the difference of elevation between highest and lowest point in a given area, while in absolute sense it refers to the highest elevation with reference to sea level. Differences in relief are attributed to the interaction between rate of uplift and rate of erosion.

Smith (1935) in his paper ‘Relative Relief of Ohio’ distinguished between ‘local relief’ and ‘relative relief’. According to him, the difference in elevation between highest and lowest points within a limited area may be regarded as the absolute and local relief of that area. The term ‘relative relief’ is used to imply regional comparison. Therefore, in this approach relation between areas and delineation of regions with similar relief becomes important objectives (p. 273).

Nir (1957) in his classic paper on ‘The Ratio of Relative and Absolute Altitude of Mt. Carmel’, felt the inadequacy of commonly used methods of giving absolute heights, as they fail to give clear-cut morphological expression. One way to expressing relief morphology is the ‘relief energy’ cartogram in which the difference of altitude between highest and lowest points within an area is taken into consideration. However, critics of this method objected to lack of uniformity in the size of squares and scale of maps which were used to prepare these cartograms. Nir (1957) used squares of one kilometre to divide the area into equal grids and instead of giving the relative altitude within a grid he employed ratio of maximum relative altitude and maximum absolute altitude within it. He also employed correlation and regression methods to classify the area and compare with other areas statistically (p. 564).

STUDY AREA

Dumka Upland is a part of the Chotanagpur Highland. It lies between 23° 59′ N- 24° 40′ N and 86°55′ E - 87°45′ E. It belongs to the state of Jharkhand, India. Dumka Upland has been chosen for demonstration purpose because of its heterogeneous character of terrain consisting of hills, plains and valleys and to demonstrate the consistency of the results in different landscape settings.

MATERIALS & METHOD

In the present paper ASTER DEM has been used for relief analysis. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is a joint project between Ministry of Economy, Trade and Industry of Japan (METI) and National Aeronautics and Space Administration (NASA). It is an Erath observing sensor developed in Japan onboard the satellite 'Terra'. It is in operation for more than ten years since its launch in December 1999. DEM is generated from stereo pair of images acquired with nadir and backward angles over the same area. ASTER DEM is developed based on these data. Global Digital Elevation Model Version 2 (GDEM V2) has been released on October17, 2011.

Survey of India toposheets (1:50000 scale), District Resource Map of Dumka (1:250000 scale) published by Geological Survey of India, District Planning Map Series of Dumka (1:250000 scale) published by National Atlas and Thematic Mapping Organisation (NATMO) have been used as additional sources of information.

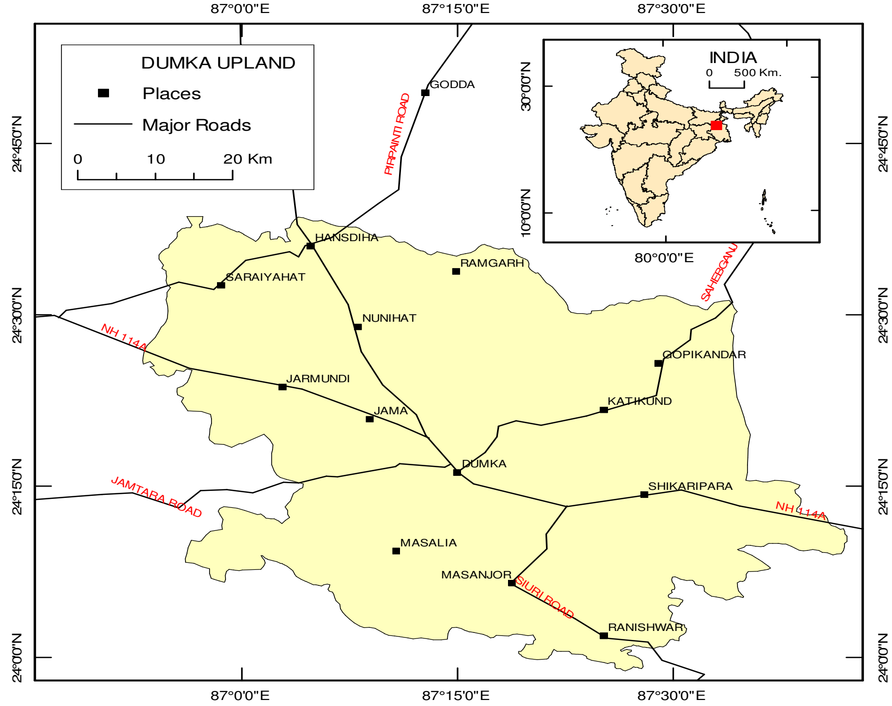


Figure 1 Location of the study area

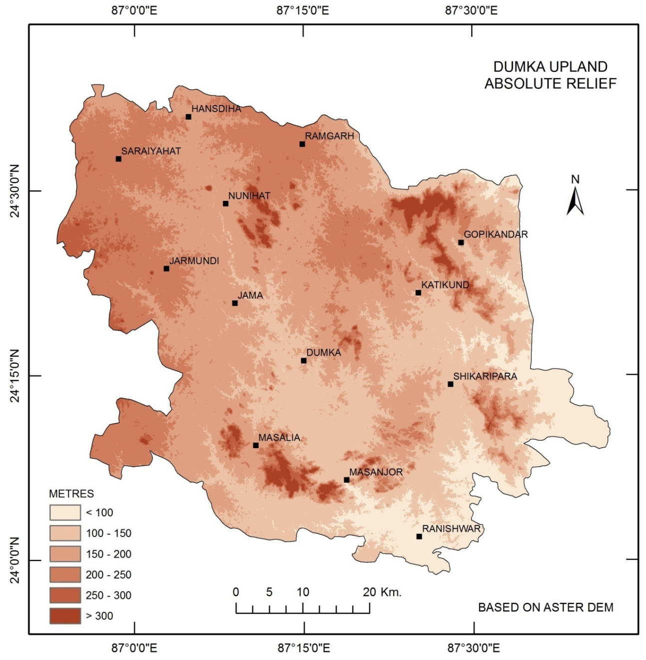


Figure 2 Absolute relief of Dumka Upland derived using 3/3 window

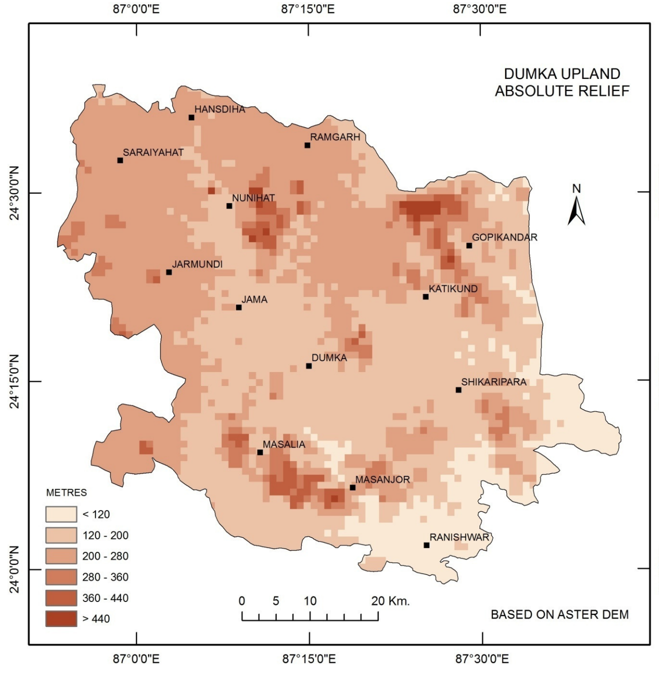


Figure 3 Absolute relief of Dumka Upland derived using 1 square km. window

ABSOLUTE RELIEF

In the present study ASTER DEM (30 m resolution) has been used for analysis of relief characteristics. A moving window of 3/3 pixel and another of one square kilometre has been prepared to scan the entire study area and to obtain highest elevation in each cell. Squares were classified according to the highest elevation obtained in them.

Terrain classified in this way greatly exaggerate altitude, as a cell containing a high altitude within a small area is classified as the same category as one in which the same altitude occupies a larger area. Bringing out of high points may 'help to indicate ancient erosion levels, since this cartogram largely eliminates dissection caused by stream beds, and it makes possible the construction of secondary classification of landscapes' (Nir, 1957, p. 565).

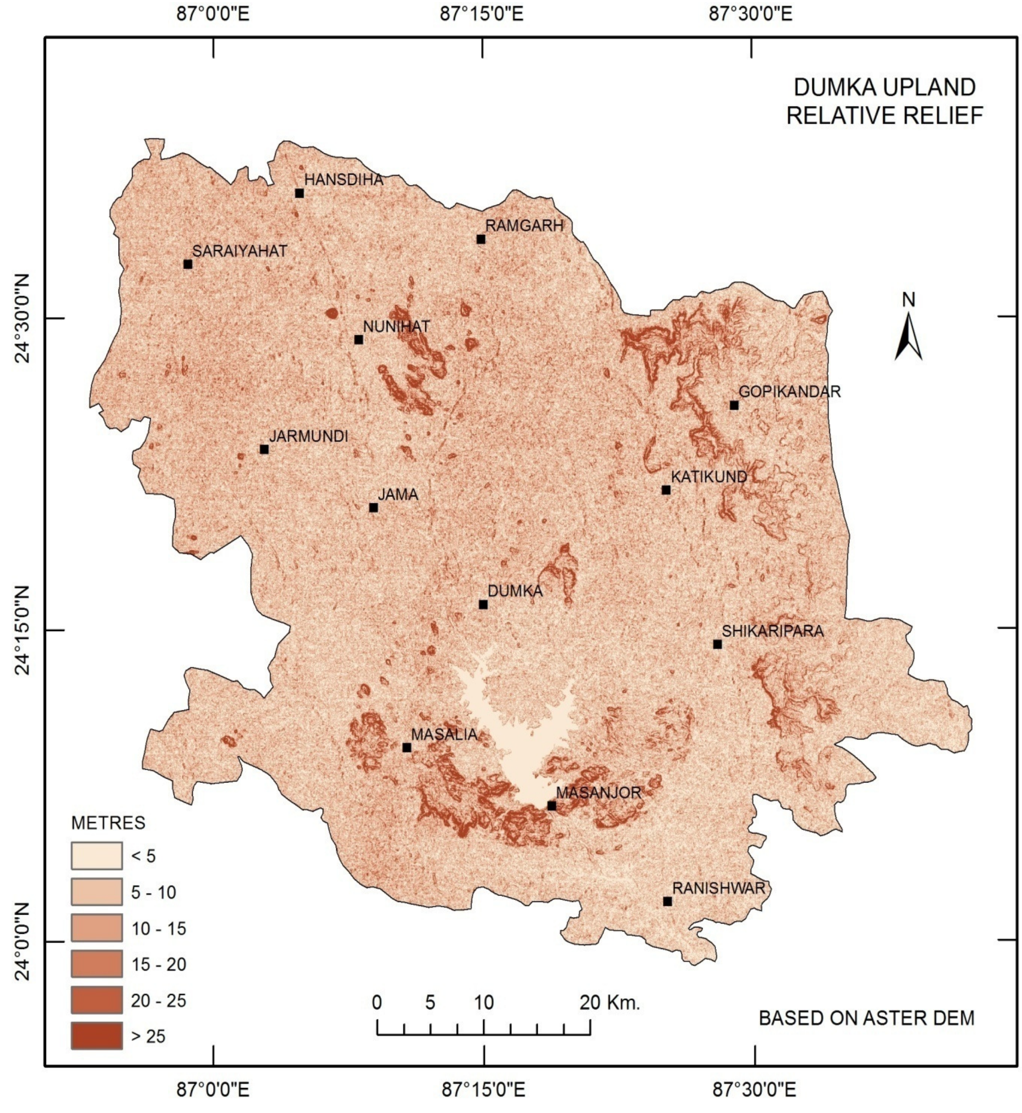


Figure 4 Relative relief of Dumka Upland derived using 3/3 window

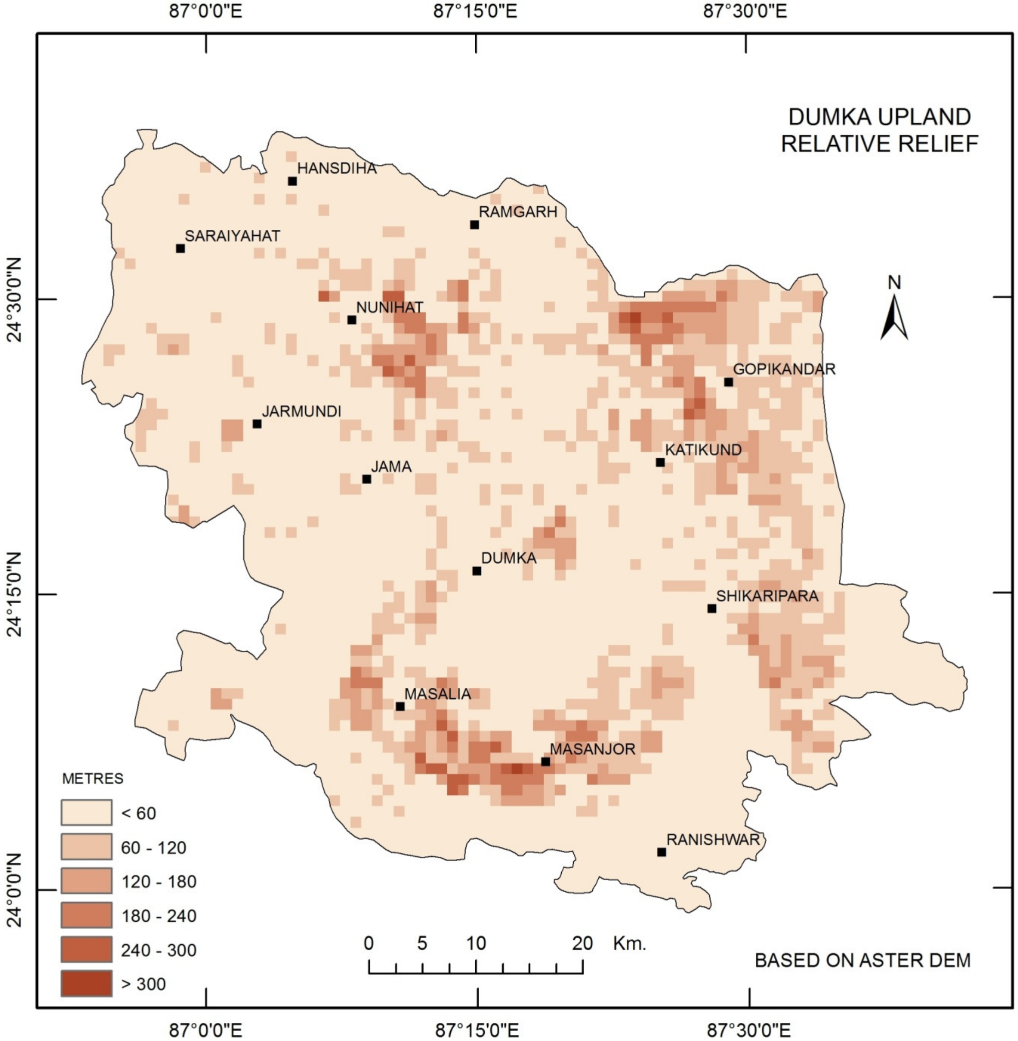


Figure 5 Relative relief of Dumka Upland derived using 1 square km. window

RELATIVE RELIEF

A moving window of 3/3 pixel and another of one square kilometre has been prepared to scan the entire study area and to obtain difference of elevation between highest and lowest value in each cell. Squares were classified according to the values of relative relief. The relative relief is calculated for the same squares as used for calculation of absolute relief.

The area containing highest absolute altitude may have only a medium relative altitude. This is typical of medium-high mountains in which summit are a region of low rounded hilltops. Whereas, relief may appear sharpest on the margin of the mountain, and wherever stream beds cut across. Hence, this cartogram is an improvement over absolute relief. Further, the correlation between relative and absolute altitude can be used as an expression of relief energy and has got potential for further research (Nir, 1957, pp. 565-568).

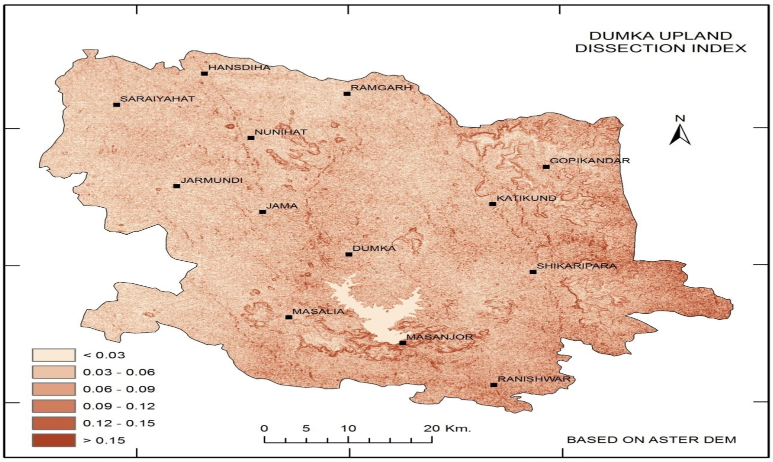


Figure 6 Dissection index of Dumka Upland derived using 3/3 window

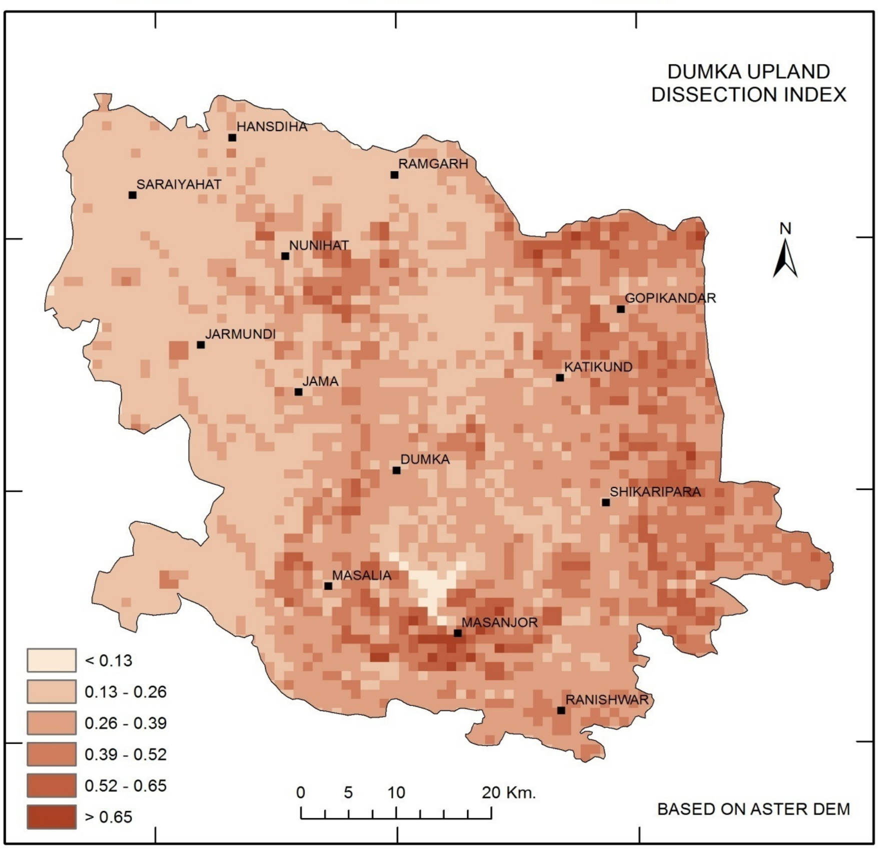


Figure 7 Dissection index of Dumka Upland derived using 1 square km. window

DISSECTION INDEX

A moving window of 3/3 pixel and another of one square kilometre has been prepared to scan the entire study area and to obtain absolute relief and relative relief for each cell. In order to obtain dissection index for each cell, relative relief has been divided with absolute relief. Squares were classified according to the values of dissection index. The dissection index is calculated for the same squares as used for calculation of absolute relief and relative relief.

Nir (1957, p. 568) felt the inadequacy of relative altitude as a criterion of relief energy. Equal relative altitude may not be of equal importance as the absolute altitude on the basis of which it has been calculated may differ. Therefore the inference drawn for this method is only partial as it fails to take into account the vertical distance from the erosion base or the dynamic potential of the area. In order to overcome this problem of relief expression, the writer suggested the use of ratio between maximum relative altitude and maximum absolute altitude. The ratio ranges from 1 to 0 both designates extreme cases. On one extreme is the vertical cliff at seashore and on the other there is complete absence of dissection. A general and objective index is obtained having universal application. The writer termed it 'dissection index'.

SLOPE

The slope tool calculates the maximum rate of change in value from that cell to its neighbours. The steepest downhill decent from the cell is determined by the maximum change in elevation over the distance between the cell and its neighbour cells.

Conceptually, the tool fits a plane to the Z-value of a 3/3 cell neighbourhood around the processing cell. The slope value of this cell is calculated using average maximum technique. If there is a cell in the neighbourhood with No Data z-value, the z-value of the central cell will be assigned to that cell. At the edge of the raster, at least three cells will contain No Data value. These cells will be assigned central cell's z-value. This results in flattening of the 3/3 plane fitted to this edge cells, which leads to a reduction in the slope. The output slope raster can be expressed in either degrees or percent (Burrough & Mc Donnel, 1998, p. 190).

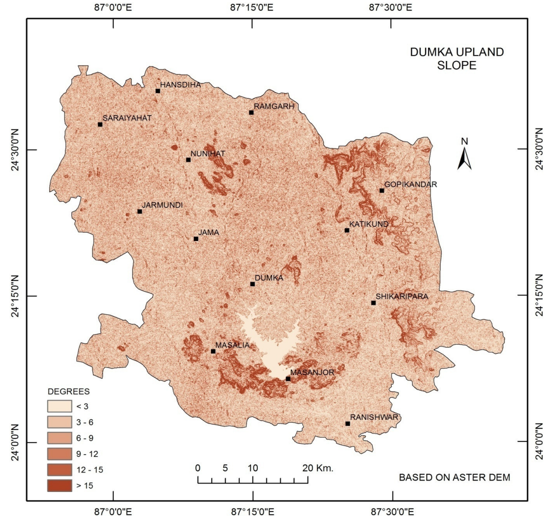


Figure 8 Slope map of Dumka Upland derived using 3/3 window

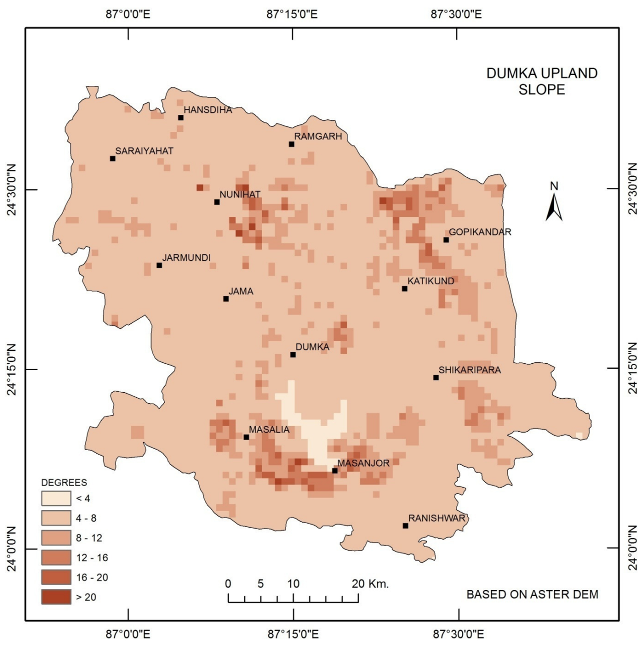


Figure 9 Slope map of Dumka Upland derived using 1 square km. window

RESULTS & DISCUSSION:

Table 4.1 Classification of Absolute Relief in Dumka Upland

Absolute relief(metres)	Area (Km^2)	Percentage area	Class
< 120	356.77	9.49	Very low
120-200	1538.60	40.92	Low
200-280	1580.71	42.04	Moderately low
280-360	180	4.79	Moderate
360-440	82.73	2.20	Moderately high
> 440	21.27	0.57	High

Table 4.2 Classification of Relative Relief in Dumka Upland

Relative relief(metres)	Area (Km^2)	Percentage area	Class
< 60	2757.07	73.32	Very low
60-120	680.35	18.09	Low
120-180	220.35	5.86	Moderately low
180-240	79.00	2.10	Moderate
240-300	21.27	0.57	Moderately high
> 300	2.03	0.05	High

Table 4.3 Classification of Dissection Index in Dumka Upland

Dissection Index	Area (Km^2)	Percentage area	Class
< 0.13	22.34	0.59	Very low
0.13 - 0.26	1495.65	39.78	Low
0.26 - 0.39	1404.82	37.36	Moderately low
0.39 - 0.52	625.80	16.64	Moderate
0.52 - 0.65	191.20	5.08	Moderately high
> 0.65	20.25	0.54	High

Table 4.4 Classification of Slope in Dumka Upland

Relative relief(metres)	Area (Km^2)	Percentage area	Class
< 4	52.97	1.41	Level
4 – 8	3093.71	82.28	Gentle
8 – 12	449.62	11.96	Moderate steep
12 – 16	123.24	3.28	Moderate steep
16 – 20	33.42	0.89	Moderate steep
> 20	7.09	0.19	Steep

Table 4.5 Correlation matrix of relief parameters

Variable	Absolute Relief	Relative Relief	Dissection Index	Slope
Absolute relief	1			
Relative relief	0.72	1		
Dissection index	0.11	0.74	1	
Slope	0.74	0.89	0.59	1

Local relief is scale dependent. The larger the grid over which it is measured, the greater the relief and vice versa. The choice of grid is dependent on the scale of enquiry and on the resolution of the DEM. For regional level enquiry, one square kilometre grid is the most preferred choice. In the present paper, ASTER DEM (30 m resolution) has been used for analysis of relief characteristics. A moving window of 3/3 pixel and another of one square kilometre has been prepared to scan the entire study area and obtain various relief parameters. The grids having higher absolute relief also have higher relative relief and steeper slopes. Grids having higher altitudes have greater potential for relief development. Higher altitudes also support steeper slopes. Hence, high correlation can be seen among absolute relief, relative relief and slope. However, relation between absolute relief and dissection index is very low. In Dumka, high absolute relief, high relative relief and steep slopes are found mainly over the summits of residual hills, which have survived dissection because of their structural resistance.

CONCLUSION

The method discussed in this paper shows that geospatial technology can be used for analysis of relief characteristics. Free geospatial data have great implications particularly in developing countries. Basic topographic data in many developing countries are often incomplete or restricted. Geospatial data that exist are often too expensive for individual researchers. Free geospatial data including ASTER DEM have great potential for morphometric analysis and the information derived from such analysis can be utilised for various applications.

REFERENCES

Burrough, P. A., & Mc Donnel, R. A. (1998). *Principles of Geographical Information Systems.* New York: Oxford University Press.

Montogomery, D. R. (2006). Relief. In A. S. Goudie, *Encyclopaedea of Geomorphology* (pp. 840-842). Taylor and Francis e-library.

Nir, D. (1957). The Ratio of Relative and Absolute Altitudes of Mt. Carmel: A Contribution to the Problemof Relief Analysis and Relief Classification. *Geographical Review* , 564-569.

Smith, G. H. (1935). The Relative Relief of Ohio. *Geographical Review , Vol. 25, No. 2*, 272-284.

LIST OF CONTRIBUTORS

1 ***A.N.Satyanarayana***
Manager, Antenna System, National Remote Sensing Centre, Indian Space Research Centre, Department of Space, Govt. Of India

2 ***Abhilasha Chourasia***
Associate Professor, Department of Applied Geology, Dr. HarisinghGour University, Sagar, M.P., India E-mail: abhi9080@gmail.com

3 ***Achiransu Acharyya***
Assistant Professor, Dept. of Economics, VisvaBharati University, Santiniketan-731235 E mail: achiransu@gmail.com

4 ***Amrit Kamila***
Department of Remote Sensing and GIS, Vidyasagar University, Midnapore-721102 amritkamila90@gmail.com

5 ***Anurupa Paul***
Vidyasagar University, Midnapore-721102, West Bengal, Email: fgrsgis@gmail.com

6 ***Arijit Das***
Assistant Professor, Department of Geography, University of Gour Banga
E-mail: arijit3333@gmail.com

7 ***Ashis Kumar Paul***
Vidyasagar University, Midnapore-721102, West Bengal, Email: fgrsgis@gmail.com

8 ***Avijit Mahala***
Research Scholar, CSRD, SSS, Jawaharlal Nehru University, New Delhi, 110067
Email: mahala.avijit@gmail.com

9 ***B.Chandrasekhara Rao***
Group Head, Satellite Tracking Systems, National Remote Sensing Centre, Indian Space Research Centre, Department of Space, Govt. Of India

10 ***Baisakhi Sarkar***
Former Deputy Director, NATMO, Kolkata, E-mail: baisakhisarkar2010@gmail.com

11 ***Balak Ram***
Ex Principal Scientist, Central Arid Zone Research Institute, Jodhpur

12 ***Balwant Kumar***
Integrated Science Education and Research Centre (ISERC), Institute of Science, Visva-Bharati, Santiniketan, West Bengal, India,

13 ***Bhaskar Das***
Department of Geography, Visva-Bharati Email id-dbhaskar85@gmail.com

14 ***Biswajit Ghosh***
Research Scholar, Department of Geography, The University of Burdwan, Barddhaman713104, West Bengal, India email: bswjtghsh40@gmail.com

15 ***Biswaranjan Mistri***
Asst. Professor, Department of Geography, The University of Burdwan,
E-mail: brmistri@gmail.com

16 ***C. P. Singh***
Associate Professor & Head, Department Of Geography, Udai Pratap (Autonomous) Collage, Varanasi, Email Id: c.p.singhscp@gmail.com

17 ***D. K. Mandal***
Associate Professor, Department of Geography & Applied Geography University of North Bengal E-mail: dkmandalnbu@gmail.com

18 ***Deblina Choudhury***
Research scholar, University of Gour Banga, E-mail: deblina.choudhury123@gmail.com

19 ***Dipanwita De***
Department of Geography, Swami Niswambalananda Girls' College, Bhadrakali, Uttarpara, Hooghly

20 ***Diptimayee Behera***
Senior Research Fellow (UGC), Dept. of Education, RabindraBharati University, Kolkata, West Bengal, India E-mail: diptimayeebehera.db@gmail.com

21 ***Gopinath Patra***
Guest Faculty, Department of Geography, Sripat Singh College, Jiaganj, Murshidabad

22 ***Hemanta Kumar Ghosh***
Assistant Teacher, (PGT in Geography), Lohapur M.R.M. High School, Lohapur, Nalhati, Birbhum, West Bengal, E-mail: hkghosh.hkg@gmail.com

23 ***Ismail Mondal***
Research Scholar, Department of Remote Sensing & GIS, Vidyasagar University PaschimMedinipur -721102 e-mail: ismail@mail.vidyasagar.ac.in

24 ***J. S. Chauhan***
Chief Technical Officer, Central Arid Zone Research Institute, Jodhpur,
E Mail: dr.brmayank@gmail.com

25 ***Jatisankar Bandyopadhyay***
Vidyasagar University, Midnapore-721102, West Bengal, E-mail: 1kbrsgis@gmail.com & jalemkiran@gmail.com

26 ***Jitendra Shukla***
Associate Professor, Department of geography, Ranchi University, Ranchi, Jharkhand.
Email: subhankar.sbm123@gmail.com

27 ***K.Koteswara Rao***
Head SD & ASD, National Remote Sensing Centre, Indian Space Research Centre, Department of Space, Govt. Of India

28 ***K.V.Ratna Kumar***
Dy. Director, SDR&ISA, National Remote Sensing Centre, Indian Space Research Centre, Department of Space, Govt. Of India Email: satyanarayana_an@nrsc.gov.in, ans_1010@yahoo.com

29 ***Kiran Jalem***
Centre for Land Resource Management, Central University of Jharkhand, Ranchi

30 ***Kalikinkar Das***
Research scholar (M.Phil), University of Gour Banga, E-mail: geokinkar@gmail.com

31 ***Kartic Bera***
Centre for Land Resource Management, Central University of Jharkhand, Ranchi

32 ***Kshudiram Chakraborty***
Research Scholar, E-mail: khudiram0@gmail.com

33 ***Madhumita Minz***
Research Scholar, P. G Department of Geography,Ranchi University, Ranchi (Jharkhand)
E-mail: madhumita29minz@gmail.com

34 ***Malavika Sinha***
Assistant Professor, Department of Geography, Jogamaya Devi College, Kol 26
Email: malavikasinha123@gmail.com

35 ***Mousumi Roy***
Research Scholar, Department of Geography, University of Calcutta, 35 B. C. Road, Kolkata

36 ***N. C. Jana***
Associate Professor, Department of Geography, The University of Burdwan, West Bengal, India; E-mail: jana.narayan@gmail.com

37 ***Namita Chakma***
Assistant Professor, Department of Geography, The University of Burdwan, Bardhaman 713104, West Bengal, India email: namitachakma@gmail.com

38 ***Prolay Mondal***
Assistant Professor, Department of Geography, Raiganj University, West Bengal

39 ***Rahaman Ashiquellahi***
UGC-Project Fellow, Department of Geography, The University of Burdwan, Barddhaman

40 **Ranjan Kumar Das**
Assistant teacher of Bamshore High School E-mail id-ranjankumardas18@gmail.com

41 ***R.K. Rawat***
Research Scholar, Department of Applied Geology, Dr. HarisinghGour University, Sagar, M.P., India

42 ***Reshma Chakraborty***
Research Scholar, IIEST, Shibpur, Howrah Email- chakrabortyreshma@gmail.com

43 ***Sanat Kumar Guchhait***
Professor, Dept. of Geography, The University of Burdwan, Burdwan – 713 104, West Bengal
E-mail: sandipanghosh19@gmail.com

44 ***Sandipan Ghosh***
Assistant Professor, Dept. of Geography, Chandrapur College, Burdwan – 713 145, West Bengal

45 ***SangeetaYadav***
Associate Professor & Head, Department Of Geography, Udai Pratap (Autonomous) Collage, Varanasi,

46 ***Sathi Sampad Roy***
UGC Junior Research Fellow, Department of Geography, The University of Burdwan, West Bengal, India; E-mail: roysathisampad@yahoo.in

47 ***Sayan Choudhary***
Department of Geography, Visva-Bharati, Santiniketan-731235,
Email: sayanchoudhary@gmail.com

48 ***Senjuti Nandy***
Research Scholar, Department of Geography, Visva-Bharati
E-mail: nandyseju2010 @ gmail.com

49 ***Shekhar Kumar***
Indira Gandhi National Open University, New Delhi Email: kumarshekhar19@yahoo.co.in

50 ***Shyamal Dutta***
Research Scholar, Department of Geography,The University of Burdwan, Barddhaman
Email: duttashyamal1987@gmail.com

51 ***Sneh Pratap Singh***
Integrated Science Education and Research Centre, Siksha-Bhavana (Institute of Science), Visva-Bharati, Santiniketan

52 ***Sohini Neogy***
Guest Lecturer, Dept. of Geography, Vidyasagar College, E-mail: sohini.neogy@gmail.com

53 ***Somit Mandal***
Research Scholar, Department of Geography,VisvaBharati,Santiniketan

54 ***Srabani Bose***
Assistant Professor, Dept. of Geography, Dr. BhupedraNathDuttaSmiritiMahavidyalaya, Hatgobindapur, Burdwan – 713 145, West Bengal

55 ***Subhankar Samanta***
Assistant Professor, Kaviguru N.C.T. College, Beldanga, Murshidabad

56 ***Subrata Sarkar***
Research Scholar, Department of Remote Sensing & GIS, Vidyasagar University Paschim Medinipur

57 ***Sucheta Mukherjee***
Assistant Professor, Department of Geography,Sripat Singh College,Jiagang

58 ***Tanushree Dutta***
Lecturer, Vivekananda College for Women, Barisha, Kolkata 700008
tanushree.vcw @ gmail.com

59 ***Tanushree Maji***
Research Student, Department of Remote Sensing & GIS, Vidyasagar University Paschim Medinipur

60 ***U. K. Mandal***
Directorate of Census Operation, West Bengal, Janaganana Bhavan. IB-199, SEC-III, Saltlake, Kol-106, Email:ukmandal@yahoo.com

61 ***Umesh Kumar Singh***
Integrated Science Education and Research Centre (ISERC), Institute of Science, Visva-Bharati, Santiniketan, West Bengal, India, Email: umeshkumar.singh@visva-bharati.ac.in

62 ***Uttam Mukhopadhyay***
Head & Associate Professor, UG & PG Depts. of Geography, Vidyasagar College, Kolkata
E-mail: dr.uttammukhopadhyay2709@gmail.com

63 ***V.C.Jha***
Professor, Department of Geography, Visva-Bharati, Santiniketan, E-mail : vcjha@asia.com

64 ***Viswajit Giri***
Research Scholar,Centre for the Study of Law & Governance JawaharlalNehru University, New Delhi, E-mail: viswajitgiri@gmail.com

65 ***Yogia Dutta***
Research Scholar, University of Calcutta, Guest Lecturer, Dept. of Geography, Vidyasagar College E-mail: yogia.dutta@gmail.com

36th INCA INTERNATIONAL CONGRESS - 2016

Indian National Cartographic Association (INCA)

EC Members, 2016

PRESIDENT
Prof. (Dr.) Vibhash Chandra Jha

CO-PRESIDENT
Surveyor General of India

PAST PRESIDENTS
Dr. V.K. Dadhwal
Dr. Swarna Subba Rao
Prof. (Dr.) Anuradha Banerjee

SENIOR VICE PRESIDENT
R. Admiral. Vinay Badhwar, NM

VICE PRESIDENT-I
Dr. P. G. Divakar

VICE PRESIDENT-II
Shri Naveen Tomar

SECRETARY GENERAL
Shri Ravindra Kumar

PAST SECRETARY GENERAL
Shri R. N. Nanda

SECRETARY - I
Dr. Murali Krishnan S.

SECRETARY-II
Shri Rajesh Kumar

TREASURER
Shri P. Krishnaiah

MEMBERS

1. Shri O. P. Sarna
2. Shri Shyam Veer Singh
3. Dr. Balak Ram
4. Shri S. K. Sinha
5. Capt. Sanjeev K. Nair
6. Dr. R. A. Prasad
7. Dr. R. B. Singh
8. Dr. Shahla Kauser
9. Prof.PremlataSinghi
10. Dr. R. K. Trivedi
11. Dr. Mahesh Kumar Ozha
12. Shri N. R. Biswal
13. Mrs. SunandaTrivedi
14. Shri Jaipal Singh
15. Prof. Bupinder Zutshi
16. Shri Neeraj Khare
17. Shri Rajeev Srivastava
18. Col. S. Sridhara Rao
19. Shri Dhiraj Shah
20. Shri D. N. Pathak
21. Shri Pankaj Mishra
22. Shri Sahdeo Ram
23. Dr.Taruna Bansal
24. Prof. Shukla Hazra
25. Mrs. Sonali Saha Bhattacharjee
26. Mrs. Swagata Chatterjee
27. Mr. Saji Krishnan
28. Dr. Sucheta Mukherjee

36th INCA INTERNATIONAL CONGRESS - 2016

Local Organising Committee

Chairman
Prof. Swapan Kumar Datta
Vice-Chancellor (Upacharya) (Offg.)

President INCA, 2016 and Convener
Prof. V. C. Jha
Organising Secretary

Prof. Uma Sankar Malik

Treasurer
Dr. Gopal Chandra Debnath

Members
1. Prof.Tapati Mukhopadhaya
2. Prof.Sabujkoli Sen
3. Dr. Debashis Chakrabarty
4. Dr. Mani Mukut Mitra
5. Prof. Sudendhu Mandal
6. Prof. Dilip Mitra
7. Prof. Madhabi Ruj (Ghosh)
8. Prof. Dulal Pal
9. Prof. Kailash Pattnaiak
10. Shri A.P. Trivedi
11. Dr. Prashant Meshram
12. Prof. Sumantro Mukherjee
13. Prof. Debasish Das
14. Prof. Malay Mukhopadhyay
15. Prof. Sutapa Mukhopadhyay
16. Dr. Manjari Bhattacharji
17. Dr. Premangshu Chakrabarty
18. Dr. Krishnendu Gupta
19. Shri Bhairu Lal Yadav
20. Smt. Sudipta Sarkar
21. Dr. Bhaskar Das
22. Dr. S. N. Ojha
23. Dr. Amrendra Kumar
24. Dr. Abhijeet Banerjee
25. Dr. Umesh Kumar Singh
26. Dr. Subhash C Roy
27. Dr. Anil Kumar
28. Dr. Sujit Kr. Pal
29. Shri Anirban Sircar
30. Shri Ashok Kumar Mahato
31. Dr. Punnya Brata Hazra
32. Dr. Sucheta Mukherjee
33. Dr. Utpal Mandal
34. Shri Somit Mandal
35. Dr. Mausumi Bhattacharya
36. Shri Abhijit Sengupta
37. Shri Chandan Kumar Das
38. Shri Swasti Vardhan Mishra
39. Shri Mohammad Arif
40. Shri Kishore Bhattacharya
41. Dr. Tanusree Paul

36th INCA INTERNATIONAL CONGRESS - 2016

National Advisory Committee

Prof. Ashutosh Sharma
Secretary, Department of Science and Technology Government of India, Chief Patron

Shri A. P. Singh
Consultant,
National Water Mission Ministry of Water Resources, River Development & Ganga Rejuvenation

Prof. Chitta Ranjan Pathak
Professor (Retd.), Department of Architecture and Regional Planning, IIT Kharagpur

Dr.Madhavan Nair Rajeevan
Secretary, Ministry of Earth SciencesGovernment of India Patron

Dr. A. Senthil Kumar
Director, Indian Institute of Remote Sensing

Prof. N. K. De
Professor (Retd.),Department of Geography,The University of Burdwan

Dr.Vinay Kumar Dadhwal
Director, Indian Institute of Space Science and Technology

Dr. Ravinder Kaur Director
(Officiating), Indian Agricultural Research Institute

Prof. Subhash Chandra Mukhopadhyay
Professor (Retd.), Department of Geography, University of Calcutta

Dr. Y. V. N. Krishna Murthy
Director, National Remote Sensing Centre

Shri Rajiv Gauba Secretary,
Ministry of Urban Development

Prof. Nageswar Prasad
Professor (Retd.), Department of Geography,The University of Burdwan

A.S. Kiran Kumar Chairman,
Indian Space Research Organisation

Dr. Nisha Mendiratta
Director, Climate Change Programme, Department of Science and Technology

Dr. Parth Sarathi Chakrabarti
Former Chief Scientist, WBSCST, Govt. of W. Bengal

Dr.RakeshTewari
Director General, Archaeological Survey of India

Dr. S.K. Jha
Vice Admiral, AVSM, NM (Retd.)

Prof. Sunando Bandyopadhyay
Professor Department of Geography, University of Calcutta

Shri Saibal Dasgupta
Director General, Forest Survey of India

Shri. J. L. Jain
Professor (Retd.) Department of Geography, Gour University

Shri Gopinath Saha
Former Director, National Atlas and Thematic Mapping Organisation

Dr. Paramjit Singh
Director, Botanical Survey of India

Prof. Surya Kant
Professor (Retd.) Department of Geography, Panjab Univ.

Prof. Ranjan Basu
Professor, Department of Geography, University of Calcutta

Dr. Prithvish Nag
Vice-Chancellor, Mahatma Gandhi Kashi Vidyapith

Dr. Kalyan Rudra
Chairman, West Bengal Pollution Control Board

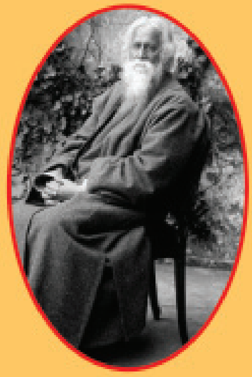
36th INCA INTERNATIONAL CONGRESS - 2016

Sub-Committee

1	**VENUE & EXHIBITION**	***Prof. Uma Sankar Malik, and Dr. Mausumi Bhattacharya,*** **Joint Co-ordinator,** ***Bratin Roy, Sudipta Sarkar, Dr.Tanusree Paul, Dr.DebashisMahalanabis, Sougata Samanta***
2	**LOGISTICS**	***Anirban Sircar, and Chandan Kumar Das*** **Joint Co-ordinator** ***Dr.Sujit Kr. Pal Dr.Krishnendu Gupta, Dr.Abhijit Banerjee,***
3	**REGISTRATION**	***Dr. Manjari Bhattacharjee, Dr.Sucheta Mukherjee*** **Joint Co-ordinator** ***Dr Mahesh Sawata Khetmalis, Sudipta Sarkar, Sayan Choudhary, Senjuti Nandy***
4	**CULTURAL PROGRAMMES**	***Prof. Malay Mukhopadhyay, BhairuLal Yadav,*** **Joint Co-ordinator,** ***Prof.Sutapa Mukhopadhyay, SudiptaSarkar, Dr. S.C. Roy***
5	**HOSPITALITY**	***Dr.Krishnendu Gupta, AnirbanSircar*** **Joint Co-ordinator,** Prof. Debashis Das, Avijit Banerjee, Somit Mandal
6	**ACADEMIC PROGRAMME**	***Prof.Sutapa Mukhopadhyay, Dr. S. N. Ojha,*** **Joint Co-ordinator** ***Dr.Mausumi Bhattacharya, Dr.Premangshu Chakrabarty, Dr.Umesh Kumar Singh, Dr Tanusree Paul, Bhairu LalYadav, Dr. Bhaskar Das, Dr. Anil Kumar***
7	**PROGRAMME, PUBLICATION & COORDINATION**	***Dr. S.N. Ojha, Prof. Uma Sankar Malik*** **Joint Co-ordinator** Prof.Sujit Pal, Dr.Premangshu Chakrabarty, Dr.Mausami Bhattacharya, Dr.Kasinath Bhattacharjee, Sumanto Karmakar, Dr.Sucheta Mukherjee, Dr. Bhaskar Das, Sujay Lahiri, Md. Arif, Swasti Vardhan Mishra, Dr.Biplab Loha Choudhury, Shri Abhijit Sengupta, Dr.Tanusree Paul
8	**FINANCE & PROCUREMENT**	***Prof. Uma Sankar Malik, Dr. G.C. Debnath,*** **Joint Co-ordinator** ***Dr.PrasantMeshram, Dr. Amarendra Kumar, Dr. Krishnendu Gupta***

CO-SPONSORS


OF CLIMATE CHANGE
9-11th November 2016
OF CLIMATE CHANGE
Organised by : Department of Geography
VISVA-BHARATI, SANTINIKETAN



শান্তিনিকেতন

আমাদের শান্তিনিকেতন।
সে যে সব হতে আপন।

তার আকাশভরা কোলে
মোদের দোলে হৃদয় দোলে,
মোরা বারে বারে দেখি তারে নিত্যই নূতন।
মোদের তরুমূলের মেলা,
মোদের খোলা মাঠের খেলা,
মোদের নীল গগনের সোহাগ মাখা সকাল সন্ধেবেলা।
মোদের শালের ছায়াবীথি
বাজায় বনের কলগীতি,
সদাই পাতার নাচে মেতে আছে আম্‌লকি কানন।
আমাদের শান্তিনিকেতন।

আমরা যেথায় মরি ঘুরে
সে যে যায় না কভু দূরে,
মোদের মনের মাঝে প্রেমের সেতার বাঁধা যে তার সুরে
মোদের প্রাণের সঙ্গে প্রাণে
সে যে মিলিয়েছে এক তানে,
মোদের ভাইয়ের সঙ্গে ভাইকে সে যে করেছে একমন।
আমাদের শান্তিনিকেতন॥

শ্রীরবীন্দ্রনাথ ঠাকুর

৭ই পৌষ
১৩২৬