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ABOUT THE JOURNAL

The **INDIAN CARTOGRAPHER** is a peer reviewed journal (of the INCA, Hyderabad) published bi annually(June and December) and fulfilling the UGC – CARE List criteria. It considers research articles from diverse disciplines which employ cartographic techniques as part of its investigation and analysis to report conclusive findings. The research articles addressing the nature, scale and extent of the maps, digitalization and influence that citizenry have on local, focal, regional and global aspects of the Earth are welcome. Indian Cartographer is an open access journal focusing on cartography i.e. art and science of mapmaking, and therefore research and review papers of significance that are written clearly and well organized will be given preference. All papers, solicited and unsolicited, will be first assessed by a Reviewing Editor. Papers found unsuitable in terms of the overall requirements of the journal will be returned to the authors. The others will be sent for detailed peer-review. Authors of these papers will be notified of acceptance, need for revision or rejection of the paper. It may be noted that papers once rejected cannot be resubmitted. Illustrations and other materials to be reproduced from other publications must be properly credited. It is the authors' responsibility to obtain permission for reproduction of figures, tables, etc. from published sources (copies of letters of permission should be sent to the editor).

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Editor's Note

Earth Sciences in the new millennium explores the relation between human action and the physical environment. Natural events in our physical environment affect human and their societies. The recent developments in spatial sciences rely on cartography for visual, verbal, mathematical, digital, and cognitive approaches for interpretation of environmental-societal dynamics. Cartography lends precision to explore environmental dynamics linking physical systems to economic, social, and political systems. The need to address exchange dynamics between the natural world and human-societal interface as a consequence of environmental change requires spatial representation of spatio temporal scales of investigation. The interpretation of a natural phenomena is more precise with measuring and modeling techniques offered by geospatial technology. Earth scientists are now relying heavily on geospatial outputs and statistical methods - Arc GIS, SAS, SPSS, and ERDAS which provide efficiency in a dynamic digital way for deep understanding and a critical approach to map explain and model the processes operating in the environment. The geomorphological processes, risks ,hazards to problems of climate change perturbations like changes in the physical nature of the cryosphere, lithosphere hydrosphere and biosphere ,the critical zone interface resulting in degradation, desertification, GLOFs, riverine floods, coastal submergence, shrinkage in areal limits of mangroves and rainforests are of deep concern now.

The Indian Cartographer reflects these concerns and offers a platform to academics, professionals and researchers alike to address and raise responsible intellectual awareness among its readers for shaping humane and socially relevant issues which arise in the new millennium. This volume has research articles that utilize dynamic cartographic techniques. The articles by Markandey as part of Manzoor Alam memorial lecture on the occasion of 41st INCA International Congress 2021 give a detailed explanation on development of digital cartography, Jain elucidates upon cartographic generalizations and Sarkar delves into techniques used for mapping our national boundaries which are worth reading. Case studies by Kanchan et al, Singh, Chandramauli and Dhurve, Suresh A. et al, Deka & Konwar and Raghav et al., deal with spatial phenomena using advanced cartographic techniques to explain their findings. I sincerely hope that this diverse array of articles will encourage the reader to appreciate the role of cartography in modern society. Societal welfare is imperative to national growth and in the words of Heyman 2006 the goal for Earth sciences should be to encourage "intellectual leadership and of shaping social agendas along more humane and socially just lines" for a welfare and vibrant nation.

Professor Vibhash C. Jha
Chairman
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Indian Cartographer

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Modern cartography and the use of geospatial data Manzoor Alam Memorial Lecture (41st INCA International Congress)

Kalpna Markandey

Cartography of yore was based on planimeters, mylar sheets and such other traditional devices. However, the scenario is different today with digital cartography on the anvil. Cartography is vitally oriented towards representation, while GIS which is the mapping face of Digital Cartography with analysis of spatial relationships, also has a time element attached to it. Digital Cartography relies on GPS, GIS and remote sensing (Fig. 1). **GPS** is used extensively for land surveying, navigation, tracking traffic, locating features like facilities and amenities on the ground besides a whole horde of other uses. **GIS** is a computer aided system for capture, storage, retrieval, analysis and display of spatial data. Spatial analysis is carried out by one and all, knowingly or unknowingly. Cloud computing which is a later day development, helps users to take GIS on the go and makes real time mapping possible. **Remote Sensing Satellites** help in updating land use, land cover and other maps like those of wastelands, water features etc. Today **aerial photography** banks to a large extent on unmanned aerial vehicles (UAVs) which are better understood as drones. They make large scale mapping, change detection and record keeping easy. **Sensors** can be used to detect change, events and physical characteristics of an area like undulations etc. LIDAR is a good example of a sensor which enables 3-D laser based aerial mapping and modelling. The Digital phase of cartography with its grounding in geospatial data and technology, has made cartography more accurate and comprehensive in scope.

Components of Digital Cartography:

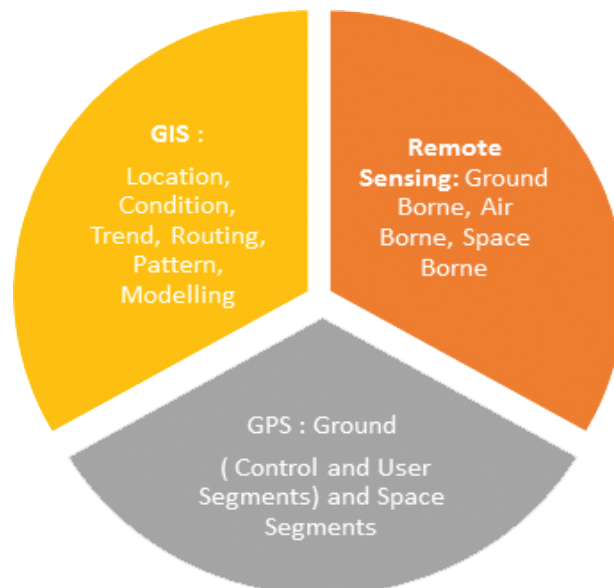


Fig. 1

The government of India has relaxed several guidelines on the collection and use of geospatial data, which enables and aids its strategy towards Atmanirbhar (self- reliant) Bharat. The Department of Science and Technology (DST), Government of India, will lay out rules on the usage of this data, and the users will have to follow them. While most of the areas are open to mapping, DST will outline the sensitive attributes that cannot be linked to mapped data. The process of data acquisition will be abridged and greater lucidity will be built into the same. The redundant government policies of the olden days will thus be dispensed with and replaced. The new procedures will be helpful in embracing the geospatial technology. The requirement of obtaining permission from Ministries and government bodies will be done away with under this dispensation. This would mean a great economy of time as well in carrying out the mapping processes.

Geospatial technology aids in spatial analysis i.e. knowing the location of things, the interrelationship of places, which stem from areal differentiation and the consequent decisions which flow out of them followed by actions. Spatial analysis helps in finding answers to questions pertaining to location (where and what is at a particular place?), conditions (what are the causative factors for its occurrence?), trends (the pattern of change or inclination), routing (the best possible way in terms of time or cost or distance travelled), pattern (the form of a particular feature which can be correlated with other underlying geographical conditions) and modelling (exhibiting an ideal situation or a future tendency).

GIS helps in measuring size, shape and distributions of phenomena or other attributes pertaining to an area, analyzing differences and the connections, finding ideal location for facilities and amenities and predicting for the future. It can also be used as a dashboard for real work as for instance, before establishing a school in a locality, the relevant variables like children of school going age, accessibility etc can be considered for different sites in the locality and the optimal location picked up. Thus, description, analysis and prediction as they are the sequential stages in the development of any science are all embedded in the geospatial technologies and these enable a head on tackling of the spatial problems of an area. Spatial reasoning and dialogue are also built into mapping with the help of these technologies which are readily updatable and facilitate spatial correlations with ease and alacrity. Due to their easily updatable nature, they are amenable to dynamic mapping and decision making based on it. It may be mentioned that GIS provides an easy and effective decision support tool to the policy makers. In other words, it enables science- based planning.

The geospatial tools help in gaining an in-depth view into the spatial features, lending a kind of spatial intelligence to the user. Spatial intelligence or locational intelligence helps the government take smart decisions with regard to tackling disasters, risks and laying out policies and plans for the development of an area.

Geospatial data can also be used effortlessly for **disaster management** and even early warning like the track of a cyclone or the spread of an epidemic, disease, vector monitoring and spatial correlation analysis of the occurrence of the disease with other underlying factors, as for instance the contamination of a source of water and related diseases etc. When a disaster occurs, relief can reach the affected people quickly when the agencies providing relief rely on this data for ascertaining the intensity of impact of the disaster in different pockets. Areas with varying intensity of impact can be identified with the help of GIS and can accordingly be served by the agencies. GIS also helps in selecting a hassle-free route, which does not have roads that are impacted by the disasters like flood or avalanche besides others; supplies to the affected people can thus be provided from an obstacle free and fast route. Safe roads can be identified to reach the

supplies like relief material, water, medicines and food to the affected people and to carry out rescue and relief operations; likewise, evacuation and subsequent rehabilitation and re-construction of roads, houses or shelters can be planned with the help of GIS. Crowdsourced data also comes in handy in the case of disasters. It helps to manage, infer, and integrate details into the work process. Data from the cloud is also being used extensively and it is low on cost, productive, adaptable and aids quick results. Real time data can be built into the relief operations to know how the floods etc have been spreading or receding. Real time data also makes for better allocation of resources by the response teams by opening a window into the ground reality.

GIS is also useful for the mapping of **hazard zones**. GIS in combination with remote sensing can help in preparedness for hazards, adaptation and also mitigation plans. Safe zones for rehabilitation can be identified as also those where it is not advisable to carry out construction. Geotechnology can help to locate the quickest route to a hospital considering the traffic and other obstacles. GIS and GPS can help in ambulance routing with ease and effectiveness.

Businesses can make use of high-resolution data and can use advanced technology to locate mobile devices more precisely. Earlier it required a lot of government permissions to produce, access, or distribute such geospatial data, leading to extensive delays. Geospatial data is the cornerstone of many businesses today: E commerce websites such as Amazon, Meesho and Flipkart use it to organize consignments, look for the optimal location of warehouses etc; food delivery apps like Swiggy and Zomato resort to geospatial data to reach their customers, transport apps like Uber, Ola etc use it to plan their trips and pricing based on the demand for their services. This data also helps businesses to become conversant with the customers. E.g., a store that aims a particular age group can create maps showing the concentration of that age group so that they can aim their selling activities at those areas. Alternatively, areas with the highest household income within a specified distance from a store can be located so that they can be targeted for selling luxury products. This technology, thus aids business and marketing for targeted planning, improved decision making, better communication and also precise maintenance of records.

With regard to **Agriculture**, geospatial data helps in ascertaining the soil moisture, weather conditions etc, which can assist farmers in their agricultural operations. The farmers can also ascertain the appropriate crop to be grown in an area based on its characteristics like soil, weather and topography besides others. These technologies also aid crop management decisions to maximize yields and help with optimal fertilizer input, as well as organic or genetic tracking.

GIS can be used to study **weather conditions** like clouds, rainfall, wind direction and intensity, track weather hazards, thus enabling a quick forecast of the weather conditions which can be of use to the farmers, fishermen, aviators and the people at large in making smart decisions.

Geospatial technology also helps in the analysis of **climate change**. An eye in the sky or the satellites can detect melting ice caps or receding glaciers, rising temperatures of sea water, disappearing islands as a result of the rise in the sea level and changes in land cover. GIS can help to assimilate data pertaining to atmospheric conditions, environmental changes and the people's response to climate change. These techniques including Digital Terrain Models (DTM) can be instrumental in the decision-making process and finding solutions to the environmental problems.

Archaeology and heritage studies also rely impressively of satellite data, GPS, sensors and GIS. Under - sea investigations for the remains of historical sites through sensors, collating information from diverse sources and putting it in the framework of GIS enable fast and reliable archeological studies in the present-day context. Space - time patterns

can be generated in the archeological arena with the help of geospatial technologies.

Geospatial technologies also come in handy in the **finance** sector, where financial inclusion becomes easy with the help of these technologies. For instance, the location of ATMs, bank branches etc can be planned with the spatial database of the customers. While alienation of select groups in remote locations can be handled with the help of this data, it also helps in identifying the densely populated area which may require a greater concentration of these services. Point buffers of accessibility to financial services can be prepared. Spatial gaps in the provision of these services can thus be aimed at and tackled.

Geospatial technologies are used in handling **medical services** as well. Apart from routes of least resistance, as has been noted in the case of ambulances, these technologies have made a mark during the Covid 19 period. Nations have been tracking the spread of this disease through contact tracing, movements of sick people, parks and other spots that they visit, car, phone and credit card transaction tracking all of which are spatial measures enabled by GPS. India also has its own Arogya Setu App which gives a dynamic insight into the presence of Covid 19 positive cases within specified buffer zones from a person. Recently drones are also known to have delivered medical kits and vaccines showcasing the empowerment of technology in reaching out to people in need and salvaging the providers from many hurdles.

GIS along with GPS is used in **transport planning** where information pertaining to the assets of the transport department like bridges, tunnels, signals, switches, sidings, road crossings, junctions, their location and value as well as their requirement of maintenance, site selection, locating houses on streets besides a lot of other things can be mapped and used in fine tuning the services. If road widening is required, then a 50 feet buffer using GIS can be made astride the road and properties falling within the buffer can be identified. GIS can help in finding the property owners and they can be contacted by the government in a short span of time, thus saving time and resources for the government. Map data becomes interactive and hence more advantageous, when GIS and related geospatial technologies are used. For instance, one can click on a street map and get an insight into the number of lanes, speed limit, need for repairs to the road if any and other attributes of the road like pot-holes, road cracks, weeds or plants on the road and the need to control them.

As GIS can integrate and assimilate volumes of data, it is useful in **route alignment** where a multitude of variables have to be taken into consideration. GIS with the effective tool of DEM, which takes care of gradient, aspect, slope etc, apart from a horde of other features like soil and susceptibility of landslides have to be taken into consideration in route alignment. The geospatial technologies enable this in a short duration of time through computer algorithms and iteration.

GIS along with GPS is used aggressively in **real estate** business, where an agent can support a picture of the property with a map of the neighborhood, roads, accessibility, neighboring properties along with the attributes of the occupants. It gives an immense value addition to their efforts of selling the properties they intend to.

GIS is also used in **crime mapping** where the hot spots of crimes can be delineated based on the incidence of various types of crimes and safe passage routes can be defined. Geospatial Technology can also be used for investigating crime scenes and correlating it with collateral data. Emerging areas of crime, the gradient of crime from the hotspots as identified by the isopleths of crime intensity can be identified. It makes available evidence in several cases of crime and is an evidence- based aid in predicting and resolving them. The law enforcement agencies can rely on these techniques and can do a temporal profiling of the areas also so far as different types of crimes are concerned.

Mapping and by extension geospatial technology found its initial users in the **defense** field, Digital Elevation models (DEM) are used extensively by the defense personnel. They help in easily finding the line of sight and enable cross – country visibility, apart from giving an insight into slope convexity, slope concavity, aspect, steepness of slope and these come in handy for strategic operations. Satellite data is also used extensively in logistics, whether it is from the military point of view or for relief workers. Modern day wars are largely planned in the board room with the help of GIS and satellite data besides other geospatial technologies.

In other contexts, **DEMs** are also used to find out the altitude of soil layers, contact zones of soil and rock, water table, drainage basin delineation, etc. Cut and fill issues in road design and other civil and military engineering missions can be handled with the help of DEM. DEM can also be used for planning location of dams, routes of roads and for statistical comparison of varying kinds of topography. Erosion and run- off can also be estimated with the help of DEMs. By substituting altitude with any other continuously varying attribute, DEM can be used to represent travel surfaces by way of travel time and travel cost; levels of pollution, population growth or population density. Trend surfaces of various features can thus be represented.

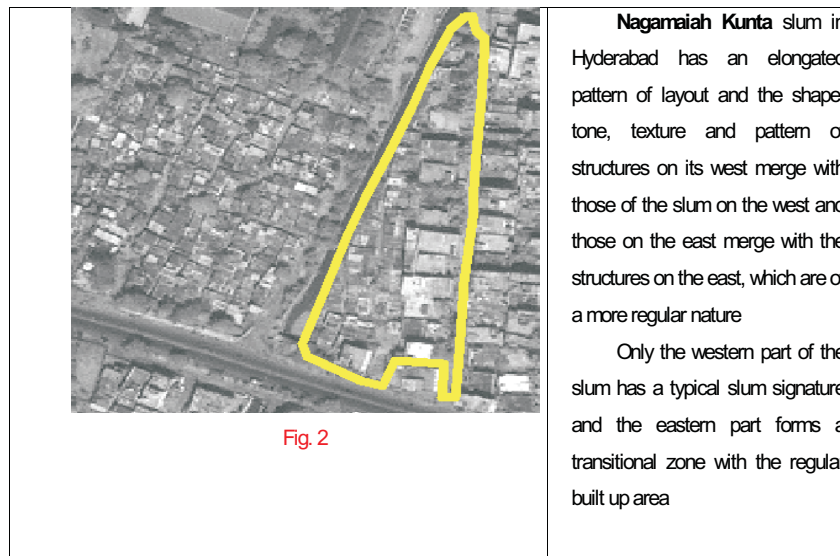
Remote Sensing and UAVs can be used for planning for **sustainable development**, taking care of **natural resources like forests** by measuring the extent of damage caused by forest fires, fire hot spots, mapping and modelling potential areas of occurrence, aerial guidance for spraying to extinguish the fires, besides cloud seeding etc,

GIS is not being used extensively for **landscape architecture**, though it has a lot of potential. As GIS has excellent graphical qualities apart from its basic analytical and collating properties, it can be used very efficiently for landscape design. This fact should be highlighted by the researchers for the benefit of Landscape planners.

Regional and community planning, would benefit immensely from these revised rules of the GOI and that would be beneficial for the economy in the ultimate analysis.

Data pertaining to **water resources**, watersheds and drainage, treatment maps – check - dams, water harvesting structure, ground water potential, **soil survey information, fishing zones, biodiversity, coastal zones, wetlands, shoreline shift, oil slicks, turbidity, siltation, surface flow analysis, change of river course, erosion, contamination, sedimentation and eutrophication in lakes** can also be effectively studied and tackled with the help of Geospatial Technologies.

Geospatial data helps in finding locations in **urban areas**, like the location of a restaurant, petrol pump, mall and other facilities and amenities as well as fixing and being reminded of the maintenance schedules of these amenities and facilities. Data pertaining to carbon footprints, slums, indiscriminate waste disposal, pockets of pollution, land use change and haphazard growth of cities can enable proof – based planning for better cities in the future. **Asset mapping** can be done with ease, questions pertaining to the location, characteristics, optimal utilization, repair of assets, maintenance schedules of assets and mapping of inventories can be done. Data from thermal sensors can be used to identify heat islands in urban areas. Apart from this satellite data can also help identify slums in urban areas with the help of their spectral signatures. Much before the municipalities notify the slums; they appear on the urban landscape as squatter settlements. At this stage if they can be recognized with the help of their signatures (Fig. 2) and ameliorative measures taken, the cities administrators can avoid the burgeoning problems that accompany them. The 'Slum Signature Library' can thus help in creating awareness and knowledge base, which can arm the government, forewarn it and help it in taking preventive measures towards the taking root of slums.



Even studies pertaining to **Elections** have made extensive use of GIS and it can help in understanding the Electoral Geography of a state or district or whatever the unit of study. It also helps in making the elected representatives, party workers and the common man more spatially enabled and more enlightened and equipped to understand the nitty - gritty of the correlations and co – variations that associate with the electoral outcomes (Fig. 3).

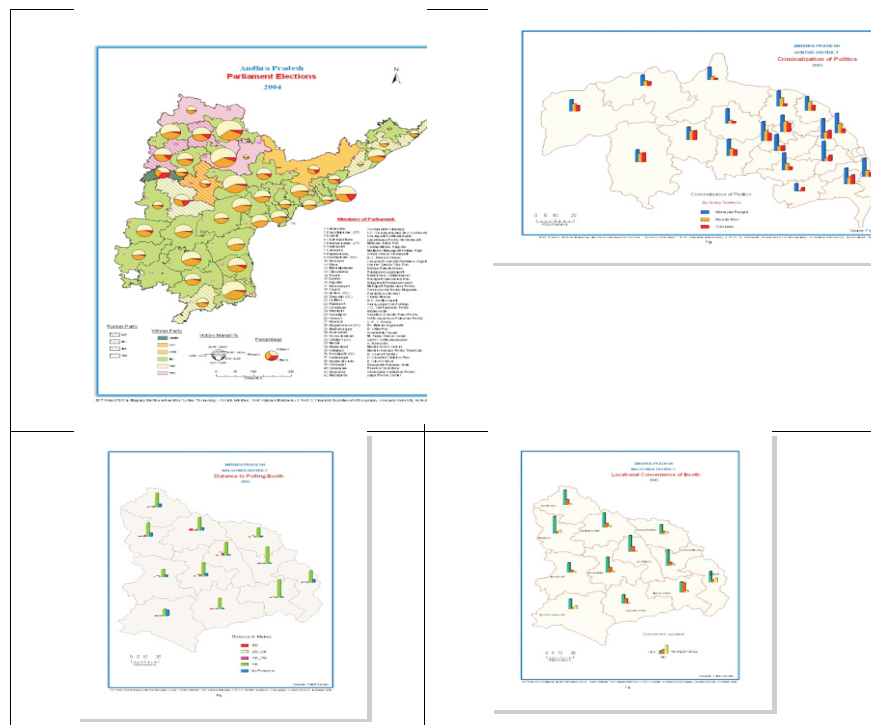


Fig. 3



Fig. 4

Apart from this **Digital Atlases** can now be prepared which will present results of spatial information in an interactive mode and help in making informed decisions.

GIS has also embarked into **location-based services (LBS)**. LBS allows fleet tracking, vehicle navigation (telematics), clinical health care operations, emergency response, personnel monitoring, and other facilities and amenities in close vicinity, with the help of GPS enabled mobile devices.

Environmental degradation owing to exploitation of land resources like mining activity, water pollution due to indiscriminate disposal of mine wastes, mine drainage, coal washing operations, land degradation due to massive excavation, landslides in hilly terrain, deforestation due to chopping of trees for construction of roads and for fuel, damage of sites of cultural, historical and scenic importance, can all be tackled by GIS by simulating alternatives for effective decision making.

Satellite data offers evidence about various natural resources on a periodic basis and changes can be monitored in a dynamic framework and corrective measures to arrest or minimize deterioration of environment can be taken up.

Geotechnology can be effectively used for **environmental impact assessment**. GIS layers of different attributes pertaining to the environment can help in effective decision making for obtaining optimal results. Capturing of features and regular updating will aid in this effort.

Object-oriented program design, big data, mobile mapping, WebGIS and such other techniques have lent a new dimension to GIS and by implication mapping. Mapping is no longer the domain of the cartographers. Almost anyone who deals with spatial data, be it an academician, a researcher, a planner, a government official, a strategist or any one related to any discipline or even the person on the street, they all require mapping with its present-day embodiment of Geospatial Technologies. These technologies have brought mapping to the doorstep or rather the palm top of all and sundry and have a long way to go in enhancing awareness and responsiveness of all concerned.

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Reading between the map symbols : User's perspective on cartographic generalization

Jawahar Lal Jain

Abstract

Needless to emphasize that generalization constitutes the most covert and equally crucial aspect of the entire cartographic endeavor. This brief paper focuses on the dichotomy of producer's and user's perspectives on cartographic generalization and geovisualization. In the milieu of multi-scale data representation on digital media it has taken new dimensions and challenges. The paper concurs with the conviction that despite all the trends and requirements of computerized procedures for standardization and automation of generalization norms in professional mapping institutions, it will likely continue to be somewhat intuitive and hinged on human ingenuity.

While geographers constitute a major category of map users, they also marginally belong to the category of cartographers – often conveying the final analysis-synthesis of their research/academic endeavors rather ingeniously as synoptic, composite maps and cartograms etc. In this backdrop geographers must be fully aware of cartographic generalization processes behind mapping and should also be able to work their way up through these processes in the course of geovisualization and interpretation. Digital Image Processing methods and Augmented Reality technology open further leads in the realm of these fields.

The paper also highlights geographer's innate ability and proclivity to create in his/her mind a panoramic, macroscopic view of extensive areas through proper geovisualization, which should enable him/her to 'read between and beyond the map symbols and toponymy'. The paper highlights specific strengths and weaknesses of geographers in this respect. Building on these aspects, the paper also takes a brief look on what may be called geographic or academic cartography and makes specific suggestions to enhance professional grade training/ education in cartographic generalization and geovisualization.

Keywords— *Cartographic generalization, Producer's and User's Perspective, Geovisualization, Multi-scale representation, Geographical 'macroscopy'.*

Reading Between The Map Symbols : User's Perspective On Cartographic Generalization

If reduction to scale is the most essential function of mapping; generalization is inherently its necessary corollary. If the former reduces dimensions and distances to scale, the latter simplifies the complexity of details of features and areas. It clears the representation of the local, superfluous details that would otherwise clutter the visualization of bold regional outlines and patterns.

With ubiquitization and democratization of geographic information usage, Cartography now entails production

as well as use of geographic information; and umpteen sorts of people are using this information.

Map generalization is the most subtle, covert, and crucial aspect of Cartography.

Patent Cartography books discuss cartographic generalization only from map maker's angle. Most of the map-work type books simply skip over very important aspect of the subject.

Thus, a serious map user is left to grope one's way up the generalization process to guess what the map conveys/ suggests beyond symbology.

If cartographic generalization involves dimensional as well as complexity reduction of the ground reality to scale, map visualization and interpretation entails the inverse journey up the map symbology and generalization process to reach as nearly as possible to the ground reality.

However, the practical situation is that the map user is left to surmise a fuller Geographic Landscape - a little further beyond the symbolic representation. **This involves the acumen of 'reading between and beyond the map symbols', because while the map symbology is apparently visible on the map, generalization is just hidden and implied. However, it is implicitly suggestive also.**

There is no exposition to cartographic generalization process beyond pedantic/ professional Cartography books; or manuals of premier mapping institutions for their inhouse training. Small-time or out-house trainees are given no exposure to these aspects of the Cartographic practice.

Thus, the general map user, say from academic circles, is left to grope in the dark to visualize what the map suggests beyond symbols. And a peculiar silence appears to prevail on this aspect of Cartographic practice

Premier state institutions are generally concerned with only certain type of mapping (mostly topographic) and at a few predecided scales. They follow some set rules and norms of generalization at given scales.

Other mapping agencies are only involved in secondary, thematic-type mapping, wherein the cartographic generalization also becomes of a different nature – from a pre-mapped data on a certain scale to a reduced scale, and highlighting their main theme/s and side lighting other pertinent elements as background

Cartographic generalization on a certain final scale may also be differently implemented in a thinly populated, underdeveloped area from that in a thickly populated and/or developed areas; therefore - it may signify different landscapes in those areas.

Groping through the cartographic generalization process – along with symbology – is **implicitly taken to be a common-sense ability on the part of map user. For want of this faculty, people generally fail to tap the full potential of cartographic communication. Clearly, there is need and scope to cultivate and nurture user's perspective on cartographic generalization To make geovisualization and interpretation a more realistic practice.**

How can one go about this cherished aim? – I can only dimly guess **some ways out** (other than field check).

Aerial photography in early and middle decades of the 20th century provided a most practical means of **verifying one's visualization of skeletal map landscape** with the fuller view in the vertical aerial photographs or photomosaic. Many a book on map interpretation included samples of specific map areas and corresponding air photos. The situation in this respect is quite different in India – due to strict restriction on use of aerial photos for civil purposes.

This image source was greatly augmented with the advent of satellite imagery, which not only added vast new

information from the infrared data, but also readily provided look of extensive areas where one could discern the geological structures and regional patterns at a glance.

Moreover, these satellite images are also amenable to ever expanding realm of digital analysis that could reveal hidden or covert areal information.

Some substantial exposure and a little hands-on practice in some civil type mapping institution can be a starting step.

There can be developed sort of workbook to carry out such practice in some given scenarios for prospective trainees of Cartography. Such workbooks would be greatly enriched by including image sample at appropriate resolution and scale and comparable map section. Moreover, digital elevation models (DEM) can even be draped with orthoimage.

Finally, the geographic information user must cultivate the art of using geographic information with a 'macroscopic'* faculty that can take him to a vantage point to take a panoramic view of the extensive landscape, and also probe specific details of local areas with the digital image analysis techniques.

One way to test this acumen can be to select some project report and try to write its essence with the help of its map/s only. **The two descriptions should essentially tally, which bespeaks the success of the mapping as well as of the map interpretation.** They would better tally if the report were based essentially on its map/s.

I would also figure out a workbook that can present some typical examples of map representation at, say 1:25k, 50k, and 250k scales in different geographic regions - like semiarid area, humid plain area, subhumid area of high relief and one in an area of low relief for settlements, routes, drainage, relief, etc., and ask students to write their interpretation regarding those elements. Then supply them with sat images at nearly comparable scales and ask them to review their interpretation with the help of images.

Here the point is that the same generalized representation, such as a few red squares or rectangles may represent only a few scattered hutments in an area of low population density, and a much bigger settlements of many more houses in a densely populated area. Thus, the same level and type of cartographic generalization may signify different scenarios in different type of geographic regions.

Such exercises can be developed for specific themes such as physiography, land use/ land cover, soil types, settlements, routes, etc; or for specific development projects. The trainees of specific fields can also tap thematic maps of their themes, if available, say at 1:1 m. Scale from NATMO.

Only a few such exercises will convince them best 1. of the importance of cartographic generalization in map interpretation; 2. of the ample scope of visualizing beyond the map symbology; 3. of the potential of interpreting different themes in appropriate band data or band-combination data (if they too can be provided).

Again, if seasonal images can be procured, they can reveal seasonal differences in the look of areas and landscapes against the general picture of topographic maps.

In this context I recall two project reports done by the veteran geomorphologist of Indian land forms, Prof. R. Vaidyanathan of Waltham university, e.g. 1. 'Index to a set of sixty topographical maps illustrating specific physiographic features from India', (1968) 2. 'Index to a set of seventy aerial stereopairs illustrating specific physiographic features from India', (1973).

A larger training would require comparing cartographic generalization practice of several major mapping

institutions on comparable scales. This would prerequisite transcription of sample maps of several eminent cartographic. Institutions. This would serve a larger purpose of Comparative Cartography.

Most Geography Departments have at least a few sets of to posheets for teaching interpretation and other mapwork; they should now endeavor to procure corresponding satellite images to accompany the maps. Better still if they procure digital versions of these data and DEM tiles. Comparing the map and the image will help them look beyond the map symbols and grope their way up the cartographic generalization process.

Next, they can select some type areas and procure 1:25k topographic maps and relevant images on 1:25k or even 1:12.5k scale for those areas in digital version for a more realistic exercise.

Comparing the map and the image will help look beyond the map symbols and grope one's way up the cg. Process.

Conclusion - the paper underscores a genuine need to cultivate user's perspective in cartographic generalization and figures out some ways out for it. It is grossly wrong contention that cartographic generalization is the concern of cartographers only; no, it is now as much the concern of geographic information users also, though slightly differently.

I hope someone may further workout its problems, prospects and opportunities, as also of modalities of incorporating it properly in the geo spatial education curricula.

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Map our mountains and coastal frontiers: Save our boundaries

Baisakhi Sarkar

Abstract:

India shares international boundaries with several sovereign countries. It shares land borders with China, Bhutan, Nepal, Pakistan, Afghanistan in the north and northwest, and Bangladesh and Myanmar in the east. India shares water borders with Sri Lanka, Maldives and Indonesia. Total land frontier boundary is about 15,200 km and water frontier is 7516.6 km including the coastline of the mainland, Andaman and Nicobar and Lakshadweep. Maritime borders of India are the maritime boundary recognized by the United Nations Convention on the Law of the Sea; it entails boundaries of territorial waters, contiguous zones and exclusive economic zones of India, with its claim of a twelve nautical miles territorial maritime zone and 2,000 nautical miles exclusive economic zone. About entire land border has been delineated in accordance with physical features like river bed, ridgeline etc. These are clearly identifiable in satellite images. However, due to gradual shifting of river courses and river bank collapse, the border separating Bangladesh from West Bengal (India) is ever changing, it is getting altered at micro level. Similarly, coastline is getting modified due to emergence and submergence of land following denudational processes and tectonic movements. Our northern border, north western border is consistently endangered due to our aggressive neighbours who try to infiltrate our frontier frequently. The country needs regular vigilance of its boundary so that border territories would not suffer infiltration. The vigilance in remote areas depend on remote sensing at micro level and GPS (for correct latitudinal and longitudinal values), aerial survey with drone is highly effective. Hence, mapping of our borders and protection of strategic locations would involve use of digital cartographic and remote sensing applications. GPS, GIS, drone applications would help to update maps in near real time.

Key words : Sir Creek, Kalapani, Aksai Chin, Galwan Valley, Remote Sensing, GPS, Digital Cartography.

India shares international boundaries with several sovereign countries. The boundary extends along the lofty mountains on the north, northwest and northeast and hot tropical desert in the west. Besides, rivers, estuaries and creeks with constant oscillatory movements separate the country from Bangladesh on the east and from south eastern part of Pakistan on the west; here Sir Creek marks the international border. The vast coastal stretch and islands are country's coastal frontier that is everchanging due to geomorphic and tectonic processes operating upon. Hence, the configuration of country's boundary is getting altered slowly. So, updating of maps is required. Digital cartography and remote sensing technology could serve this need in near real time.

Land Frontier:

India shares land borders with China, Bhutan, Nepal, Pakistan, Afghanistan in the north and northwest; and Bangladesh and Myanmar in the east. The table below gives the details of neighbouring countries. Length of land border is about 15,106.7 km. Excepting the boundary with Bangladesh and Pakistan, the land frontiers consist of a series of mountain chains with snow-capped summits, deep valleys and rolling foothills. These are terrains difficult to access. Pakistan border is demarcated through *Rann* of Katchchh (marshy tract), Thar desert and fringes of the Western Himalaya. Bangladesh shares boundary with India that is demarcated mostly by navigable rivers; over Bengal and Tripura plains it is demarcated and maintained by fencing with wire; infiltration and illegal trafficking (both ways) are regular practices due to loose vigilance

Table 1.
Neighbouring Countries along Land Border.

COUNTRY	BORDER LENGTH	FORCE
Bangladesh	4096 km	Border Security Force
Bhutan	578 km	Open border; Sasastra Seema Bal
China	3488 km	Indo-Tibetan Border Police and Special Frontier Force
Myanmar	1458 km	Assam Rifles and Indian Army
Nepal	1752km	Open border; Sasastra Seema Bal
Pakistan	3310 km	BSF and Indian Army
Afghanistan	106 km	-
Sri Lanka	0.1 km	BSF at Adam's Bridge

Water Frontier:

The mainland of India is girdled by sea front on three sides (0.13 million sq km of territorial waters). The country shares water borders with Sri Lanka, Maldives and Indonesia. Total water frontier is about 7516.6 km including the coastline of the mainland, Andaman and Nicobar and Lakshadweep.

Under the Environment (Protection) Act,1986, a notification on Coastal Zone Regulation has been issued

declaring coastal stretches of seas/bays, estuaries, creeks, rivers and backwaters within 500 metres of high tide line as "Coastal Regulation Zone". There are four Coastal Regulation Zones as briefed below:

CRZ-I: Ecologically sensitive and important areas and areas between low tide and high tide line. No construction work is permitted here.

CRZ-II: Developed areas close to shore, mainly urban/built-up areas.

CRZ-III: Undisturbed areas and those areas which do not belong either category I or II.

CRZ-IV: Coastal stretches along Andaman, Nicobar, Lakshadweep and small islands.

It is apparent that coastal frontier needs protection from external enemies as well as internal foes of coastal environment. Due to its strategic importance, Indian Ocean also needs consistence vigilance by the Indian Navy.

Maritime borders of India are the maritime boundary recognized by the United Nations Convention on the Law of the Sea; it entails boundaries of territorial waters, contiguous zones and exclusive economic zones of India, with its claim of a twelve nautical miles territorial maritime zone and 200 nautical miles exclusive economic zone. The country shares altogether more than 7,000 km maritime border with seven nations. These countries are Bangladesh, Indonesia, Myanmar, Pakistan, Thailand, Sri Lanka, Maldives.

Large and small inlets indent the western littoral. Rann of Katchchh is a dark silty plain with saline patches. To its south are situated Katchchh peninsula, Kathiawar peninsula, Gujarat plain, Konkan coast, Karnataka coast and Malabar coast. Gujarat plain is the broadest part of the west coast. The east coastal plain is wider than its western counterpart. It is 100 to 130 km wide in Tamil Nadu and at Andhra coast, both are densely populated. The Adam's Bridge, a submerged reef, connects the two necks of India and Sri Lanka.

Besides deltaic islands at the mouths of the Ganga, Mahanadi, Krishna rivers, there are a few islands off the coasts of India. These are found at the mouth of the Dhamra river and north of the Mahanadi delta. Some are found in the Chilika lake. Along the west coast, some depositional islands are found at Narmada estuary. Off the south coast of Saurashtra, there are two prominent islands, one of which is Diu. There are several small islands in the Gulf of Katchchh and in the Rann of Katchchh. The islands of Mumbai on the west coast and Sriharikota on the east coast have now become parts of the mainland. The ancient land link between south India and Sri Lanka now survives in the form of Pemban island and Mannar island (connected by Adam's Bridge, which is a chain of islands surrounded by shallow sea). Quite a few tiny islands front the Tuticorin coast.

The Andaman and Nicobar group of islands in the Bay of Bengal (Lat 14°N to 6° 30' N) forms a north-south trending arcuate chain of unsubmerged peaks. It is composed of 265 islands covering a cumulative area of 8,090 sq km. These islands stretch in two distinct groups – the Andaman chain on the north, separated by the Ten Degree Channel from the Nicobar group on the south.

The Lakshadweep group of islands (11° 45' N to 8° N) in the Arabian Sea is an assemblage of 25 small islands. These islands are made up of corals and rise less than 5 metres above mean sea level. Minicoy is an isolated island situated 250 km south of Kavaratti. The islands north of the eleventh parallel are collectively known as Amindivi islands. Those south of this parallel are designated as Cannanore Islands.

About entire land border of India has been delineated in accordance with prominent physical features like river thalweg (centre line joining the deepest points of a navigable river), ridgeline of a mountain chain, etc. These are clearly identifiable in satellite image. However, due to shifting of river courses and river bank collapse, the border separating Bangladesh from West Bengal is ever changing, it has been getting altered at micro level. Similarly, coastline is getting modified due to emergence and submergence of land due to denudational and tectonic processes operating upon.

Some recent border disputes: Nepal shares an open border with India. But recently Nepal has prepared a map that shows hitherto a part of India under Nepal's occupation.

Kalapani territorial dispute: In political map of India Kalapani is shown as a part of India. But Nepal government has recently claimed this river channel as part of its territory. Kalapani has become an issue of contention between India and Nepal after Nepal government raised objections to its inclusion in India's political map dated 2nd November 2019. This map was published after the formation of union territories of Ladakh, Jammu & Kashmir on 31st October 2019.

Nepal government claimed that the Kalapani territory located in its far west is an integral part of her territory. Nepal government made the claim on 6th November 2019. Kalapani is located at an altitude of 3600m on the Kailash Manasarovar route. It borders Uttarakhand in India and Sudurpashchim Pradesh in Nepal. Since Indo-China war of 1962 Kalapani is controlled by India's Indo-Tibetan border force. Nepal claims that the river channel located towards the west of the territory is the main Kali river and thus it falls in its territory. India claims a ridge -line towards the east of the Kalapani territory is the legitimate international border hence the disputed valley belongs to her.

India-China border disputes: India shares 3,488 km of border with China that runs along Ladakh, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh. The main cause of war in 1962 was a dispute over the sovereignty of Aksai Chin in the north of Ladakh and Arunachal Pradesh border regions. Aksai Chin is claimed by India as integral part of Ladakh while China claims it to be a part of its Xinjiang province.

Since 1962 war the northern plain of the Galwan valley in Ladakh marks the Line of Actual Control between China and India. China claims a sizable part of north Arunachal Pradesh to be under its jurisdiction. But India is rigid about her possession and it is stated that boundary of disputed territory of Arunachal Pradesh extends along the ridge-line. Hence the disputed territory belongs to Indian Union. Infiltration across Arunachal Pradesh border is a frequent event. Satellite (American satellite) image of 1st November 2020 shows that China has built up settlement within Indian territory in Tesari Chu river valley in Upper Subansiri district. Couple of weeks ago this happened in the territory of Tawang district. Chinese troop often penetrates Indian territory; builds up shelter, road, bridge etc. Indian security force has to remain vigilant to wipe out this kind of construction and infiltration. Also, it is reported that on 25th January 2021 Chinese Army and Indian Army had a serious scuffle and encounter at Nathu La Pass in Sikkim-China border.

India-Pakistan border disputes: Separating Sind (Pakistan) and Katchchh (India) exists a 96 km long estuary named Sir reek (locally called *Baan Ganga*). The creek is navigable for most parts of the year and is economically important for fish resource. A joint survey (based on application of GPS technology) held by India and Pakistan during 2007 claimed that Sir Creek had shifted 1.5 km eastward (due to silt deposition and also due to tectonic reasons). It may be mentioned that south western border of Pakistan (boundary with Iran) is tectonically highly active and might be the reason behind this shifting. Also, accretion in the Indus delta periphery could lead to eastward shifting of this estuary. Pakistan claimed that the border is aligned along the eastern bank of the Sir Creek while India claims that the international border passes through the centre of this creek. Sir Creek is navigable for most of the year. According to international law a boundary can only be fixed along the middle of a navigable channel, hence India's claim is justified. In Jammu & Kashmir (Indian Union) after reorganisation of union territories of Jammu & Kashmir and Ladakh on 31st October 2019, the districts of Muzaffarabad, Mirpur and Punch are now shown as under the union territory of Jammu and Kashmir (vide India Political map dated 2nd November 2019); previously most parts of these districts were used to be shown as under Pakistan occupied Kashmir. In the same map Gilgit and Baltistan (formerly depicted as under PoK) has been shown as parts of the union territory of Ladakh (India).

India-Bangladesh border panorama: Bangladesh and India share 4,096 km long international border, the fifth longest land border in the world. This include 262 km in Assam, 856 km in Tripura, 318 km in Mizoram, 443 km in Meghalaya, 2,217 km in West Bengal.

India and Bangladesh, with different perceptions of their maritime boundaries and exclusive economic zones, got engaged in eight rounds of bilateral negotiations since 1974, which remained inconclusive until 2009 when both the countries agreed to undergo Arbitration under UNCLOS (United Nations Convention on the Law of the Sea). The Convention has become the legal framework for marine and maritime activities over the maritime border shared by two nations.

A depositional island in Ganga delta emerged over the maritime border during early 1970s. Bangladesh claimed that it was an aftermath of Bhola Island cyclone and associated soil erosion that happened in 1970. From remote sensing data India recognised the existence of this shoal (two miles long and half a mile wide) called New Moore as early as 1974.

Bangladesh authorities came to know about the island four years later. Bangladesh claimed it to be her own. But Indian ownership had got already established by then. India named it *Purvasha/* New Moore; while Bangladesh called it South Talpatti Island. However, the conflict is now over as the island has now submerged and vanished.

Following a mutual Land Boundary Agreement dated 1st August 2015, 162 border enclaves in India-Bangladesh border were inter-exchanged. One hundred and eleven enclaves (17160.63 acres) got transferred from India to Bangladesh and reciprocatively the latter transferred fifty one enclaves (7,110.2 acres) to India. In addition, the choice of citizenship in either country was offered by both the States to residents of these enclaves.

There is no problem regarding the international boundary shared with Bhutan.

Why border regions are to be monitored regularly?

Border region and communities, some of them far away from the heartland, constitute India's first line of defence, a critical link in its safety and sovereignty. Border Security Force is India's first line of defence against infiltration, smuggling and military assault by hostile and scrupulous neighbour. Aerial survey (oblique angle), sensing through high resolution remote sensing satellites, imaging by drone etc are important for monitoring the enemy activities in the border; location of bunkers/shelters, movement of the trespassers, manpower of intruders – all information could be available in near real time.

Country's northern border and north western border are consistently endangered due to aggressive neighbours who try to invade/infiltrate our frontier frequently. The territories of India close to LoC with Pakistan and LAC with China stretching along Ladakh and Arunachal Pradesh border, Sikkim border -- all are under constant threat of illegal occupation, terrorist attack and infiltration by civilians and soldiers of neighbouring countries. Hence, to protect our borderland day to day vigilance applying the modern technology and equipment is a necessity.

Vulnerable citizens:

As many as 140 sensitive districts have been identified in relation to the international border and coastline of the country. These are our vulnerable areas; vulnerable from the perspective of terrorist attack, infiltration, communal riots, smuggling related lawlessness, border conflicts, difficulty of accessibility. Density of population in these 140 districts situated in outlying parts of the country varies from 2.4 persons per sq km (Lahul & Spiti) to 26,553 persons per sq km (Chennai).

Need for remote sensing technology:

Day to day vigilance of remote areas depend on application of remote sensing technology and GPS (for correct latitudinal and longitudinal values). Hence real time mapping of our borders and protection of strategic locations would involve use of latest cartographic and remote sensing techniques. It may be mentioned that wide rivers along Bangladesh-India border are always shifting their courses, Bank of the Padma river along Rajshahi district of Bangladesh is protected by guide walls. So, bank collapse occurs along the Indian side and the river gradually migrates towards Murshidabad district of India. If it happens continuously, India would lose a sizable amount of fertile land with settled villages; with shifting Padma river international boundary would shift remarkably towards Indian territory.

Conclusion:

No map is a document for time indefinite. It has to be updated. Shifting river courses at international boundaries, emerging islands, ever-altering coastlines – all are to be mapped regularly. Remote sensing, GIS and GPS technology are indispensable for monitoring the activities of aggressive intruders along northern, north eastern and western borders. Unmanned Aerial Vehicles (UAV) are highly useful for gathering information at micro level. Deploying drones for intelligence, surveillance and reconnaissance (ISR) missions has been part of military operations for years. Systems have been taken to the sky for long-range persistent surveillance intelligence gathering and combat operations, typically carrying electro-optical (visible) and infrared sensors. Now, the sensors as well as the systems are getting smaller and more compact; however, their capacities are expanding. A frontier guard can pull a nano-drone out of his/her pocket and send it to gather information about the neighbourhood (with a zooming capacity for about 4km radius). Such systems have become smaller, more endurable, accessible not only for military clients but also for civilian applications. These apparatuses are essential tools for real time mapping of India's international border zones.

Source of information:

Published articles and reports of Ministry of Defence, Survey of India and National Atlas of Thematic Mapping Organisation.

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Identification of potential landfill sites for Surat-Bharuch industrial region using AHP and GIS techniques

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Abstract

Inappropriate industrial waste dumping is a critical issue in urban areas as well as in the vicinity of settlements because it affects the environment. Solid waste management is essential tool to minimize the environmental hazards. The present study is an attempt towards this. The study area adjoins the Gulf of Khambat, Surat-Bharuch Industrials region, which is the hub of industries. Besides, many large scale industries, there are 14 GIDC in the study area. In this study, potential industrial waste landfill sites were identified with the help of Analytic Hierarchy Process (AHP), Remote Sensing and Geographical Information System (GIS) methods. For this study, seven criteria (LULC, settlement and industrial belt, roads and railways, river, pond, water depth and land elevation) were evaluated in relation to landfill site selection. All the criteria were selected on the basis of previous literature and expert opinions. Thereafter, AHP was performed for deriving weight, assigning rank of criteria and sub-criteria. Each criteria were mapped in GIS environment and Overlay Analysis Technique was applied to produce final suitability map. The results, illustrated that 2.75% was highly suitable, 71.48% moderately suitable, 5.57% marginally suitable and 20.21% unsuitable. Finally, 14 identified sites were investigated with GPS and considered for best suitable potential industrial waste dumping sites.

Keywords : Landfill Sites, AHP MCDA, Remote Sensing and GIS, Solid Waste Management, Overlay Analysis

1. Introduction:

Globally, regionally as well as locally industrial waste is of growing concern . Rapid population growth, industrialisation, urbanization, economic development and improving living standards in cities have increased the amount of waste generation . Industrial waste refers to the waste produced by industrial activities which contains raw materials which are useless during a manufacturing process such as sludge, product residues and ashes. The useless waste material includes wide range of contaminants such as petroleum hydrocarbon, chlorinated hydrocarbons, heavy metals, various acids, alkalis, dyes and other chemicals . These waste materials are of many types and it depends upon on individual industrial product generation and its operations. In chemical industry, the waste may include organic compounds, metals, nutrients or radioactive material (**Krauskopf et al., 2003**). In case of cotton textile industry, the wastewater is extremely alkaline and contains high concentration of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS) and alkalinity during production, process and decomposition . Whereas, pharmaceutical industrial waste may include chemotherapy drug residues, expired drugs etc. . With the increase of demand for different products in the production and consumption of goods. The generation of the industrial solid waste have also substantially increased. Industrial waste becomes an environmental problem when it starts affecting the soil and also adversely affects the human health. In addition, air also gets affected by the gas emissions. Hence, it is essential to manage such industrial waste in a proper way .

For the management of solid waste, many techniques such as thermal treatment, zero landfilling, biological

treatment and recycling are used. Landfill is one of the most useful techniques for waste disposal. The first step for the planning of landfill is the evaluation process through site selection for highly suitable waste disposal area . For the evaluation process, various factors such as local geomorphology, geology, slope, land use/land cover, water depth, water body, vegetation, soil and economic features like transportation (road and railways), settlement or built-up, industrial area, protected area etc. are to be considered for the site selection . Location of landfill should also maintain the government's regulations so that economic, environmental, health and social costs are minimized . In addition, the waste disposal site must not harm the biophysical environment .

The development of Remote Sensing (RS) and Geographical Information System (GIS) and its use has contributed in improving waste management systems. In this context, the former technique provides potential information about land features through satellite imagery that is useful for land use/land cover classification. GIS is one of the most sophisticated advance technologies to capture, store, manipulate, analyse and display spatial data . It is a flexible platform which generates many layers of data or maps in single window. Geographical Information System helps to take most effective decisions on the basis of spatial data product. GIS plays a major role in waste management applications by delivering outcome for decision support and assessment of larger projects such as site selection (landfill point) for waste disposal, generate optimal route for collecting solid waste. It is capable to provide waste management databases and maps. It also reduces time and cost of the site selection and provides asset management services for future monitoring program of the site . This technique provides conversion tool which helps in converting spatial data (vector data) into raster form that is useful for Weighted Overlay Analysis in GIS .

Analytic Hierarchy Process (AHP) is a semi-quantitative approach and is one of the best Multi Criteria Decision Making method which is widely applied in decision making problems . Integrating of AHP and GIS techniques also improves the accuracy of analysis in landfill site selection . Therefore, this study focuses on the application of GIS-based Multi-criteria Decision Analysis.

2. Modeling Theory

Multi-criteria Decision Making Analysis (MCDA) is a widely useful technique which enables the users to take appropriate choice among several criteria in a particular region. AHP belongs to MCDA and basically is a mathematical method designed by Satty in 1977 ; . There are many techniques included in MCDA such as Weighted Sum Model (WSM), Weighted Aggregated Sum Product Assessment (WASPAS), Analytic Network Process (ANP) etc. but Analytic Hierarchy Process (AHP) is a useful method in potential landfill selection ;. AHP deals with complex decision making problems by breaking down the problem into a hierarchic structure and facilitate by identifying and weighting of selection of criteria, evaluation of data and accelerate the decision making process (**Satty 1980**). In application, the AHP is not adequate method because it is controlled by human judgments and ranking in a comparison matrix. Therefore, ranking might be biased and doubtful .

In AHP, pairwise comparison provides comparison of each criteria and generate criteria weights within a matrix which also calculates the Consistency Ratio (CR) of decisions. In the present study seven (7) criteria were taken for determining the relative importance in PCM and Satti's pairwise comparison matrix range scale was followed (Table 1). Subsequently, a questionnaire was designed to derive expert knowledge who have expertise in this field, 10 experts were requested to fill the questionnaires as per comparison scale for weighted factors of each criteria ; .

If n numbers of criteria to comparison, the AHP method performs following steps for to determine the weights of these criteria .

- a) Initially, establish $(n \times n)$ pairwise matrix B for n objectives i.e. (1)

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{1n} \\ b_{21} & b_{22} & b_{2n} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ b_{n1} & b_{n2} & b_{nn} \end{bmatrix}$$

Table 1
Assessment scale of

Numerical value of b_{ij}	Degree of preference
1	Equal importance of i and j
3	Moderate importance of i over j
5	Strong importance of i over j
7	Very strong importance of i over j
9	Extremely importance of i over j
2,4,6,8	Intermediate values i over j

where b_{ij} demonstrate how much more important the i th objective is than the j th objective, while making the suitable material handling equipment selection decision. For all i and j , it is necessary that $b_{ij} = 1$ and $b_{ij} = 1/b_{ji}$. The possible assessment values of b_{ij} in the pairwise comparison matrix, along with their corresponding interpretations, are represent in Table 1.

- b) Then, new Q (column) matrix is construct in the AHP using the elements of B matrix. Here, element of q_i is denoting the relative degree of importance (weight) of the i th objective which producing the principle eigenvector.

$$Q = \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_n \end{bmatrix} = \begin{bmatrix} \frac{b_{11}}{\sum b_{i1}} + \frac{b_{12}}{\sum b_{i2}} + \dots + \frac{b_{1n}}{\sum b_{in}} \\ \vdots \\ \frac{b_{n1}}{\sum b_{i1}} + \frac{b_{n2}}{\sum b_{i2}} + \dots + \frac{b_{nn}}{\sum b_{in}} \end{bmatrix} \quad (2)$$

c) Given procedure is taken for check the consistency of judgments in the matrix of pairwise comparison as follows:

- 1) D matrix represents the results of multiplication between B and Q matrix which shows the consistency vector.

$$D = B \times Q = \begin{bmatrix} b_{11} & b_{12} & b_{1n} \\ b_{21} & b_{22} & b_{2n} \\ \vdots & \vdots & \vdots \\ b_{n1} & b_{n2} & b_{nn} \end{bmatrix} \times \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_n \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} \quad (3)$$

- 2) Calculate λ_{max} .

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \frac{x_i}{q_i} \quad (4)$$

where λ_{max} is the largest principle eigenvalue, n is the order of the pairwise comparison matrix.

- 3) Consistency index (CI) define as below equation.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

The consistency of judgment should be checked in Random Index Table (Table 2) proposed by

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

(Saaty 1980).Table 2 Random Index values (Saaty 1980)

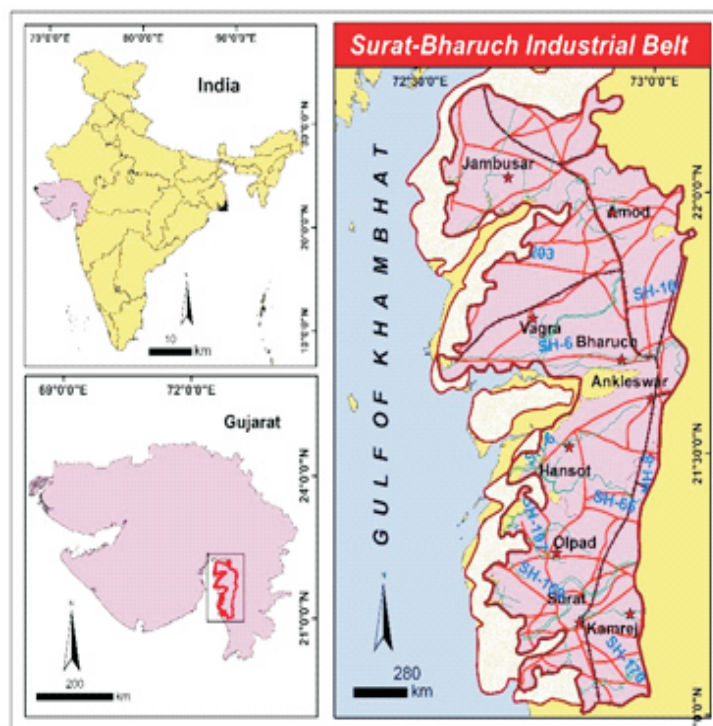
CR is defined as

$$CR = \frac{CI}{RI}$$

where CR is Consistency Ratio. RI is the average of consistency index which vary upon matrix . This CR value is essential to calculate and check the consistency of pairwise matrix. If the CR value exceeds '0.10', it indicates set of decisions is inconsistent and needs improvement .

3. Study area:

The districts of Surat and Bharuch adjoin the eastern flank of Gulf of Cambay. This region covers an area of about 4200 sq. km. and extends between 72°28'E to 73°30'E longitude and 20°59'N to 22°11'N latitude. The two district have many industrial zones like Jambusar, Vagra, Bharuch and Ankleswar in Bharuch Districts and Olpad, Surat and Hazira in Surat District. Surat is the major industrial hub of the region. Besides it, the other important centres are Sachin Pandesaran, Icchapore-Bhatpore, Kawas, Hazira, Kathodara, Olpad. The Ankleshwar Industrial Estate incorporates two broad industrial zones: (1) Ankaleshwar Industrial Area (AIA) and (2) Panoli Industrial Area (PIA). Both these regions together encompasses approximately 3,000 industrial units which produce chemicals, pharmaceuticals, manufacturing dyes, paints, fertilizers, pulp and paper and pesticides (Bruno 1995; Suyash Kumar et al., 2008). This region has two major plains: Northern part is Baroda plain and southern part is Bharuch plain. Rivers Narmada and Tapi intersperse this region and they join Gulf of Khambat making estuaries. This area has low gradient slope and falls under the subtropical climatic region. It receives greater amount of annual rainfall from south-west monsoon between June and September and in the intervening month of October. The average annual rainfall ranges between 600 and 850 mm. The population of this region is about 54, 11,039 persons according to the 2011 census. This area is well connected by roads and railways line. National and State Highway major district roads facilitates the industrial development Dahej, Hazira port is operated by Gujarat Maritime Board (GMB) and also contributed to the development (District Census Hand Book 2011).

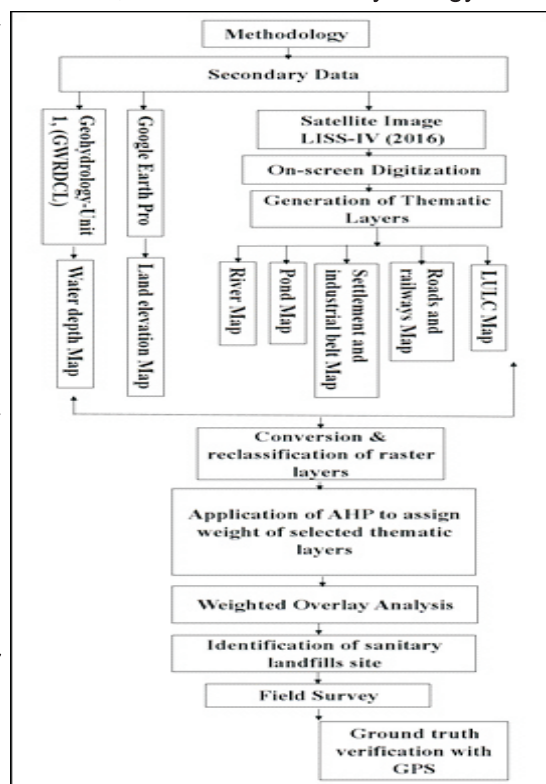


4. Methodology

The methodology of the study was divided into two phases, i.e. data collection and preparation. The spatial database used in this study was collected from the various sources. Based on Central Public Health and Environmental Engineering Organization (CPHEEO, 2016) and published literature. Seven criteria were selected for the site selection. Land elevation map was prepared with Triangular Irregular Network (TIN) using GIS analyst tools. Data of water depth

was collected from Gujarat Water Resource Development Corporation Limited, Office of the Geohydrology-Unit 1 (GWRDCL). It was further converted into surfaces using IDW interpolation technique. In addition, land use/land cover, settlement and industrial belts, roads and railways, rivers and ponds map layers were prepared by visual on-screen digitization technique from the high-resolution (5.8 m) multispectral IPS 6-LISS IV (2016) satellite imagery. All data layers were georeferenced within GIS framework using WGS 1984, UTM Projection System (43 N Zone). Thereafter, geoprocessing tasks such as buffering, clipping and reclassify were performed in ArcGIS (Version 10.2) and Spatial Analyst tool was used for Weighted Overlay Analysis. For the overlay analysis, each thematic layer was converted into raster grid format and considered as a homogenous unit which were represented as a decision criteria layer. The AHP weights were extracted using SuperDecision (Version 2.1) software.

Multi-Criteria Decision Making Analysis was applied for prioritization of criteria and weights (W) and each criterion were estimated (**Table 3**). The Consistency Ratio (CR) of all the comparisons were below '0.10' which indicated criteria weights were consistent or satisfactory. Later, for the overlay analysis, ranks were given, providing lower rank to most unsuitable area. Subsequently, the suitable solid waste disposal sites were identified. The field survey was carried out to verify the final suitable landfill sites. The GPS (Garmin GPSMAP 78S) was used to collect actual position of sites which checks the accuracy level. The methodology adoption, creation of GIS database and suitability analysis is exhibited in **Fig 2**.



Weighted Overlay Analysis Method:

Weighted Overlay Analysis is a useful method to solve the complex spatial problems in GIS environment. It allows overlying of several thematic raster's layer with the same measurement scale and weights based on their percentage of influence. This technique was used here to get a final suitability map and identify the site for solid waste disposal ; . The weighted overlay analysis is done by using the following equation:

$$WOA = \sum_{i=1}^n W_i \times R_i$$

Where, W_i is express the weight of the factor i , R_i is the selected raster layer of the criteria, n is the total number of decision criteria.

Selection of Criteria Evaluation

A suitable landfill site should be placed and designed to meet the favorable environmental and socio-economical conditions. It should maintain the safest distance from groundwater, surface water (pond, river) and pollution of the air and soil. Settlement and industrial belt aspects must also be considered for landfill site selection. It should be located near to the existing roads so that the transportation and collection costs are reduced . The analysis of selected criteria for landfill site selection is explained in the following sections

Table 3
Total weight of all criteria and subcriteria and CR

Criteria	Weight	CR	Subcriteria	Subweight	CR	Total weight
LULC	0.357	0.0682	Built-up/ water bodies/ coastal wetland	0.0524	0.0252	0.01870
			Agriculture	0.1210		0.04318
			Saltpan	0.2292		0.08179
			Barren land and Others	0.5974		0.21319
Distance from settlement and industrial belt	0.268		<500	0.0942	0.0486	0.02527
			500-600	0.1417		0.03801
			600-800	0.2143		0.05748
			>800	0.5498		0.14747
Distance from roads and railway (m)	0.133		<500	0.0979	0.0469	0.01304
			500-600	0.1304		0.01737
			600-800	0.1923		0.02561
			>800	0.5794		0.07718
Distance from pond	0.083		<200	0.1346	0.0789	0.01113
			200-300	0.1682		0.01391
			300-500	0.2362		0.01953
			>500	0.4611		0.03813
Distance from river	0.059		<100	0.0939	0.0789	0.00555
			100-200	0.1761		0.01042
			200-400	0.2472		0.01462
			>400	0.4827		0.02855
Water depth (m)	0.055		< 2	0.0910	0.0560	0.00499
			2 - 10	0.2180		0.01196
			>10	0.6910		0.03789
Land elevation (m)	0.045		<20			0.03297
			20-30	0.7324	0.00386	
			>30	0.1297		0.00584
				0.1378		0.00621

Source: Computed

Land Use and Land Cover

Land use/land cover map is an important criteria in solid management studies . It gives the clear idea of spatial distribution of the land and it also helps to predict the possible future developments. In this study, six broad categories of the land use were identified such as agriculture (76.07 %), built-up (10.15 %), water bodies (4.03 %), barren lands (8.25%), saltpan (0.73 %) and other lands (0.82 %). This vector layer was converted into a raster format for the reason of rating and providing weight values. In order, most suitable land classes was given highest weightage and least suitable lands were provided with low weightage. Thereafter, for the site selection, the unsuitable classes (agriculture, built-up and water bodies) were merged and were given low weightage. Rest of the suitable lands containing barren land, sparsely natural vegetated land and saltpan area were considered suitable for landfill siting. Each classes were defined and weightage was provided by AHP (Table 3, Fig 3).

Distance from Settlement and Industrial belt

Disposal sites are not recommended in the vicinity of settlement areas and industrial belt because they are the major sources of toxic gas emissions, noise generation, dust etc. . Therefore, according to the CPHEEO (2016), landfills are not be recommended within 500 meters of settlement areas. In this area, industries are located at Surat, Ankleshwar, Panoli, Bharuch, Dahej, Olpad, Pandeshara, Vagra and Jambusar.

In this study, distance from settlements and industrial belts were buffered and categorized into four classes as shown in Table 4. Hence, ratings and weights assigned (Table 3) for buffer zones increase with increasing distance such as <500 m buffer zone was given scored as 1 (unsuitable) and 19.34% of area was covered, 500-600 m buffer zone was scored as 2 (marginally suitable) which covered 3.10% of area, 600-800 m buffer was scored as 3 (moderately suitable) with had 6.13% of area and >800 m was scored as 4 (highly suitable) and was spread over 71.44% of area (Fig 4).

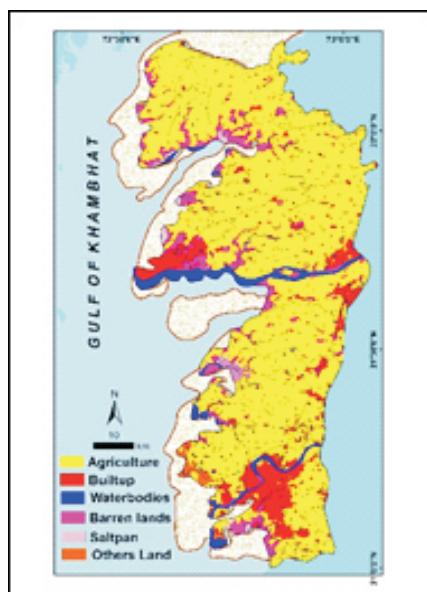


Fig: 3 Land use/land cover map

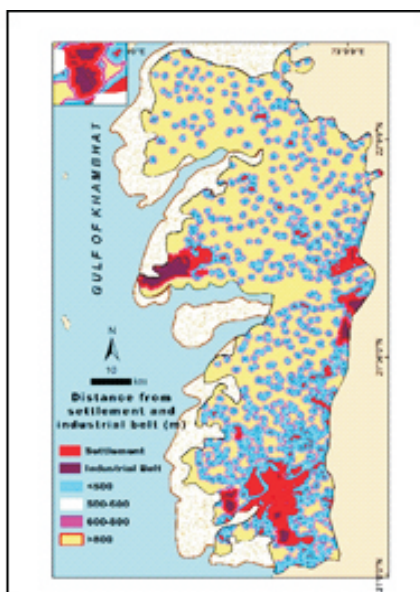


Fig: 4 Distance from Settlement and Industrial belt

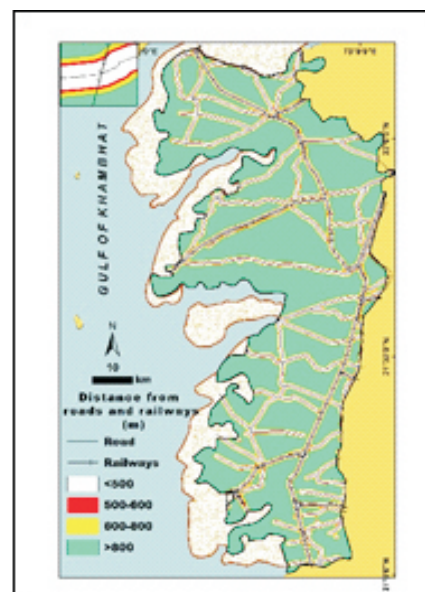


Fig: 5 Distance from Roads and Railways

Distance from Roads and Railways

Distance from the roads and railways are an important criteria for the waste management. According to waste management rules (CPHEEO 2016), landfill should be located at the distance of 500 m. In this study, buffered distance was measured from the existing roads and railways and were categorized into four separate classes (Table 3). All the buffer zones were weighted by AHP and areas that was at a distance of <500 m from roads was given scored as 1 and spread over 13.14% area, 500-600 m buffer zone was scored as 2 and had 2.49% of area, 600-800 m buffer zone was scored as 3 and spread over 4.84% of area and >800 m zone was given the highest score (4). It was spread over 79.53% of area (Table 4 and Fig 5).

Distance from River

The study area adjoins of Gulf of Khambhat and two major rivers Narmada and Tapi and other minor rivers (Mahi, Dhadhar, Kim) flow through the area. According to the (CPHEEO, 2016) regulations, landfill sites should not be located near the river because fresh water and polluted the sub surface water can merge through leaching process . River water when contaminated from waste disposal contains low dissolved oxygen which is affected by animal and plants species .

Accordingly, distance from river layer was generated and four buffer zones with specified relative distance around the river was created (Table 3). Each buffer zone were weighted by AHP. By considering all the rivers, > 400 m buffer zones were drawn for highly suitable zone and score of 4 was given and it had 80.94% of area. 200-400 m buffer zone was scored as 3 and it was spread over 6.87% area. 100-200 m buffer zone was given a score of 2 which had 3.68% of area. Lowest score (1) was assigned to a buffer of <100 m (Table 4 and Fig 6).

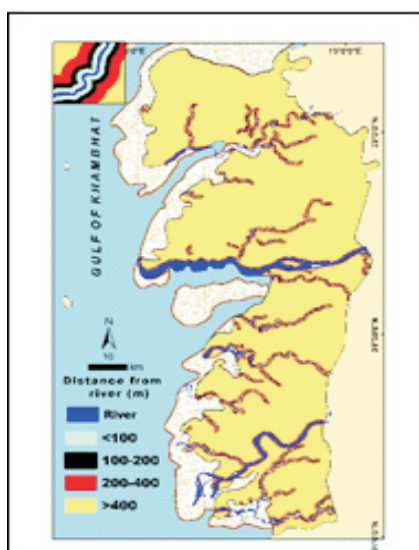


Fig: 6 Distance from River

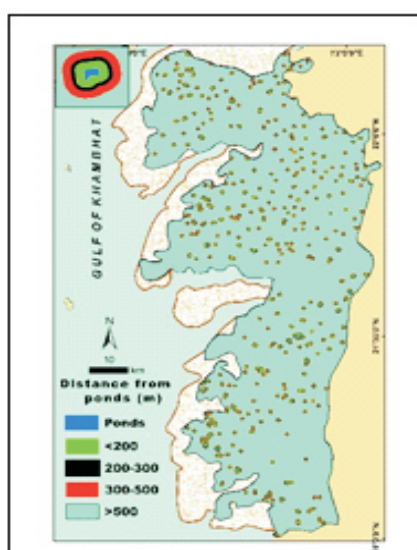


Fig: 7 Distance from Pond

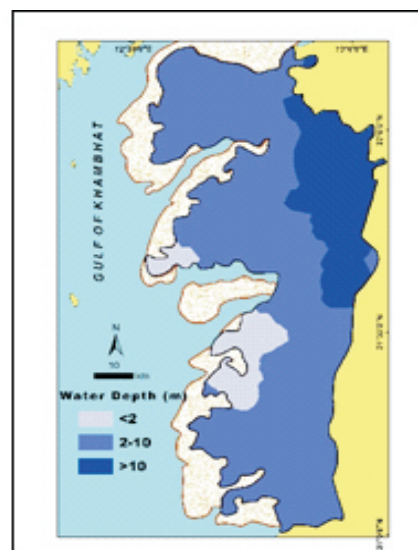


Fig: 8 Water depth

Distance from Pond

Inappropriate dumping in the vicinity of pond is a greater threat to environment and human health. Thus, dumping site should not be located nearer to the pond . According to (CPHEEO, 2016) landfill site should be >200 m. Otherwise, waste water may contaminate the soil and water by leaching process . In the study area, lakes and ponds were scattered over the entire area and were largely located near the habitats. Therefore, in this study buffer zones were produced in 4 discrete classes such as <200 m buffer zone was scored as 1 and it was spread in 2.89% area. 200-300 m buffer was scored as 2 which covered 2.01%; 300-500 m buffer zone was scored as 3, it had 5.27% of area and >500 m buffer zone was given highest score (4). It spread over 89.82% of area (Fig 7). All the buffer zones were individually weightage by AHP in Table 3 and area estimation was given in Table 4

Water Depth

Water depth is an important factor for landfill site selection. In general, sufficiently deep area is preferred for suitable site. Therefore, keeping in mind, that where shallower depth is present there landfill site should not be located because waste may affect the groundwater quality in leaching process . According to Central Public Health and Environment Engineering Organization (CPHEEO), the bottom of the landfill should be 2 m above from the highest water table. Therefore, entire area was categorized into three classes (< 2 m, 2-10 m and >10 m depth) and weighted separately by AHP in Table 3. Thereafter, map was generated using inverse distance weightage interpolation (IDW) method in ArcGIS software (Fig 8). Sites within 2 m depth area from the surface was not considered and remaining area were given high score value (Table 4)..

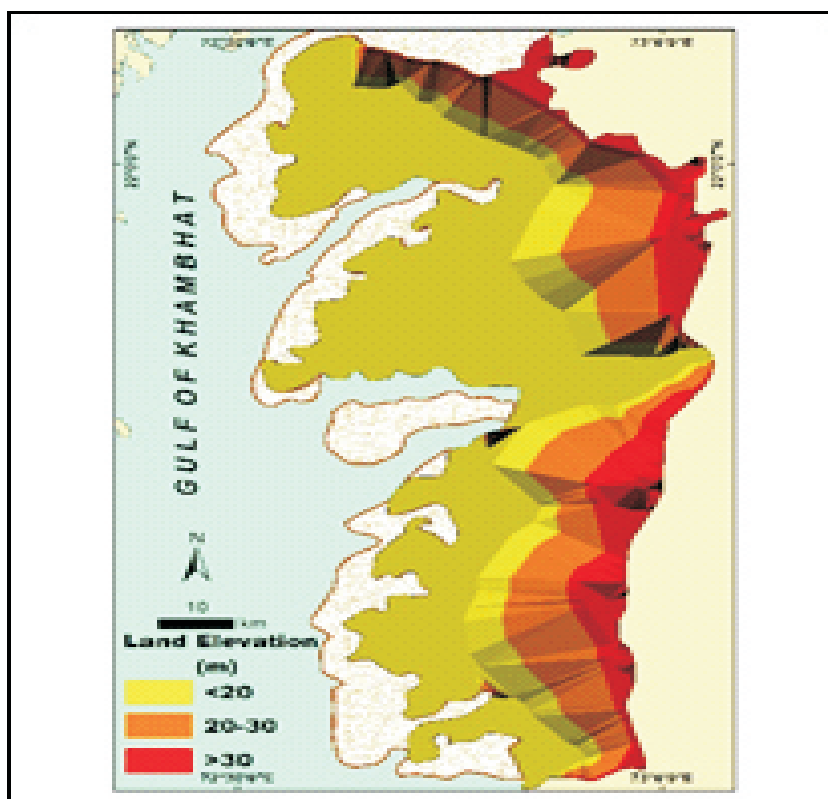


Fig: 9 Land elevation

Land Elevation

Land elevation is largely associated with landfills site selection because construction and transport operation cost is maximum at higher elevated region ; ; . The highest elevation was 47 m from the mean sea level (MSL). This elevation was divided in three classes and scores were assigned (Table 3, 4; Fig 9) e.g. <20 m was given as 4; 20-30 m scored as 3 and >30 m was scored as 2. Each buffer zones were separately weighted by AHP.

Discussion and Conclusions

The single layer final suitability map depicting the distribution of potential landfill location in four (4) discrete classes' was generated. According to estimated figures, highly suitable area for landfill sites was spread over 2.75%,

moderately suitable class covered was 71.48%, marginally suitable occupied 5.57% area and unsuitable zone encompassed 20.21% of area (Fig 10). In this study, seven suitable sites are chosen in the northern and seven in southern part. Landfill sites (Site-1, Site-2 and Site-3) are located in the vicinity of Jambusar City which is in northern part of the study area. They has an adequate space to serve for disposal of industrial waste. Site-4 is located around 5000 meters east of Sarbhan village in the north-eastern part of the study area and at a linear distance of 7000 m from Amod town. Site-5 is located at north-eastern part. This site is nearby Nabipur village, at a linear of distance 2300 m. Site-6, is located close to Vagra town is approximately 6000 m away from the center of town. This site can be considered as a suitable place for landfill because it is currently a barren land and is away from settlement. This site is devoid of waterbodies (pond, river), and railway but is well connected with roads. Site-7 is near Dahej industrial belt, at a distance about 6 km. The site is located in uncultivated area. There is no railway connectivity but is well connected with road network. Site-8, is located within 5000 meters of highway and is also outside the buffer of >8000 meters from settlement and industries. Site-9 and 10, are located at a safe distance from settlement and are accessible in terms of transport connectivity. The water depth is 6-10 m deep. Both the sites are far from proximity of industrial zones of Ankleshwar and Bharuch. Site-11, is located at north-western part and is closest to Kim, Popodara and New Padri. The site is well connected by road network (Mumbai and Delhi - NH-8). Site-12 is located at a distance of 3000 m from Olpad town. Site-13 is located in the south-western part and is near GIDC Surat (10 km). The site is found in barren land, with pond not existing in the vicinity of the site. Site-14 maintained a safest distance from the settlement area (>1000 m) and is located in the southern part of Surat City and outside the buffer zones of pond, river and biodiversity.

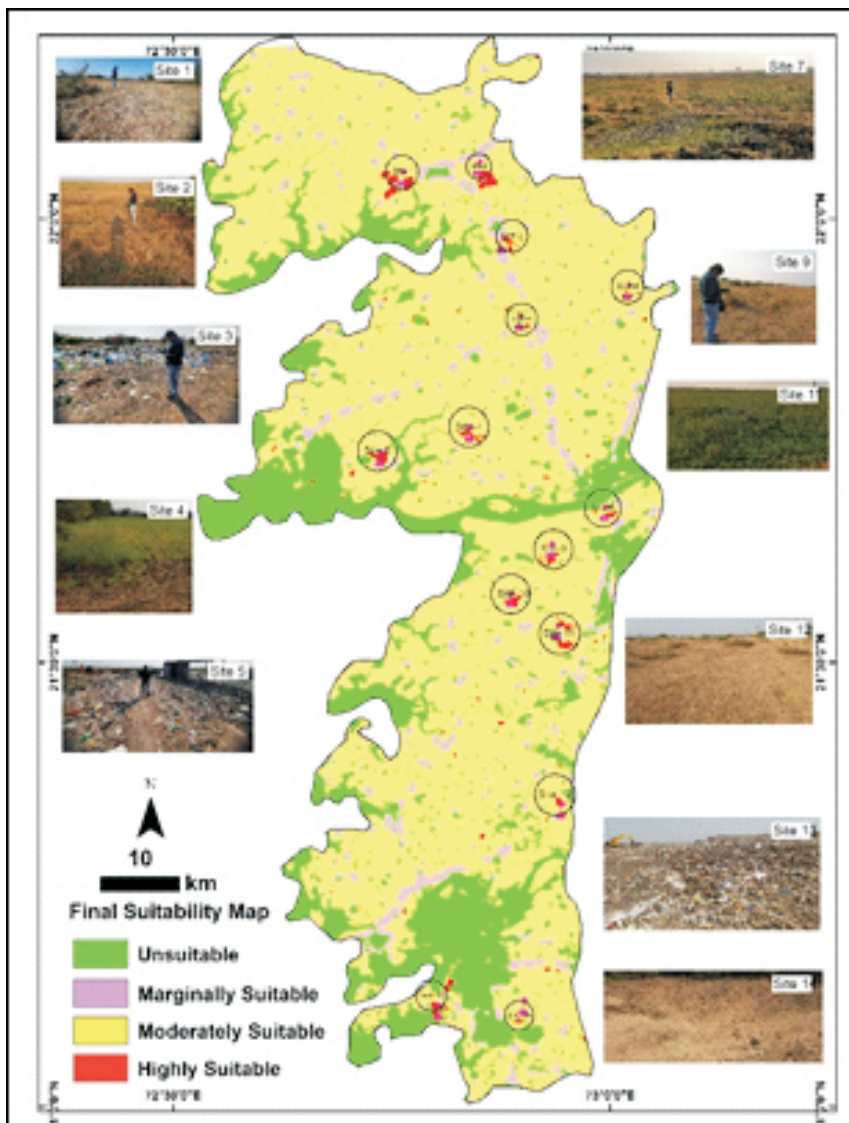


Fig: 10 Final Suitability Map

However, with the selection of new industrial waste dumping sites the pollution risk would be minimized. Hence, the technique Analytic Hierarchy Process helped in the selection of the landfill sites and the transportation cost will be minimized.

Table 4
Subcriteria areas and level of suitability

Criteria	Subcriteria	Level of suitability	Score	Total (%)	Area
LULC	Built-up/ water bodies/ coastal wetland	Unsuitable	1	14.18	
	Agriculture	Marginal suitable	2	76.07	
	Saltpan	Moderate suitable	3	0.73	
	Barren land and Others	Highly suitable	4	9.07	
Distance from settlement and industrial belt	<500	Unsuitable	1	19.34	
	500-600	Marginal suitable	2	3.10	
	600-800	Moderate suitable	3	6.13	
	>800	Highly suitable	4	71.44	
Distance from roads and railway (m)	<500	Unsuitable	1	13.14	
	500-600	Marginal suitable	2	2.49	
	600-800	Moderate suitable	3	4.84	
	>800	Highly suitable	4	79.53	
Distance from pond	<200	Unsuitable	1	2.89	
	200-300	Marginal suitable	2	2.01	
	300-500	Moderate suitable	3	5.27	
	>500	Highly suitable	4	89.82	
Distance from river	<100	Unsuitable	1	8.52	
	100-200	Marginal suitable	2	3.68	
	200-400	Moderate suitable	3	6.87	
	>400	Highly suitable	4	80.94	
Water depth (m)	< 2	Unsuitable	1	7.62	
	2 - 10	Moderate suitable	3	73.45	
	>10	Highly suitable	4	92.38	
Land elevation (m)	<20	Highly suitable	4	49.33	
	20-30	Moderate suitable	3	18.93	
	>30	Marginal suitable	2	4.67	

Source: Computed

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The Khanderi Rock: A note on its strategic importance during the 17 Century

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Abstract:

The Khanderi Rock (18.70° N, 72.81° E) is located at the mouth of the sea lane leading to Mumbai harbour. It is because of its historical significance, especially in terms of the strategic role it played in Maratha politics during the 17th-18th centuries that the rock has been renamed as Kanhoji Angre Island. Kanhoji Angre was Maratha admiral during the early 18th century who successfully established navigational control over Konkan waters in the teeth of European opposition. It was Chhatrapati Shivaji (d. 1680 CE), the founder of the Maratha *Swarajya*, who first realized the strategic importance of the Khanderi Rock – then a desolate spot, spread within less than two square mile circumference – for his naval establishment. He not only occupied, but also fortified the rock in 1679 CE. A Maratha naval outpost in the immediate vicinity of the channel leading to Bombay – the main harbour of the English East India Company [EIC] – made the EIC uncomfortable, as it enabled Shivaji to keep a close eye on the movements of vessels to and from Bombay. This included the flotilla of the Siddi of Janjira – the avowed enemy Shivaji, who used Bombay harbour as spring-board to carry-out naval depredations on adjoining Maratha territories. In panic, therefore, the EIC's Indian Marine forced a naval battle upon Shivaji, but failed to wrest the control of Khanderi rock from the Marathas. This paper argues that despite suffering from obvious technological limitations, the Maratha navy could firmly hold its ground on account of a careful assimilation of the geographical realities of the maritime surroundings in its naval strategy.

Key words: Khanderi, Shivaji, Siddi, Janjira, EIC, Konkan, Indian Marine

I

Introduction:

John Fryer (1967), the British surgeon who visited India in the late seventeenth century, gives a glimpse of the surroundings of Bombay by describing the islands of Bombay, Trombay, Elephanta, Karanja along with the Rock of Henry-Kenry as 'so many mountains arising out of sea...' Here, Khanderi, in particular, has been referred to as 'the great rock or barren islet of Henry-Kenry'. It need not be reiterated here that after the landing of Vasco-da-Gama at Calicut in 1498 CE, the Portuguese dominated the sea lanes of the Indian Ocean and the Arabian Sea largely on the strength of their superior and well equipped armada supported by coastal strongholds all along. The seventeenth century saw the Portuguese naval power in the East being challenged vigorously by the English and the Dutch Trading Enterprises. By

the second half of the seventeenth century the balance of power over the Indian seas had more or less settled in favour of the English and the Dutch. Both, however, tried to create their maritime spheres in such a manner so as not to interfere with each others' domains. Naval power had been the basis of the European control in the East. Hence, like the Portuguese, the English and Dutch also looked for having their own naval bases – coastal as well as off-shore. The English East India Company [EIC] had an eye over Portuguese Bombay for such reasons. Bombay was described as 'nothing but a group of small islands, with numerous backwaters, producing rank vegetation, at one time dry, and at another overflowed by the sea... that the older travellers agreed in allotting not more than three years for the average duration of life there...' (Hamilton, 1971). Notwithstanding, however, the EIC still showed extreme urgency in getting control of it from the British King Charles II who had received it as a part of dowry from the Portuguese in 1662 CE. The EIC subsequently got it on lease from the British Crown in 1668 CE. By the next year the island was garrisoned and works on a triple layer of fortification was taken at hand (Fawcett, 1936). The fortification of Bombay was further expedited in the wake of the sack of Surat by Shivaji in 1670 CE (Duff, 1980). The defenses of the island were also strengthened by bringing under control all the fordable creeks like, Mahim, Sion, etc. Bombay soon became a centre of boat-building; gunpowder was also being manufactured and stored by the EIC at Bombay in good quantity (Fawcett, 1936). The isolated location of Bombay aided to its gradual makeover as a naval base by the EIC on the western coast of India (Kosambi, 1985). Owing, thus, to the obvious strategic advantages Bombay offered as a base in comparison to other English settlements on the Indian coast, the EIC, in 1687 CE, shifted its headquarters from Surat to Bombay. Subsequently, the Indian Marine Service – the EIC's small armada, which was founded in 1613 CE to protect Company's trading vessels in the Indian waters – was rechristened as the Bombay Marine (Low, 1985). It should be noted here that the territory adjoining Bombay mostly belonged to the Portuguese and the Marathas. As a result Bombay, which did not produce anything, was dependent on its adjoining areas for the supply of food-grain, cattle and other provisions (Edwards, 1909).

II

Chhatrapati Shivaji had organized the Maratha race into a nation which he called the *Swarajya*. The nascent Maratha state integrated Konkan – the narrow stretch of fertile land along the west coast – also known for its riches on account of overseas trade and commerce (Tamaskar, 1979). While consolidating his hold over the Konkan coast, the Maratha visionary quickly figured out that to have an effective control of the coast he also needed a naval set up. Hence, when he set the keel afloat around 1659 CE, in the back of his mind it must have been the overawing big, armed ships of the European nations plying across the west coast. In addition, the threat posed by the flotilla of his avowed enemy, the Siddi of Janjira – at that time a servant of the Adil Shah of Bijapur – also called for his immediate attention. Contemporary Portuguese documents make the earliest mention of Shivaji's naval enterprise which seems to have benefitted from Portuguese expertise particularly in ship-design and fire-power aboard (Pissurlencar, 1967). As Shivaji had amicable

relations with the Portuguese government at Goa, to ward-off any confusion in their mind, he declared that the main purpose of his navy was to fight against the Siddi of Janjira (Sabhasad Bakhar, 1920).

Throughout the medieval period, right from the establishment of the Delhi Sultanate, it has been seen that adventures belonging to many races immigrated to India in search of better fortune. Abyssinians or the people of African origin were one such group- generally referred to as the Siddi (Ali, 1996). A group of Abyssinians settled along the west coast of India, and had gradually come to occupy the offshore island of Janjira (18.29° N, 72.96° E). They subsequently fitted out a fighting flotilla. The local, land based rulers usually roped them into their services- mostly for the ferrying of the *Haji* pilgrims. In return, the Siddi chief of Janjira would get a *Jagir* or a stretch of land near the coast for subsistence. Janjira, being an island fortress, also offered strategic advantages to those who possessed it. When Shivaji's army overran the Konkan sometime during the middle of the 1660s, it came across the Siddi of Janjira. In the ensuing fight, the Maratha forces cornered the Siddi in such a manner that the Siddi had to take shelter in his island fortress of Janjira. Shivaji, whose navy had become fully functional by that time, simultaneously launched a naval campaign against the Siddi. Accordingly, the Maratha navy virtually enforced a naval blockade of Janjira, but failed to capture it or even make a dent on it owing to its high walls over which heavy artillery was placed. The failure to wrest Janjira from the Siddi impelled the Maratha visionary to look for similar strong points along the coast and, thus, undertake the occupation of the desolate Khanderi rock located at the mouth of the Bombay harbor, more than a decade later. In this duration, Shivaji never stopped thinking of the ways to augment the capabilities of his naval set up. The English Factory Records take note of the numerical strength and organization of the Maratha naval strength at that time. The Maratha flotilla was divided into two naval *subah* or maritime territorial zones, each overseen by an admiral. There are different estimates of the numerical strength of the Maratha fleet ranging from 150 to 400 vessels of various types (Sen, 1979; Low, 1985; ERS, 1931). The *Sabhasad Bakhar* (1920), a contemporary account of Shivaji, prepared by one of his courtiers named Krishnaji Anant Sabhasad, mentions the names of Mainak Bhandari and Daulat Khan as the top commanders of the Maratha navy during the reign of Shivaji.

It would be relevant to have an idea of the philosophy of the Maratha navy as outlined in the contemporary Maratha documents. The Maratha naval philosophy has two main components: (i) assimilation of the geographical features in the construction and usage of Maratha vessels, and (ii) policy directives vis-à-vis naval defense of the *Swarajya* and its overseas trade and commerce. The *Rajniti* of Ramchandra Pant Amatya (1929), a state policy manual of the Marathas, outlines that ship of medium size, which does not require much wind for navigational maneuverings, should be made. This principle was in accordance with the coastal surroundings where wind velocity dropped, making it difficult for the bigger ships, mostly belonging to the European nations, to maneuver. The policy further recommended that lighter rowing boats with flat bottoms should be constructed. Such vessels had dual advantages. First, during naval duel, they were faster to attack or retreat; second, their flat bottoms allowed them to navigate in shallow waters and take shelter in the numerous coves and creeks dotting the Konkan coast (Spate & Learmonth, 1967; Deshpande, 1948). The

biggest advantage was that since the Maratha vessels offered war near the coast, they could not be chased down by bigger or deep-hulled European vessels without the fear of hitting submerged rocks or sand banks and, thus, running aground. The *Sabhasad Bakhar* (1920) further elaborates upon the philosophy of the Maratha navy. It notes that the sea-going ships and the sea forts were the two arms of navy, uniting which Shivaji sought to 'saddle the sea'. This is enough proof of Shivaji's ingenuity in his naval endeavors. Further, we get to know of the strength and strategic location of Maratha naval forts from the accounts of contemporary travelers. For example, Bartheleme Carre, who visited India during the reign of Shivaji, mentions that Shivaji selected such maritime places as were easier to defend and more difficult to attack (Sen, 1977). The *Sabhasad Bakhar* provides a list of fortified maritime locations along as well as off the coast, garrisoned by Shivaji. Duff (1986), who published the first comprehensive account of the Maratha History in the early nineteenth century, also noted that Shivaji occupied, repaired and provisioned the coastal forts which he had taken from the enemies. Aware of the strategic value of an offshore naval base, one of the earliest things that Shivaji did was to construct naval headquarters of his *Swarajya*. It was an off-shore stronghold which was christened *Sindhudurg* which literally translates into 'Ocean Fortress'. By 1665 CE, the Maratha fleet was so well organized that Shivaji felt the need to 'test the waters' by undertaking the famous Basrur naval expedition. His presence on-board lifted the morale of the Maratha fighters (Shejwalker, 1942).

On the nature of Maratha naval vessels and the philosophy of the Maratha navy, it has been argued by Jadunath Sarkar (1973), the Modern biographer of Chhatrapati Shivaji, that the purpose of the Maratha navy was never to fight against the Europeans since it was essentially weak. Prima facie, Sarkar's argument seems convincing. We do not come across any such contestation of the Marathas with the Europeans which could be categorized as terminal in nature, whereas the Maratha-Siddi naval contest always took the shape of a 'mortal combat'. The Maratha navy might appear weak in comparison with the Europeans, but it was well adapted to operate in the coastal surroundings. It incorporated the geographical realities in its strategy and tactical operations in such a manner so as to minimize its dependence on a pivot weapon. We have reference of Maratha naval skirmishes with the Europeans in which vessels or men or both were held at ransom for arriving at a settlement. In fact, a thorough perusal of the Maratha policy document makes us believe that Shivaji was in a position to use his navy for advancing his political interests. The *Rajniti* (1929) elaborates that by sending an assurance of safety to seafaring merchants belonging to foreign countries, they should be persuaded to come and settle at various ports. Shivaji, thus, tried to regulate the movements of the European traders in the Konkan surroundings by issuing navigational passes (Apte, a.1967; b.1973). The defaulting vessels, so found after thorough inspection of navigational pass they possessed, were escorted by the Maratha patrolling vessels to the nearest Maratha ports where they were confined for further search and examination. If the confiscated vessel belonged to a European or any 'enemy nation', an inventory of the goods it was carrying, along with its estimated value, was diligently prepared. The port officials were strictly warned not to pilfer any goods from the confiscated vessels till the time a settlement was arrived at with the concerned party. The Maratha naval action, therefore, does not fall into the category of commerce raiding

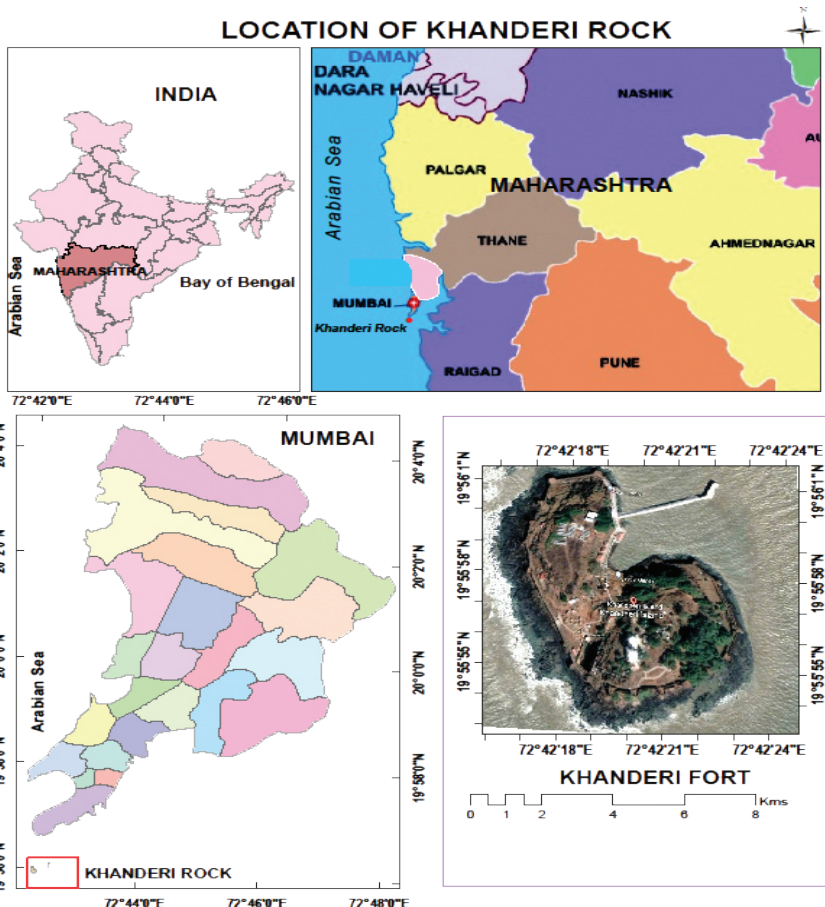
during the reign of Shivaji. The confiscation of vessels, in this manner, seems to be a well considered policy where the navy was being used as a tool for furthering the political interests of the Maratha *Swarajya*. The confiscated vessels, along with their goods and crew, were used as a bargaining chip. In fact, some specific demands of money, arms, trading concessions, etc. could be negotiated in this manner. The vessels and goods were mutually restored after negotiations. The entire exercise seemed to stop where coercion started. V. B. Kulkarni (1963), another modern biographer of Shivaji, argues that 'Shivaji's dealings with the European traders in India were marked by caution and kindness and, at the same time, by a determination not to allow them to encroach upon his *sovereign* rights.' (Italics mine) Thus, by entering into serious naval conflict with the Europeans, Shivaji, under no circumstances, would have liked to disregard the lucrative prospects of trade and commerce offered by them. The Rajniti (1929) also confirms the same by recommending that trade should be increased as it will cause the growth of income from customs.

III

As noted above, the Maratha navy, despite its best efforts, had failed to wrest the island fortress of Janjira from the Siddi. The Siddi, on the other hand, was put into great distress because of the relentless naval pressure of the Marathas. The Siddi's master, the Adil Shah, was unable to provide him succour during the Maratha offensive. Under duress, the Siddi, therefore, approached the Portuguese and allegedly transferred his allegiance to sometime in 1667 CE. A perusal of Portuguese documents, confirms that the 'new masters of the Siddi' supplied him with rice and other essentials during the Maratha blockade and kept him well fed (Pissurlencar, 1967). The fact remains, however, that the Portuguese could not openly come in support of the Siddi, perhaps because of the fact they had amiable relations with Shivaji, and they did not want to give him offense. On the other hand, the EIC was keeping an eye over the developments in the wake of the Maratha-Siddi naval contest. On pretext of playing arbitrator in this contest, the EIC thought of acquiring Janjira from the Siddi (ERS, 1931). The EIC's desires, however, did not fructify as the Siddi, who had been cornered by Shivaji, decided to join the Mughal services instead, in 1671 CE. Interestingly, the change of Siddi's loyalty happened in the background of some serious political developments. Owing to relentless Maratha pressure, the discontented Siddi nobles had planned a coup to remove him. The conspirators contemplated handing over Janjira to Shivaji in exchange for lucrative *jagirs* to settle down. The plan of the 'castle revolution', however, was discovered in the nick of the time, and the damage control exercise done (*Muntakhabu-l Lubab*, 1952). The Siddi chief immediately approached Aurangzeb – the staunchest of Shivaji's adversaries, for help. Aurangzeb, thus, entered into an alliance of convenience with the Siddi of Janjira who was appointed as the Mughal admiral on the west coast. With the Siddi fleet with him now, Aurangzeb – the pious Muslim – did not have to bother about the safety and security of the Mughal convoy for the annual *Haji* pilgrimage. The Mughal-Siddi union tended to tilt the balance of power in favour of the Siddi who got a free hand to deal with the Marathas on the sea. The Mughal military reach against the Marathas also considerably extended as Shivaji's attention was now divided on two fronts. On the other hand, because of the elevated status of the

Siddi as the Mughal admiral, the EIC had to, perforce, cooperate in his naval adventures against Shivaji. The EIC extended the facilities and courtesy of Bombay dock to the Siddi on numerous occasions – be it for wintering of his vessels or for supply of water and other provisions (ERS, 1929). The English sponsorship to the Siddi in this way did invite the anger of Shivaji. In return, he would put pressure on Bombay – surrounded by Maratha territory – by denying grains, provisions and other essentials to pass through his territory. The EIC authorities at Bombay did appraise the ground situation – particularly their vulnerable position vis-a-vis the Marathas – to the Company's headquarters at Surat. But Surat had its own compulsions. Being located within the Mughal territory, it was vulnerable to seizure from the Mughals. The larger commercial interests, therefore, compelled the EIC authorities to keep the Mughals in good humour. In this way, more than often, the practical considerations of Bombay was overlooked or not given priority by the Company's Governor at Surat. The threat of Maratha invasion, thus, always loomed large over Bombay. Documentary evidences further suggest that Shivaji warned the EIC officials that he would offer military support to the Dutch Company to capture Bombay if the English did not desist from aiding the Siddi in his misdemeanours against the Marathas (Kail, 1981; ERS, 1929).

The failure to capture Janjira from the Siddi coupled with the latter's joining hands with the Mughals further required Shivaji to expand naval defence of the *Swarajya* and especially think of having more off-shore bases on an urgent basis. It was under such circumstances that Shivaji came across the idea of occupying the Khanderi rock. The Khanderi rock, as noted above, was located near the channel leading to the Bombay Island (see the map on the facing page). In fact, it was the location of the rock which the Maratha visionary wanted to make strategic use of. He knew that it would be an absolute wastage of his resources if he picked up a naval fight with the EIC. However, by converting this barren rock into a fortified naval station, the level of the capacity of his naval set-up would have greatly expanded. After all, the principles of naval warfare in the pre-modern period also epitomized that it was the latent capacity to fight that



gave meaning to the use of naval force in connection with negotiations with other powers. The purpose of Shivaji vis-a-vis the EIC, in this case, was to discourage it from facilitating Siddi's anti-Maratha activities. The Siddi used to shelter a large portion of his fleet annually at Bombay because he had lost most of his coastal footholds to the Marathas. There was virtually no safe haven to overhaul his ships to escape the ferocity of monsoon. In addition, there was persistent danger of the beached ships being put to fire and destroyed by the Marathas, if left unguarded. What annoyed Shivaji most was that the Siddi used Bombay as a spring-board to launch his naval raids on the adjoining Maratha territory. A naval watch point at Khanderi, thus, would have enabled Shivaji to keep an eye over the movements of Siddi's vessels and take anticipatory measures.

With such considerations in his mind, Shivaji planned to occupy and fortify the Khanderi rock. It was in the summer of 1679 CE that the Maratha troops landed there with construction materials and other provisions. The work of fortification commenced immediately. By the time Bombay could get to know about it, the Maratha troops were in complete control of the rock. The very thought of the presence of an 'enemy post' at Khanderi made the English uncomfortable in view of the danger it could pose to the navigation of Bombay. The EIC, therefore, immediately protested the Maratha action (Fawcett, 1936). The EIC laid claims over the Khanderi rock and asked Shivaji to immediately stop construction activities and vacate it. But Shivaji refused to oblige. In military terminology, through forcible occupation and fortification of the uninhabited rock of Khanderi Shivaji achieved the 'geographical objectives' of his military machinery, i.e., to overthrow the enemy from strategically important areas and to prevent them from occupying one. It is difficult to comprehend as to why the EIC did not claim or fortify the barren rock earlier. In fact, it is believed that the very location of the rock had earlier tempted the Portuguese too, to occupy it. But they had to abandon the idea because of non availability of drinking water over there (ERS, 1929). Whatever the case may be, in panic, the EIC decided to settle the matters right with the Marathas by making use of its naval prowess. In December 1679 CE, the EIC's Indian Marine, therefore, entered into a direct naval confrontation with the Marathas over the control of the Khanderi rock – a desolate piece of barren rock, a little less than two square miles in area.

We may, for the sake of our argument here, forego the lengthy details of the Anglo-Maratha naval contestation for the Khanderi rock. The details of the naval engagements on a daily basis can be found in the English Factory Records. Here, we would take into consideration the strategy adopted by the Marathas. To ensure unopposed completion of fortification of the rock, the Maratha navy needed to prevent the EIC's Indian Marine from coming near the rock. It should be noted that the war-vessels of the EIC's Marine were better equipped and commanded superior fire-power. Despite this advantage, the India Marine still hesitated to come near the rock either to land troops or to undertake bombardment of Maratha naval positions. The reason behind this was the shallow waters and submerged rocks in the vicinity. It is strange to note that even though the Indian Marine had been operating in this region for the past 75 years or so, the idea of charting the adjoining waters never fascinated it. Hence, in the absence of vital geomorphologic information, the Indian Marine couldn't adopt an offensive posture in this engagement. Though, a few of its vessels

attempted to break through the Maratha formations, but they were beaten back by the Marathas whose small vessels outnumbered the reluctant, un-coordinated and half-hearted attempts of the English vessels. Further, for fear of the submerged dangers, the Marine could not make effective use of its artillery fire by venturing near the rock. It, therefore, tried to enforce a naval blockade so as to prevent Maratha men and materials from reaching the Khanderi rock. But, in the expanse of the vast sea, it was difficult to keep a guard on all the points. The Marathas, thus, did not find it difficult to evade the blockade owing to their familiarity with the surroundings. They could, at ease, ferry men and necessary materials required for the fortification of the rock in their numerous small, flat-bottomed vessels. The English records confirm that the 'small and swift' Maratha vessels used to slip through the English cordon in the dark of night, much to the embarrassment of the Indian Marine (ERS, 1931; Fawcett, 1936). At this juncture, the EIC sought the support of the Siddi of Janjira and planned a 'joint naval venture' against the Marathas. But, the Siddi subsequently fell out with the EIC over the distribution of the spoil of war (Fawcett, 1936). He left the Indian Marine alone, and went on to occupy another very small rock called Underi. It may be added here that so far as the objective of unobstructed fortification of the Khanderi rock was being realized, Shivaji did not consider it prudent to pick up or provoke naval fight with the EIC's Indian Marine. It was crucial for him not to waste the limited resources of his nascent *Swarajya*, and preserve them for future usage. After some times, the EIC also understood the futility of continuing with the conflict. Accordingly a treaty of peace was signed between the two sides early in 1680 CE (Fawcett, 1936). Shivaji did not live long to reap the benefits of having such a naval outpost under his command. However, during the early eighteenth century, the Maratha admiral Kanhoji Angre made the best strategic use of the Khanderi rock and virtually exercised his navigational control over the entire stretch of the sea adjoining the Konkan coast.

Conclusion:

In conclusion, it may be said that Shivaji was far ahead of his times when he laid foundations of navy for his *Swarajya*. Though, in the seventeenth century, it was too early to think in terms of European imperialism on the strength of naval power, Shivaji was alive to the needs of his *Swarajya*. He was absolutely mindful of the importance of coastal and off-shore bases for the naval defence of Maratha *Swarajya*. The occupation and subsequent fortification of the Khanderi rock reaffirms his military ideology. It is to be understood, however, that at that time the Marathas lacked both- resources as well as technological knowhow, which made any Euro-Maratha naval contestation look asymmetric. But a perusal of the Maratha policy documents proves that to overcome the expected naval shortcomings thus, a careful assimilation of geographical knowledge of the surroundings was always recommended in the naval policy. The numerous small, flat bottomed Maratha vessels not only made mockery of the EIC's naval blockade in this case, but also denied the former to carry any advantages of technology or fire power in the actual theatre of conflict. One of the principles of guerrilla warfare is to know when to disengage and disperse using the knowledge of the surroundings, thereby keeping the assets intact. In case of the contestation for the Khanderi rock, Shivaji's navy rather ensured when not to pick-up or provoke a war and achieve the desired outcome. The strategic purpose for which Shivaji undertook to occupy and fortify the Khanderi rock

was, in due course of time, fully realized by Maratha admiral Kanhoji Angre in the early eighteenth century. The Maratha navy under Kanhoji Angre was in full control of the coastal navigation.

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Changing land use pattern and its sustainable management of Anuppur, District, M. P.

✉ **Chandramauli
Jeetendra Singh Dhurve**

Abstract

The land is one of the most prestigious natural gifts of nature, which provides basic amenities for the survival of human beings as well as all living organisms in the environment. It is also important for the biodiversity of environmental sustainability. Land use means the utilization of land for different purposes in a particular area and time by the people. The land use pattern is the result of the long-term relationship between the natural environment and humans and comprises all types of land that are utilized for different purposes which are mainly determined by the physical, socioeconomic, and institutional framework at a particular time of an area. The rapid population growth is a highly affecting factor in the changing of land use patterns and declining the availability of per capita agricultural land in any area. The growth of population is increased in the residential and commercial areas of the district. Anuppur is one of the newly created districts in 2003, therefore many construction activities are going on i.e., industry, dams, roads, institutions, governmental organizations and mining activities, etc. resultant agricultural and forest areas are converted into residential and other purposes, which are directly affects the land use pattern continuously in the district. These changes of land use create different problems for the people like that decreasing of agricultural land which is creating food problems, forest degradation creates climate changes (change rainfall, temperature, wind speed, etc.), etc. In the study, area population is increasing at a faster rate while the productions of crops are limited whose are unable to fulfill the requirement of food for the society. To ensure food security, there is a need to make a proper plan for monitoring and planning of land use to maintain the imbalances of food production and requirement of sustenance of the people. The study of land use is very relevant to understanding the relationship between man and land, and monitoring current land use, pressure on land, the rate of degradation, possibilities of planning land. It is necessary for the assessment of the land use for the improvement of the economic situation of the area and motivates people for the rational utilization of land. The present study is an attempt to identify and analyze the changing land use pattern in the Anuppur district and identify the problems and prospects.

Keywords : Land use, Land use pattern, Agricultural land, Population pressure, Sustainable management

Introduction

Land resource is one of the most prestigious resources given by nature, which provide the basic amenities for the human being as well as another organism in the environment. "Land is a scarce resource, whose supply is fixed for all practical purposes at the same time. The demand for land for various competing purposes is continuously increasing with the

increase in human population and economic growth” (Mangalagowri B & H Nagaraj, 2017). Land use is the surface utilization by human beings according to their needs. Land use pattern is the outcome of a close relationship between man and the environment. “Land use is any kind of permanent or cyclic human intervention on the environment to satisfy human needs and the land use capability or land suitability is the potential capability of a given tract and to support different types of land utilization under given cultural and socioeconomic conditions (Vink, A.P.A. 1975)”. Land use pattern is the product of interaction between society's cultural background and its physical needs, and the natural potential of land on the other hand (Balak R. and Kolarkar, 1993).

“Land is an essential resource given by nature to mankind hence it is the basic resource of human society. Land use is the surface utilization of all developed and vacant land at a specific point at a given time and space. This leads to the village farm and the farmer to the fields, garden pastures, fallow lands, forests, and the isolated farm steam (Freeman T.W. 1968). The land is necessary for human survival because it provides mean with living space, with food, and with several raw materials which are used in the satisfaction of his wants. But as necessary as the land factor maybe, a man plays an important role in conditioning and transforming his physical environment” (Barlowe, R.1963).

The patterns of land use are a dynamic and multifaceted phenomenon. Land-use change is a dynamic process that occurs on biophysical surfaces over time and space, and it is extremely important in studies of the natural resource. The dynamics of land-use change are an essential aspect for the evaluation, protection, monitoring, and planning of land resources for sustainable development. The changes in land-use patterns are the fundamental concerns and challenges of ecological and sustainable development of economic growth in any region. With increases in population human activities such as deforestation, overexploitation of resources, soil erosion and degradation, pollution, and global warming are becoming increasingly damaging to the environment. The means of land use is the basic utilization of all vacant and used land at a certain time in a specific area. Primarily land use for agriculture, forest, pasture, residential, industries, mining, transportation, commercial, unculturable waste, barren and fallow land, etc. “Land use activities whether converting natural landscapes for human use or changing management practices on human-dominated lands have transformed a large proportion of the Earth's land surface” (Kuchay, S. A. and Ramachandra, T.V., 2016).

Land use is principally determined by the various factors of physical, economic, social activities, in which physical factor includes geology, topography, soil, climate, and vegetation, etc., the economic factor includes the availability of inputs, credit, capital, and market, etc. and the social factors include the relationship, characteristics, and tendency of farming in human society. The political factor also affects the land use with the formulation and implementation of acts and regulations. Although currently, technological advancement is one of the most effective factors for the changing of land use patterns in any area. “Historically, land has been an important part of Earth's physical environment with different natural and human uses. The development of human civilization makes man wiser and more efficient in the use of resources and when equipped with scientific skills and knowledge, the land becomes the most important natural resource that would be transformed to fulfill its needs for a different purpose. He began to convert the natural landscape into cultural landscapes as new land uses. As a result, a variety of land use categories have emerged globally. Reflections on the interaction between man and nature decide the composition of the land uses of a particular region in any dimension” (Ahlawat, J., 2017).

Inadequate land use generates various forms of environmental degradation thus, for the sustainable utilization of land is essential to know the physical characteristics of the location, area, potentiality, productivity, and limitation of different uses of lands in any region. For the understanding of degradation and best possibilities of land use, spatial and temporal analysis are essential of any region in a certain period. The study of land use is of great relevance to ensure to provide a better yield of land to meet needs for food, raw materials for industry and provide for effective planning of urbanization, transportation, agricultural growth, area development and thereafter accelerate the development process in the study area. It is also valuable for planners to assess the potentiality and possibilities of land use planning with their capacity and expansion of intensive use of the area and keep away from inadequate trends of land use patterns. In the early periods, population and their needs were limited. The enormous increase of the human population and their requirements has become more complex and the resultant creates changes in utilization of land and cropping patterns. "Due to the increasing pressure of human and livestock population on the land and ever-growing demand for food and raw materials, there is a bare need for scientific, rational, and economic use of every piece of land without disturbing ecological as well as the socio-economic balance of the area" (Shah, A.H. et al., 2013).

The land-use study is very relevant to understanding the relationship between man and land, and monitoring current land use, pressure on land, the trend of degradation, possibilities of land use planning. Currently, it is necessary to assess and plan for the sustainable utilization of land for the improvement of the economic situation of the area and motivate rational utilization of land.

Review of Literature

Many studies are done in the field of land use patterns. The study of land use patterns in any area is very important because they indicate the development condition of the area. Land is one of the most significant natural resources, that's quality majorly affects the economic growth of the area. Reenberg and Lund (1998) studied the land use and land rights dynamics in eastern Burkina Faso. Adeoye, N.O. (2012) studies relied on satellite images and Geographic Information System (GIS) to analyze the land use and land cover change in Lokoja, a confluence town in Nigeria between 1986 and 2007, and assessed the underlying factors and decision variables for land-use change. Tsarouchiet, et al (2014) studied the historical and future land cover changes in the Upper Ganges basin of India, his study focused to evaluate and understand the dynamics of land cover changes by monitoring and analyzing the spatial patterns of change at a high resolution. Malgorzata and Beata (2018) address the changing land use pattern in Malopolska. Agriculture land is converted into non-agricultural uses year by year. Karwariya, S. and Goyal, S. (2011) study the land use and land cover mapping of Tikamgarh district, Madhya Pradesh, using Remote Sensing. They have used satellite imagery to prepare the land use and land cover map. Tiwari, M.K. and Saxena, A. (2011) studied the status of land use and land cover areas around Mandideep and Obedullaganj between 1967 and 2003 intending to detect the land consumption rate and the changes that have taken place in this statue using both GIS and Remote Sensing data. Tamilenthir and Baskaran (2011) highlight the changes in urban development using Geospatial technology in Salem City of Tamil Nadu. Garg, Joshie, and Choudhary (2013) analyze the changing land use pattern at the coalfield region of Jamuna-Kotma, Anuppur district (M.P.) using Toposheet (1973) and satellite imagery of 2000, 2009. Singh, Brijender, and Singh, Joginder (2014) have studied land-use changes in Delhi using Remote Sensing and GIS techniques. Based on the study, they prepared the

map for the different periods and suggested that there is a great need for sustainable management of land resources. Manivel and Thirumalai (2015) analyze the land use /land cover for Perambalur district using Remote Sensing and evaluate the agricultural resource using GIS and GPS technology. Ahlawat Joginder's (2017) studies are identified and analyzed the pattern of existing land use patterns in Kanpur city. He finds that the demographic and economic factors are promoting the expanding city outward to fertile agricultural land. Reddy et al (2017) prepared maps using GIS software; ground truth observation is used to validate the result of classification. He concluded that the exploitation of natural resources is increasing with the urban sprawl and has modified the pattern of land use and land cover. Pandey and Ranganathan (2018) examine the dynamics of land use patterns in India with a focus on fallow lands. They are finding that there has been a continuous expansion in land for non-agricultural uses mostly diverted from the ecological sector. Mahato, M.K. and Jana, (2019) studies the landform characteristics of the Salda river basin and its impact on agricultural land use patterns and they analyzed the typical geomorphic attributes and their effect on the current productivity of the land.

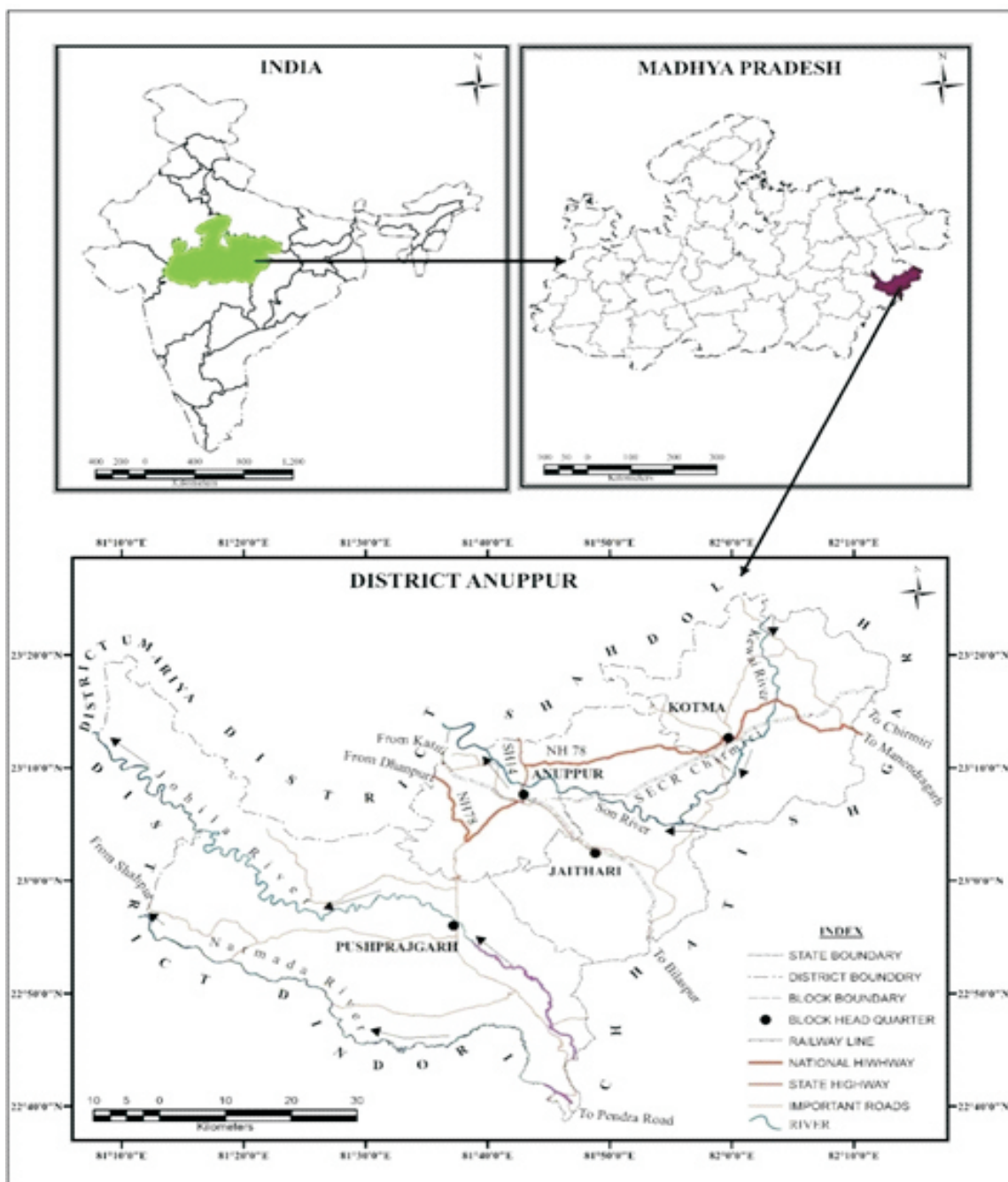
Study Area

The Anuppur district came into existence on 15th August 2003, by the restructuring of the district Shahdol of Madhya Pradesh. The district is popularly known for its hilly, plateau, valley, and undulating topography with rich biodiversity. The Anuppur district is geographically located between 22° 70' to 23°25' North Latitude and 81°10' to 82°10' East Longitude. The Anuppur District is bounded in the north by Shahdol district, in the West and South-West by the Umariya, and Dindori districts, and in the South and East portion by Pendra-Gaurela-Marvahi, and Korea districts of Chhattishgarh State. The Anuppur district extends from north to south is 86 Km and from east to west is 117 Km. The total geographical area of the district is 3,747 Sq. Km (3,74,671 ha) and the whole district is divided into four Tehsils and Blocks i.e., Anuppur, Jaithari, Kotma, and Pushprajgarh. The district Anuppur is one of the tribal-dominated districts of Madhya Pradesh, where are 47.85% tribal population, namely Gond, Baiga, Panika, Kol, Agariya, etc.

Statement of the Problem

Anuppur District is a newly created district so that many construction activities such as buildings, dams, roads, industry, institutions, etc are ongoing unsystematically, resultant the land-use patterns have highly changed. The Anuppur is known for its unusual topography, because there are maximum areas are covered with hilly, plateau, valley, and undulating plain. On the other hand, the growth rate of population in the Anuppur district is high, (12.3% according to the 2011 census), so that the population pressure on land is increasing and the ratio between man and land is decreasing. In the Anuppur district, the major activities are going on the unplanned way; resultant fertile agricultural land has been captured into residential, industrial, transport, and mining purposes, etc., and agricultural activities are extended in forest area day today. Agricultural land is converted into barren land in different ways; consequently, it is a must to the assessment of current land use and adopted proper planning of land, in this way the fertile land will be saved and used with sustainability in the Anuppur district.

Fig.1:
Location Map of District Anuppur, M.P.



Source: Census of District Anuppur

Objectives

The main objectives of the study are-

1. To study the proportion of area under different land use category
2. To analysis the temporal changing pattern of land use
3. To analysis the impacts of changing land-use patterns and planning for sustainable management

Data Source and Research Methodology

The present study is based on secondary data which is taken from the revenue office/land record office and statistical office of the Anuppur and Shahdol district. The statistical and cartographical techniques are used for the classification, tabulation, analysis, and interpretation of collected data. The Arc GIS 10.3 is used for preparing the map. The distribution of the area under different land-use categories has been calculated and shown by different diagrams for description.

Land Use Pattern of the Anuppur District

The Anuppur district is cover an area of 3,74,671 ha which is constant from the creation of the district. Table 1 express the pattern of land use of the district Anuppur. According to 2016-17 forest occupied 76,448 ha (20.40%), Area Not Available for Cultivation is 62,964 ha (16.81%), Other Uncultivated land excluding Fallow land is 7,498 ha (2%), Cultivable Waste Land is 19,498 ha (5.2%), Fallow Land is 56,446 ha (15.07%), and Net Sown Area is 151,817 ha (40.52%) in the district.

1. Area under Forest

“This category of land use includes all areas actually under forests whether government-owned or privately owned and administrated as forest under any legal enactment dealing with the forests. Besides, the forest area along roads, railways, and canals are also included in this

category” (Malik, 2012). The area of grazing lands and crops raised area within the forest are also included under the forest area. There are no changes in the forest area from 1999 to 2017 i.e., 76,448 ha (20.40%) in the district which is shown in table 1. In the Anuppur district, several patches and vast areas are uncovered by the trees, resultant in this land looking just like barren land. In the district covering of trees in the forest area is reducing very hurriedly due to forest fire, lack of monitoring to cutting trees, unfollow of restrictions for the collection of forest materials, encroachment of land by different causes such as for agriculture, grazing, habitat, industry, etc. and many constructions, mining activities are frequently conducting in the forest area.

Table: 1 Land Use Pattern of Anuppur District (1999-2000 to 2016-2017)

S. No.	Classification	Area										Change	
		1999-2000		2004-05		2009-10		2014-15		2016-17		1999-00 to 2016-17	
		a	H	% a	H	% a	H	% a	H	% a	H	% a	H %
	Total Geographical Area	74671	3.00	74671	3.00	74671	3.00	74671	3.00	74671	3.00	1	0.00
	Forest	6448	7.00	6448	7.00	6448	7.00	6448	7.00	6448	7.00	2	0.00
	Area Not Available for Cultivation	3854	5.43	2913	5.42	3542	5.29	9068	5.77	2964	6.81	9110	+ +2.44
	a) Area Under Non- agricultural uses	2506	3.68	1248	3.34	1837	3.50	6375	3.71	9089	3.04	6583	+ +1.75
	b) Barren and Unculturable land	1348	2.70	1665	2.78	1705	2.79	2693	2.06	3875	2.37	2527	+ +0.67
	Other Uncultivated land excluding fallow land	889	8.37	380	4.17	409	4.18	228	5.4	498	7.00	1391	- -0.37
	a) Permanent Pastures and other grazing lands	678	8.32	038	4.08	112	4.10	864	4.3	035	7.88	1643	- -0.44
	b) Land under misc. tree crops and groves	11	2.06	42	3.09	97	2.08	64	3.1	63	4.12	252	+ +0.06
	Cultivable Waste Land	0948	2.59	8915	2.72	9950	2.99	5567	2.82	9498	1.20	1450	- -0.39
	Fallow Land	7652	3.06	9884	4.32	4808	5.63	5065	4.7	6446	5.07	18794	+ +5.02
	a) Other than current fallows	7873	1.77	4803	2.62	5729	2.87	5642	2.84	5586	2.83	7713	+ +2.06

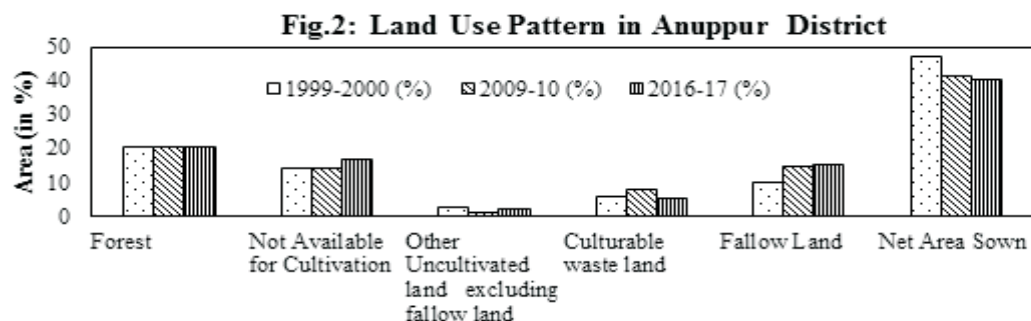
Sources: Land record office Anuppur 2001, 2011, 2017 and district statistical yearbook 2008-09, 2015-16.

2. Area Not Available for Cultivation

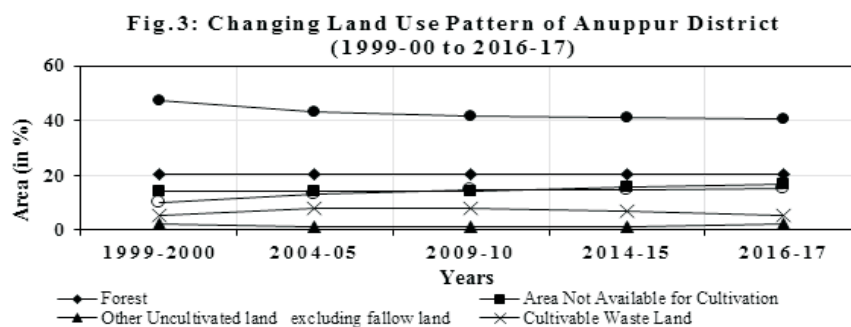
“This category includes the land put to non-agricultural uses, barren and uncultivated land. Barren and uncultivable lands are including with rocky hills (out of crops), plateaus, mountains, etc. This land can under no conceivable circumstances be brought under cultivation but at a very high cost, a very little proportion may be classed as uncultivable” (Vaishampayan, M.R., and Patil, D. Y., 2017). This category included all those areas which are not available for cultivation, in which hilly, barren, and permanently encroached areas are included in this category. This is divided into two subcategories i.e., (a) Area Under Non-agricultural uses (b) Barren and Uncultivable Land. The pattern of Area Not Available for Cultivation in the district is increasing, which was 14.37% in 1999-00 and it has increased and gone at 16.81% in 2016-17 of the total area. The growth of Area Not Available for Cultivation is 2.44% from 1999-00 to 2016-17.

(a) Area Under Non-Agricultural Uses

This land-use pattern included all those lands which are occupied by buildings, roads, railways, and underwater bodies like rivers, canals, ponds, and dams, etc, and other land put to uses other than agriculture (Azharuddin, S.K., 2015). The portion of the area in this category has been increased from 8.68% in 1999-2000 to 10.43% in 2016-17. The growth of the area in this category is 1.75% from 1999-2000 to 2016-2017. The Area Under Non-agricultural uses included those land that is encroaching for the different permanent activities year by year.



Sources: Land record office of Anuppur 2001, 2011, 2017 and District Statistical



Sources: Land record office of Anuppur 2001, 2011, 2017 and District Statistical Yearbook 2008-09, 2015-16

Table 2:
Block wise Land Use Pattern of Anuppur District

Classification	Block												C
	Anuppur			Kotma			Jaithari			Pushprajgarh			
	009-10	015-16	Change	009-10	015-16	Change	009-10	015-16	Change	009-10	015-16	Change	
	a	H	a	%	H	%	a	H	%	a	H	%	
Total Geographical Area	60211	60211	6	00841	40841	4	07247	97247	9	076372	176372	1	0
Forest	5291	5291	1	01479	11479	1	05835	25835	2	03843	23843	2	0
Area Not Available for Cultivation	452	772	8	3683	5851	5	21460	12848	1	17947	25493	3	2
Other Uncultivated land excluding fallow land	72	213	9	254	6023	1	5177	1687	1	4606	1575	3	1
Cultivable Waste Land	890	57	9	-838	2670	1	-288	8134	5	-6934	11737	1	-
Fallow Land	0254	0754	1	4201	5845	5	13243	14515	1	95327	25332	2	0
Net Sown Area	3352	3224	2	-4986	14973	1	-7244	37228	3	-0715	86392	7	-
Area Sown more than once	50	68	8	372	305	4	8871	3264	4	17237	22191	3	1
Total Cropped Area	4002	4092	2	05358	15378	1	01115	41492	4	007952	108583	1	0

Sources: Land record office Anuppur 2009-10, 2016-17 and District Statistical Year Book 2008-09, 2015-16

Table 2 represents the block-wise land use pattern in the Anuppur district. There is a forest area that is constant in every block because the maximum forest is a reserve and protected. Area Not Available for Cultivation is increasing (from 2009-10 to 2015-16) in every block, in which maximum increasing rate (27.00%) in Pushprajgarh block. Other Uncultivated Land excluding fallow land is also in increasing way from 2009-10 to 2015-16 in the study area, in which maximum increasing rate in Pushprajgarh block. Cultivable Waste Land is encroaching for the different economic purposes in every block in which maximum rate (49.37%) in Anuppur block. Table 2 clearly shows the Net Sown Area is decreasing mode in every block, resultant the pressure on agriculture land in increasing manner.

(b) Barren and Uncultivable Land

This land use category includes the land those are covered under mountains, plateaus, hill slopes, undulating topography, desert, rocky, and highly degraded lands. Mainly these lands cannot be utilized for cultivation because their transformation cost is very high with low benefits. In the Anuppur district, the share of the area under barren and uncultivable land is increasing mode, 5.70% in 1999-00, 5.78% in 2004-05, 5.79% in 2009-10, 6.06% in 2014-15 and 6.37% in 2016-17 respectively. The changing land use pattern of in this category of Anuppur district is also in increasing way 0.08% in 1999-00 to 2004-05, 0.09% in 1999-00 to 2009-10, 0.36% in 1999-00 to 2014-15 and 0.67% in 1999-00 to 2016-17. The increasing trend of this land-use pattern in this area is mainly due to the erratic rainfall, lack of irrigation facilities, and involvement of mining activities.

The Area Not Available for Cultivation is increasing, mainly due to expansion of human settlements, unauthored mines are mining in an unplanned way, lack of irrigation, erratic rainfall, uncontrol of rainwater, construction activities such as industry, link roads, railways, dams, ponds, canals, and many governmental and private institutions, etc.

1. Other Uncultivated Land Excluding Fallow Land

This land-use pattern is divided into two categories i.e., (a) Permanent Pastures and other Grazing Land (b) Land under Miscellaneous Tree Crops and Groves

(a) Permanent Pastures and other Grazing Lands

This land-use pattern is mainly comprised all those grazing lands, whether they are permanent pastures or meadows. The common grazing land of the villages is also included under this category. It covered 2.32% in 1999-2000, which decreased by 1.88% in 2016-17 in the district. The portion of this land use has been highly decreased in 2004-05 (1.08%). After 2005, the portion of this area is again increasing because agricultural land is converted into this purpose due to lack of irrigation. The trend of land use pattern of this category is in decreasing mode in the study area, which is 1.23% from 1999-00 to 2004-05, 1.22 % from 1999-00 to 2009-10 and 0.44% from 1999-00 to 2016-17. Many economic activities are going on in the newly created district of Anuppur is the main reason for decreasing of pasture and grazing land.

(b) Land Under Miscellaneous Tree Crops and Groves

Under this category includes all cultivable land those are used for agroforestry which is not comprised in Net Sown Area. Besides orchards area, causing trees, thatching grass, bamboo scrubs, and all other groves for fuel, etc are included in this group. The portion of the area in this category is in increasing by 0.06% in 1999-2000, 0.08% in 2009-10, and 0.12% in 2016-17. The increasing of this land-use pattern is due to lack of irrigation, farmers converted his land into plantation and agroforestry. The changing land use pattern of this category is also in increasing manner 0.03%, from 1999-00 to 2004-05, 0.04% from 1999-00 to 2014-15 and 0.06% from 1999-00 to 2016-17.

The changing of other uncultivated lands excluding fallow land in the Anuppur district is in decreasing pattern,

2.37% in 1999-2000, which has decreased 2.00% in 2016-2017. Processing of many constructions, economic activities, and agriculture expansion are the main reasons for decreasing of other uncultivated lands excluding fallow land in the Anuppur district.

2. Cultivable Waste Land

The meaning of cultivable wasteland is that land which has potentiality for cultivation, nevertheless currently not used for cultivation of any reason. Some land is also included in this category which was used for cultivation in the past, but at present is not being used because of physical, socioeconomic, and demographic limitations. After reclamation of this land can be used for cultivation. Table 1 represents the area of Cultivable Waste Land is increasing, which are 5.59% in 1999-2000, 7.72% in 2004-05 and 7.99% in 2009-10. After 2009-10 the Cultivable Waste Land is in the declining way, which is 6.82% in 2014-15 and 5.20% in 2016-17. The changing portion varies of the area is 2.13% from 1999-00 to 2004-05, 1.23% from 1999-00 to 2014-15 and 0.39% from 1999-00 to 2016-17. If we discuss Cultivable Waste Land at the block level it is also represented in table 1 in decreasing mode in every block level, in which in Anuppur block shows highest decreasing of 49.37% followed by Kotma (41.16%). The impact of socioeconomic and technological advancement influences the distinctive decreases of Cultivable Waste Land. The influx of progressive farmers, demands of population growth, and advanced reclamation technology motivated to encroaching of this land for cultivation.

3. Fallow Land

This class comprises all those lands which were used in cultivation earlier, but are currently not used in cultivation. Fallow land is divided into two types that are- current fallow and, other current fallow lands. Fallow land included marginal or sub-marginal lands which are not cultivated for one to five years. The fallow land is in increasing mode from 10.06% to 15.07% between 1999-00 to 2016-17 and the increasing rate is 5.02% from 1999-00 to 2016-17 in the Anuppur district. Maximum fallow land (25,332 ha) is found in Pusprajgarh and flowed by Jaithari block (14,515 ha) in the year 2015-16. The main reasons of increasing in fallow lands in the district are degradation of fertility, lack of irrigation facilities, erratic rainfall, soil erosion, crop rotation, and poor economic wealth of farmers.

a) Current Fallow Land

Current fallow refers to land that has been left unsown during the current agricultural year in order to maintain soil fertility or for other physical or socio-economic reasons. The portion of the area under this category is increasing from 5.28% in 1999-2000 to 6.69% in 2004-05, 7.46% in 2014-15, and 7.85% in 2016-17. The increasing change of current fallow land in the district is 1.41% from 1999-00 to 2004-05, 2.48% from 1999-00 to 2009-10, 2.57% from 1999-00 to 2014-15, and 2.96% from 1999-00 to 2016-17. The increasing of current fallow land in the district is due to erratic rainfall, soil erosion, crop rotation, the poor economic capacity of farmers.

b) Other than Current Fallow Land

Other than current fallow land, this category comprises all formerly cultivated lands that have been out of cultivation temporarily for at least one year and not more than five years. The total area under this category was 17,837 ha (4.77%) in 1999-2000, which has increased and gone on 25,586 ha (6.83%). The changing proportion of this category is increasing by 2.06% from 1999-2000 to 2016-17. Due to degradation of soil fertility, erratic rainfall and poor economic condition of society are the main increasing reasons of other than current fallow land in the district.

4. Net Sown Area

The Net Sown Area is the representation of the actual sown area of crop in an agriculture year. Net Sown Area is the expression of that cultivated land on which at least once in a year cropping is done. The ratio of Net Sown Area is a

very significant indicator of agricultural production and development. The total Net Sown Area of the district was 176,880 ha in 1999-00, which is declining year by year, 1,62,131 ha in 2004-05, 1,55,514 ha in 2009-10, 1,53,295 ha in 2014-15, and 1,51,817 ha in 2016-2017 respectively. The proportion of the Net Sown Area of the district has been declined from 47.21% in 1999-2000 to 40.52% in 2016-17. The decreasing change of the Net Sown Area of the district is 3.94% from 1999-00 to 2004-05, 5.70% from 1999-00 to 2009-10, 6-30% from 1999-00 to 2014-15, and 6-69% from 1999-00 to 2016-17. The main causes of decline in the Net Sown Area of the district are increasing growth of the urban and industrial areas, lack of irrigation facilities, erratic rainfall, undulating topography, encroaches for the settlements, transportation, mining, and other construction activities of the district.

Population Pressure on Land Resources

Population growth has also played a vital role to affect the land use pattern in any region because the lifestyle of human society in completely changed in the last 30 years. The shelter, cloth, food habits, and luxurious needs/requirements are transformed of the society. Humans always try to fulfillment of their needs without caring about different environmental elements. For their requirements, they have continuously invented and implemented many more instruments and scientific methods to change the pattern of land use. "Due to rapid growth of population in India, a decreasing tendency was observed in the area under the forest, cultivable wasteland, barren and uncultivable land, permanent pastures and grazing lands, miscellaneous trees, not included in the net sown area, fallow land, and other than current fallow" (Satihal and Bhargava, 2007). It is observed that population pressure is a dominant aspect in many countries in the last few decades. The rapid growth of population has been a frequently responsible factor for the population pressure in any region. The growth of the population is not only a hazard but also creates great pressure on the management and distribution of resources throughout the population. Undoubtedly, it is observed that the land use patterns are mainly affected by population growth, forest area, agricultural land, and other land use. It is well known to rapid population growth generates an extraordinary burden on available natural resources of land, water, and biomass. The degradation of forests, water, and biomass generates different types of problems related to the ecosystem of the earth. Population growth is the most responsible factor which have affected reduction of the ratio of man and land within a given land area, and it creates pressure on sustainable utilization of available resources. Every person has different types of needs and desires such as food, cloth, water, shelter, communication, transportation, medicine, etc. all having their impacts on land. The per capita availability of agricultural land reflects the population pressure and scarcity of land in any area. However, without taking into consideration the characteristics of physiography, soil fertility, the intensity of cropping, water supply, climate, technology, etc. are difficult to decide how much land area is required for the nourishment. Not only physical but also social, economic, political, technological, etc. determinant factors for the sufficiency of sustenance. Other than this a person's diet habit (vegetarian or a non-vegetarian) is also a determinant feature. "There's a lot of nutritional value in meat, but it also takes a lot more area to feed the livestock that will feed you" (Leckie, 1999). Many scholars have been decided on some standards of the sufficiency of the land to fulfill the nourishment and needs of the population. Mukherjee (1938) was not accepted, "who felt that East's calculations are based on observed requirements in Europe and America. He also argues that in India there is one acre of land (which is equivalent to 0.4 hectares of land) per capita is indispensable for the nourishment of man". While the caloric intake of people in the western countries is much more than in India for that fulfillment of nourishment only 0.5 ha of land is required per person.

Meadows and others (1972) have also described that the 0.40 ha of per capita agricultural land is indispensable for

nourishment. Norman Myers (1999) described the minimum amount of agricultural land necessary for sustainable food security, with a diversified diet similar to those of North America and Western Europe (hence including meat), as 0.5 ha per person. According to East, a minimum of 2.5 acres of land per capita is indispensable for countries in Asia. **Hence in this paper, an acre of agricultural land, which is equivalent to 0.4 ha, is taken as the absolute minimum sustenance per person.**

Table 3:
Per Capita Availability of Land (in Ha) in Anuppur District

Area	Years		
	1999-2000	2009-10	2016-17
Total Geographical Area	0.56	0.51	0.47
Net Sown Area	0.26	0.21	0.19
Total Cropped Area	0.33	0.25	0.23
Total Cultivable Area	0.35	0.32	0.28

Sources: Land record office of Anuppur 2001, 2011, 2017 and district statistical yearbook 2008-09, 2015-16

Table 3 clearly shows the per capita availability of Total Geographical Area, Net Sown Area, Total Cropped Area, and Total Cultivable Area in the district. Table 3 very evidently reveals that the year-to-year availability per capita land is decreasing in the district from 1999-00 to 2016-17. There is per capita net sown area is 0.26 ha in 1999-00, 0.21 ha 2009-10, and 0.19 ha in 2016-17, which is below from standard requirement (0.4 ha) for sustenance. In the district per capita, the total cropped area is also in decreasing mode (0.33 ha to 0.23 ha from 1999-00 to 2016-17). The per capita availability of cultivable areas in the district is in decreasing too, which was 0.35 ha in 1999-00 and 0.28 ha in 2016-17. It is indicating the population pressure on agricultural land in the district. There is very little availability of per capita net sown area (only 0.19 ha), which is not sufficient for the fulfillment of sustenance of the population in the area. In this way, it is identified the opposite relationship between population and net sown area in the district and represents the population pressure on agricultural land.

Conclusion

The above study is concluded that the land use pattern of the Anuppur district from 1999-2000 to 2016-17 is in some categories of land use are increasing and some are in decreasing way. The geographical and forest area are constant, while the area under non-agricultural uses is in increasing mode by 8.68% in 1999-2000 to 10.4% in 2016-17, barren and uncultivable land is increased from 5.70% in 1999-2000 to 6.37% in 2016-17, fallow land has also increased from 10.06% in 1999-2000 to 15% in 2016-17 in which the area of current fallow is highly increased compared to other than current fallow. While, other uncultivated lands excluding fallow land, cultivable wasteland, and the net sown area are declining mode, which is 2.37%, 5.59%, and 47.21% in 1999-2000 to 2%, 5.2%, and 40.5% in 2016-17 respectively. The main causes of decrease in these areas are the expansion of the urban and commercial area, construction of roads, railway, dams, institutional building, settlements, etc., erratic rainfall, lack of irrigation facility, undulating topography, and high population growth rate, the poor economic capacity of society, so that the pattern of land use in the district will

be highly changed. From the study, it is obvious that urbanization and technology are majorly contributors to changing of land-use patterns of the Anuppur district. Thus, it is necessary to protect the natural environments and biodiversity by planners and policymakers in the study area.

Suggestions

The present scenario is a pressing need for sustainable planning and management to subordinate solutions for present land-use problems (e.g., soil erosion, degradation of fertility, insufficient production) with the long-term planning and conservation of land resources. "Land use planning is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions to select and adapt the best options" (F.A.O., 1993). Land-use planning is a positive systematic process for identifying the problems and sustainable planning of unsystematic land use. The objectives of planning are to encourage the best sustainable use of land to meet the needs of the present as well as future population. In the study area, the population is increasing at a faster rate while the productions of crops are limited. They are unable to fulfill the required food in the area. To ensure food security we should adopt different planning processes to maintain the imbalances of food production and the requirement of the people in the area. These are:

1. To control the degradation of forest, lumbering, grazing, and fire and must be adopted reforestation/afforestation in the forest area.
2. Fuelwood and non-timber forest products (NTFPs) should be collected sustainably in the study area.
3. Agroforestry should be adopted in less fertile and cultivable wasteland areas which are fruitful for the fulfillment of sustenance and economic requirements.
4. Rapid expansions of irrigation facilities are required for increasing agricultural productivity and reclamation of wastelands in the study area. There is still a large amount of surface water is available by rainfall, which should be an initiation for the rainwater harvesting and conservation in the area.
5. For the meet of needs of agricultural products to growing population, productivity has to improve through adaptation of modern technology with the care of negligible impact on soil productivity and biodiversity of the study area.
6. Encourage the farmers to use High Yield Varieties, biofertilizer, scientific cultivation, crop rotation, cash crops, less irrigated crops, multiple crop systems, scientific irrigation methods and control the dangerous pesticides.
7. A substantial program should be initiated for the reclamation of barren, cultivable waste, current and old fallow land to make products to increase production in the study area.
8. The government should to monitoring and protection of encroachment of agricultural land for residential, mining, transportation, institutions, etc.
9. The government should to initiation steps to the utilization of land for different purposes according to their capacity.
10. Livestock farming should be adopted in less productive areas with scientific methods.
11. The government should encourage farmers to dry farming systems (less irrigation required crops) in the study area.
12. Scientific soil erosion methods (check dams, dam, plantation, gully erosion control) should be implemented in the area because the major area is affected by soil erosion.

13. An awareness program is necessary for the best and possible use in the sustainable manner of land resources to the people in the study area.

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Terrain mapping of the Nilgiris District, Tamil Nadu using Remote sensing and GIS

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ABSTRACT

Land is a base for all human activities. Land is not uniform everywhere on the surface of the earth. It varies according to geology, climate and geomorphic processes. Terrain analysis is defined as the representation and investigation of information relating to the shape of the earth. This paper attempted terrain mapping of the Nilgiris district of Tamil Nadu using SRTM data and ArcGIS software. Relief, slope, aspect, drainage density and areas of erosion and deposition were derived using GIS and areas were calculated. These maps would be useful for disaster management and mitigation at district level. Areas vulnerable for landslides and erosion can be deciphered from the maps. Since maps shows spatial distribution of these aspects, very useful for detailed studies of various aspects in future. Nilgiris district is a plateau region. From the terrain analysis, the district can be classified into low level and high level plateaus. Plateau margins and some of the areas in the interior are vulnerable for landslides

Key words: SRTM, GIS, relief, slope, aspect, disaster, erosion and landslide.

Introduction

Land is a base for all human activities. Land is not uniform everywhere on the surface of the earth. It varies according to geology, climate and geomorphic processes. Terrain analysis is defined as the representation and investigation of information relating to the shape of the earth. Elevation is the default parameter of a terrain model. Different land forms are identifiable based on the shape of the topography, drainage, geomorphology, slope and their magnitudes. Analysis of terrain is a laborious process which needs time and methods. With the advent of computer and Geographic Information System (GIS) it is possible to make quantitative or morphometric analysis rapidly and bring out erosion and land slide prone areas. Land use/ land cover depends upon landform characteristics.

Terrain analysis principles and methods were explained by Burroughet *et al*, (1998); Wilson and Gallent (2000); Corripio (2003); Quinn *et al* (1991); Jenson and Domingue (1991); Moore (1996); Jenson (1997) used digital terrain model for hydrological modelling. NEERI (2001) has used terrain analysis for the Carrying Capacity based Developmental Planning for Greater Kochi Region in Kerala. Terrain analysis was used for the Development of Biogeographical Information System for Kerala (BGIS) by CESS (2004); Neelakandan *et al* (2006). Terrain analysis was made by many authors for their studies on morphometric analysis of river basins (Arun Prasad *et al* 2010, Sukumar *et al* 2010, Magesh *et al* 2013); geomorphic studies (Anuja *et al* 2008); landslide prone areas (Sukumar *et al* 2006, Sekhar 2006, Savitha *et al* 2009, Jyothirmayi *et al* 2009); conservation of water (Panda *et al* 2009, 2010, Sulfikkar *et al* 2010, Sukumar *et al* (2012)); ground water potential regions (Diji *et al* 2010, Magesh *et al* 2012); agricultural development

(Savitha et al 2010, Panda et al 2011); land suitability analysis (Regil et al 2010); and identifying potential areas for water harvesting structures (Arun et al 2010).

Studies related to landslides and landslide prone areas of Nilgiris district were carried out by Seshagiri et al (1980), Seshagiri et al (1982), Ramakrishnan et al (2002), Ganapathy et al (2010, 2012, 2013), Manimaran et al (2012) and Subramani (2012).

In this paper, an attempt is made to delineate erosion and land slide prone areas in Nilgiris district of Tamil Nadu considering different parameters related to the formation of landforms and erosion using GIS. An appraisal is made at district level which would be useful for disaster management.

Materials and methods

Shuttle Radar Topographic Mission (SRTM) DEM data is used for terrain analysis. Survey of India topographic maps are used for base map preparation showing district and taluk boundaries. ArcGIS software is used for the study. Spatial analyst module is used effectively for the analysis. DEM is used for deriving relief, slope, aspect, drainage and drainage density. Using raster calculator in spatial analyst module, erosion and landslide prone areas were derived. Areas were calculated for different categories of thematic maps at district level.

Study area

The Nilgiris district is one of the 38 districts of Tamil Nadu state, situated on the western part of Tamil Nadu. It extends between 11°30'00" and 19°30'00" North latitudes and 76°29'52" and 76°36'00" East longitudes (Fig.1). The district is surrounded in the north by Mysore district of Karnataka State, Erode and Coimbatore districts of Tamil Nadu State in the east, Palakkad district of Kerala State in the south and Malappuram and Wayanad districts of Kerala State in the west. It has an area of 2545 sq.km with a population of 7,35,071 (Census, 2011). The district has six taluks namely Uthakamandalam, Coonoor, Kotagiri, Gudalur, Kundah and Pandalur. Uthakamandalam or Ooty is the district headquarters.



Terrain mapping of the Nilgiris District, Tamil Nadu using Remote sensing and GIS

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Physiographically, it is a part of Western Ghats. It is a plateau region flanked by Moyar Gorge and Mysore plateau in the north, Sathyamangalam - Mettupalayam upland in the east, Bhavani River and Kundah hills in the south and Wayanad plateau and Nilambur plain in the west. Dottabetta is the highest peak with height of 2637 meters above mean sea level. Slope is gentle on the plateau and steep along the margins of the plateau. General slope is towards north. The Nilgiri plateau can be divided into two viz. low and high plateau according to the analysis. Slope failure and landslides are common in steep slope regions and plateau margins. Important geomorphic processes in the district are fluvial and chemical weathering. Pykara is the largest river basin in the district. Western and southern part of the district is influenced by the south west monsoon and northern and eastern part of the district is influenced by the north east monsoon.

Analysis

Relief

Relief vary from 270m in the northeast to 2595m in the middle of the district. Gudalur taluk show relief between 300m and 1000m. In Pandalur taluk it varies from 500m to 1500m. Uthagamandalam taluk shows relief between 300m and 2600m. Kothagiri taluk it varies from 210m to 2000m. The relief is between 500m and 2000m in Coonoor taluk. Kunda taluk shows relief variation between 500m and 2500m. Maximum area is covered between 500m and 1000m which accounts for 34.77 per cent of the total area of the district, followed by 2000m to 2500m and 1500m to 2000m range with 23.39 and 23.39 percentages respectively. Fig. 2 shows relief of Nilgiris district.

Sl.No	Range of Height In meters	Area in sq.km	Percentage to the Total area
1	More than 2500	6.07	0.24
2	2000-2500	610.52	23.99
3	1500-2000	595.15	23.39
4	1000-1500	378.52	14.87
5	500-1000	884.92	34.77
6	300-500	68.38	2.69
7	Less than 300	1.44	0.06
	TOTAL	2545.00	100.00

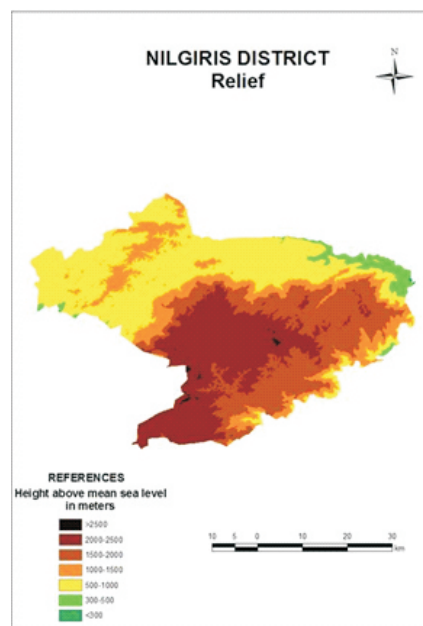


Fig-2

Slope

Slope in the district varies from 0 to more than 27 degrees. Predominant slope category in the district is between 24-27 degrees which occupy 17.04 per cent of the total area. Least slope category is between 3 and 6 degrees which occupy 3.84 per cent of the total area. In Gudalur and Pandalur slope is ranging from 0-3 degrees to 24 degrees. In Uthakamandalam, Kotagiri, Coonoor and Kunda taluks, slope is ranging from 0 to more than 27 degrees. Gentle slopes are found on the top of the plateau and lower valley portions of the district. Steep slopes are found along the plateau edges. Fig. 3 shows the spatial distribution of slope categories in the district

Nilgiris district- slope categories, area and percentage

Sl.No	Slope category In degrees	Area in sq.km	Percentage to The total area
1	0-3	218.83	8.6
2	3-6	97.84	3.84
3	6-9	125.13	4.92
4	9-12	162.09	6.37
5	12-15	218.81	8.60
6	15-18	286.35	11.25
7	18-21	359.57	14.13
8	21-24	406.02	15.95
9	24-27	433.65	17.04
10	More than 27	236.72	9.30
	TOTAL	2545.00	100.00

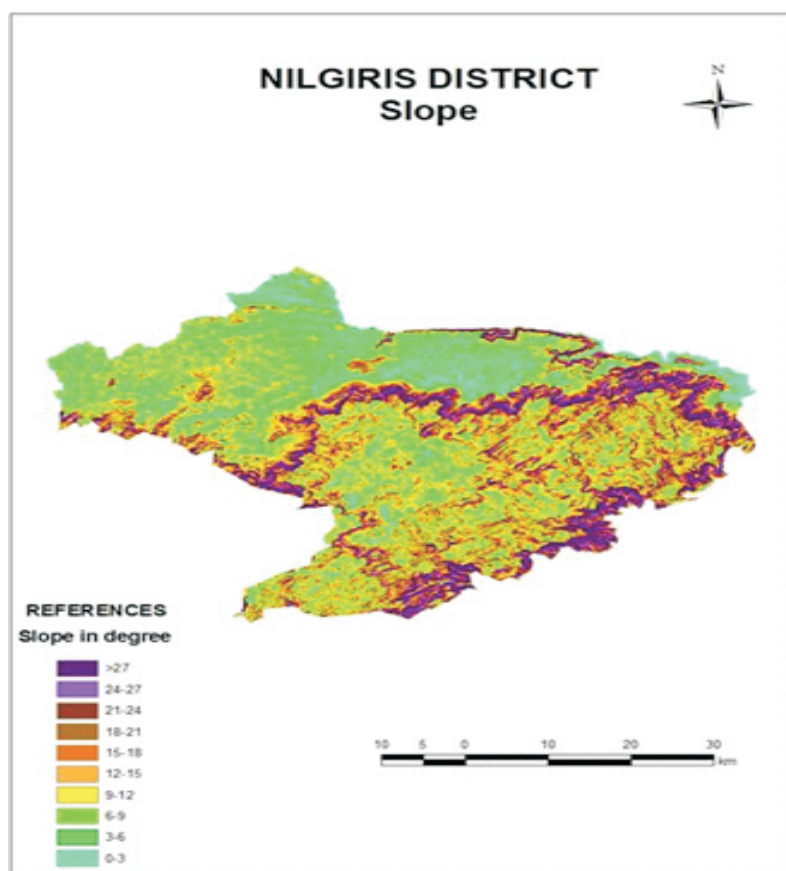


Fig-3

Aspect

Aspect refers to slope direction. Predominant slope direction is towards north. Northern slope occupy 15.57 per cent of the total area. It is followed by south east, North West, south, north east and east with 13.89 per cent, 13.47 per cent, 12.66 per cent, 12.45 per cent, 12.17 per cent respectively. Fig. 4 shows spatial distribution of slope direction (aspect) in Nilgiris district.

Nilgiris district-Aspect, area and percentage

Sl.No	Slope Direction	Area in sq.km	Percentage to The total area
1	Flat	5.04	0.20
2	North	396.34	15.57
3	North east	316.90	12.45
4	East	309.77	12.17
5	South east	353.50	13.89
6	South	322.31	12.66
7	South west	252.81	9.93
8	West	245.48	9.65
9	North west	342.84	13.47
	TOTAL	2545.00	100.00

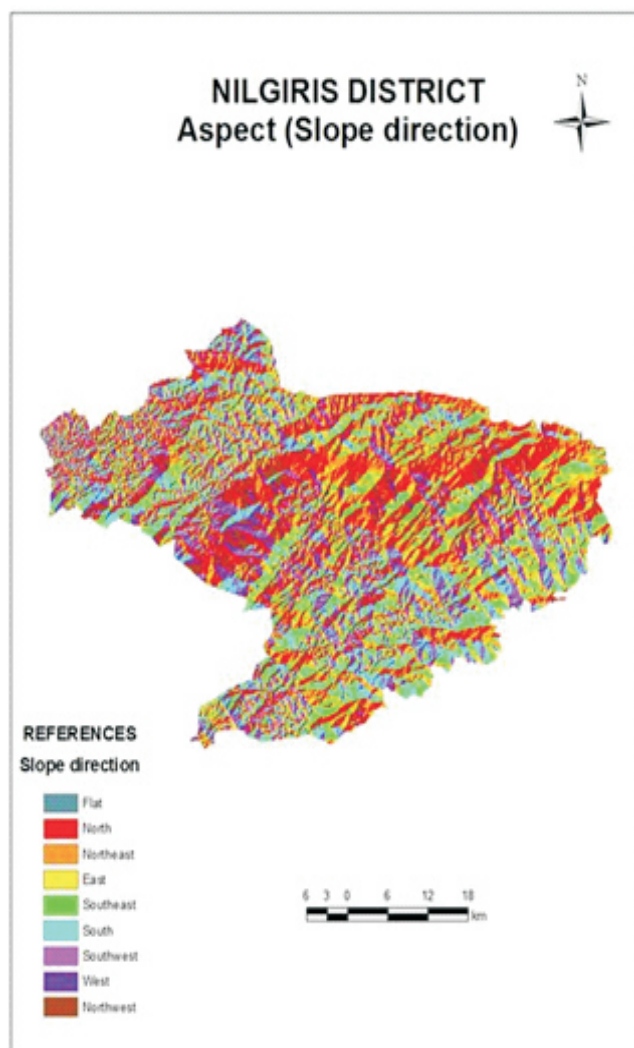


Fig-4

Drainage density

Drainage density shows concentration of drainage per sq.km. From this map, slope, surface material and rainfall of the area can be inferred and it is useful to predict landslide prone area and soil erosion prone areas in the district. High and very high density of drainage occupies 20.60 per cent of the district along the plateau margins. Moderate drainage density class is the dominant with 47.97 per cent. Fig. 5 shows the spatial distribution of drainage density in the district.

Nilgiris district- Drainage density classes, area and percentage

Sl.No	Drainage density classes	Area in Sq.km	Percentage To the total area
1	Very high	93.50	3.67
2	High	430.82	16.93
3	Moderate	1220.72	47.97
4	Low	674.62	26.51
5	Very low	125.35	4.93
	TOTAL	2545.00	100.00

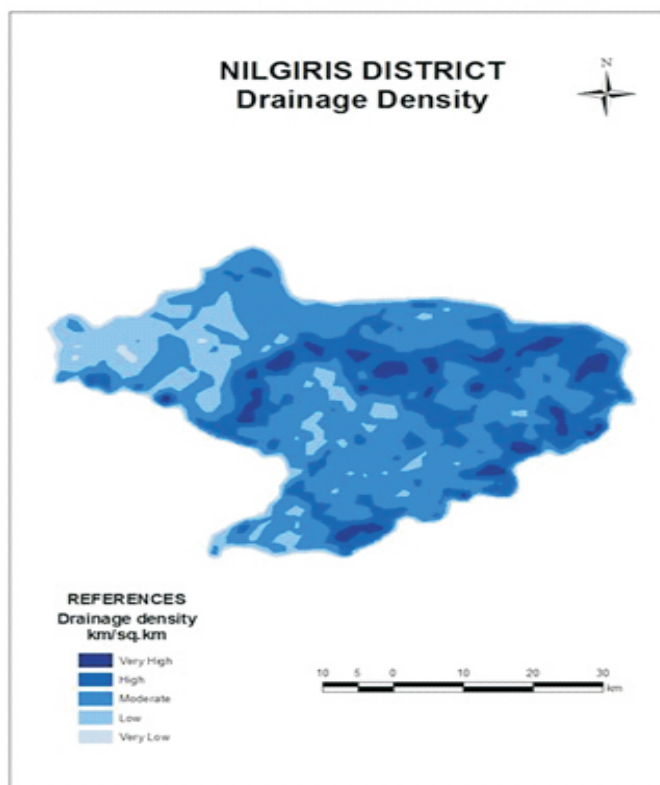


Fig-5

Areas of erosion and deposition

Areas of erosion and deposition depend upon many factors. Here it is classified based on terrain characteristics. Majority of the area (43 per cent) falls under moderate erosion category in the district. Fig. 6 shows the spatial distribution of erosion and deposition areas for Nilgiris district.

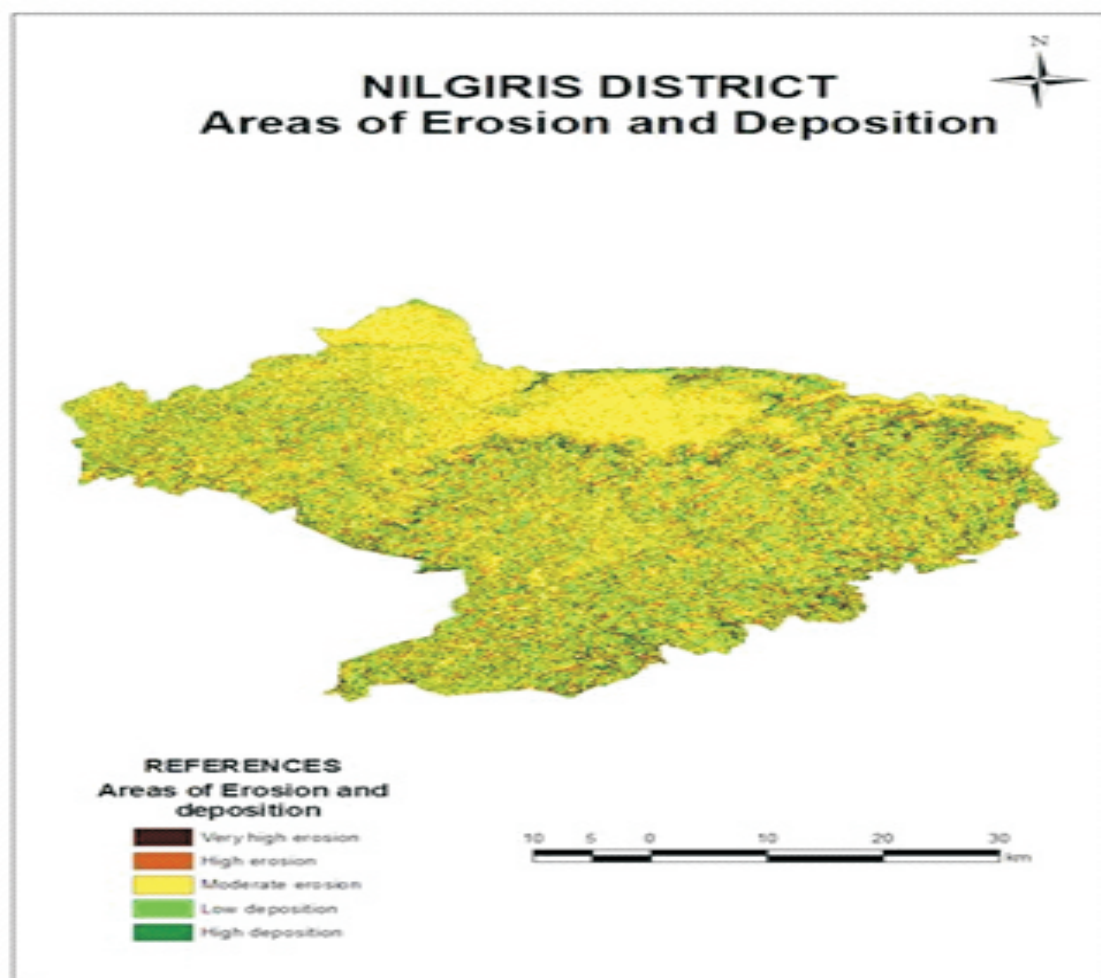


Fig-6

Conclusion

Nilgiris district is a plateau region. From the terrain analysis, the district can be classified into low level and high level plateaus. High level plateau can be classified into two levels based on extensive planation surfaces at height 1500 and 2000 meters above mean sea level. Plateau region has gentle to moderate slope whereas plateau margins have steep slopes. Plateau margin between 1000 and 1500 meters elevation is a critical region in the district. This is the region where the slope is more than 27 degrees, high relative height, high drainage density and high erosion. Any development activity should take care of these factors in the district. This is the region highly vulnerable for landslides and soil erosion. Digital Elevation Model or Digital Terrain Model is very useful for terrain analysis with the help of Spatial Analyst module and ArcGIS software. Conventional method of terrain analysis is laborious and time consuming whereas digital processing method in GIS environment is easy and the results can be used for many applications for further studies in the district.

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Land use/Land cover changes with respect to population expansion of Guwahati City, North East India using Google Earth Engine and SAGA

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Abstract:

The rampant developmental activities and increase in infrastructures have resulted in a major expansion in geographical areas of the urban landscape characterized by the settlement, population density, and proliferation of built-up areas and infrastructure development. The study area 317.742 km² includes the Guwahati Metropolitan Development Authority (GMDA). The Google Earth Engine (GEE) has widely been used in recent time to access different imagery in one consolidated system. The land use land cover maps were produced using GEE at three time periods for a total of 7 common land cover classes eg. built-up, forest, river, wetland, sand, degraded and agriculture. The overall accuracy assessment of land use land cover change was 88.12% (2009), 84.35% (2014), and 91% (2019). The change detection was performed in the System for Automated Geo-scientific Analyses (SAGA) software. The 159.18 km² of the area has been covered by a built-up area in 2019 prior to 89.51 km² in 2009. The study shows that degraded forest has been extensively transformed to the built-up area from the past few years. The study not only elucidates the LULC but also demonstrated the use of open source GEE and SAGA software and monitor the change over time.

Keywords: Google Earth Engine, SAGA, FOSS, LULC, Urbanization.

1. Introduction: Geographic Information Systems (GIS) are increasingly being used as the principal 'tool' for digital exploration of variation in landscapes (David & Michael, 2000) as they provide the necessary functions for spatial data collection, management, analysis and representation (Turner et al., 2001; Steiniger & Weibel, 2009; Steiniger & Hay, 2009). In GIS technology Free and Open-source Software (FOSS) is a new development (Steiniger & Hay, 2009), which widely been used in recent time. Learning GIS using FOSS tools offers several advantages (Ciolli et al., 2017), linked to the licenses used to distribute the programs, that allow the freedom to learn, improve and process GIS information (Zatelli et al., 2019). The Government is conducting government-sponsored capacity building workshops (Geospatial world, 2010) and training to facilitate the students and professionals from various backgrounds to actively participate and utilize the GIS technology (Jianya et al., 2017). GIS knowledge is required both in research and at the professional level (Wilson & Fotheringham, 2008) to enhance the learning experience of policymakers.

The Google Earth Engine (GEE) is a cloud computing platform designed to store (Gorelick et al., 2017), and process large data sets within a algorithm of GEE for analysis (Mutanga & Kumar, 2019). Although, GEE is easy to access high-performance computing resources for Free (Gorelick et al., 2017). It is a warehouse of necessary tools to analyze vast data (Sivarajah et al., 2016), with more than 40 years of historical and current global datasets available

(Kumar & Mutanga, 2018). And, System Automated Geo-scientific Analyses (SAGA) is software that has been designed for a user-friendly experience and effective implementation of spatial algorithms and cross-platform GIS software (Conrad et al., 2015). SAGA is programmed in the object-oriented C++ language (Cimmery, 2010) with immense capabilities for geodetic processing and analysis. The GEE and SAGA both considered as FOSS (Gorelick et al., 2017; Cimmery, 2010), which can access by professional or non-professional users in the GIS domain. Thus, the study has been done through the FOSS that can help researchers to easily disseminate their results to other researchers, policymakers, NGOs, field workers, and even the general public (Gorelick et al., 2017).

The world has recently hit a population milestone of 7.3 billion (UNO), humans, on Earth's surface, where India has support 121 core of population alone with the world's second-largest population (Survey of India, 2011). Due to the rapid increase in population global natural environment adversely impacted. These activities reflect further environmental consequences that may ultimately affect land use (Meyer & Turner, 1992). The frequent transmutation and alteration of land resources leads to the emergence of numerous environmental catastrophes (Van, 2013). The Land use/land cover (LULC) is a dynamic process that changes over time and it helps us to understand the countries land cover status in a different time with the help of geo-informatics technology (Roy & Roy, 2010). LULC change includes biophysical ones operating at various scales (Gaile & Willmott, 2004), it is an effective way to determine the current human footprint on the planet (Parker, 2002; Parker et al., 2003).

However, changes in land cover can have important consequences for global biogeochemistry (Goldewijk & Ramankutty, 2004), climate, and eventually on human distribution over the surface of the earth (Deka, 2018). (Turner et al., 1994) described that human play as a driving force between land use and land cover. The land use of urban and the periphery area have experiencing rapid industrialization due to the population expansion (Mundhe & Jaybhaye, 2014) and threat to the ecosystem of environment (Seto et al., 2012). The rate of population expansion in high-density countries is a critical variable (Jolly & Torrey, 1993), which can effect directly or indirectly in urban ecosystem. As India supports high density of population, this can affect its natural environment in urban areas. Therefore, to monitor the land use pattern (Mallupattu & Reddy, 2013), population expansion in a country or within a city is imperative for city planning. The many studies have done to monitor the LULC analysis with GIS techniques (Meyer & Turner, 1996; Thomas et al., 2003, Dewan et al., 2009, Acharjee et al., 2013; Rawat et al., 2013, Deka et al., 2014). But a very few research has been attempted in software like GEE and Saga (Patel et al., 2015; Pal & Ziaul, 2016; Goldblatt et al., 2016; Midekisa et al., 2017; Goldblatt et al., 2018; Zhang et al., 2018; Geetha, 2019). Accordingly, this study has been attempted to monitor the LULC of Guwahati city, Northeast India. The use of FOSS in GIS is significantly important to monitor the land use land cover change at given time. Henceforth, the land cover analysis has done with free and open-source software eg. GEE and SAGA that help others to access freely.

2. Materials and Methods:

2.1 Study area:

The Guwahati city is one of the preeminent places of North East India, as it is considered the Gateway of North East India (figure.1). Guwahati has seen a rapid influx of population from different parts of the country, chiefly for education and occupation purposes resulting in undesirable expansion of population in the city, which further brings

many collateral problems in the city. The population expansion of Guwahati is one of the primary factors leading to forest depletion. However, the unplanned infrastructure development had a loss of many forested area of the city. Guwahati has seen a rapid influx of population from different parts of the country, chiefly for education and occupation purposes resulting in undesirable expansion of population in the city, which further brings many collateral problems in the city. The city has been endured with recent development and expansion of the human population over the last 10 years. Hence, It is a significant river port city of Assam and one of the quickest developing urban areas of India. The study area 317.742 km² includes the Guwahati Metropolitan Development Authority (GMDA). The aerial extension of Guwahati is between 26°5' to 26°13' North Latitude and 91°35' to 91°52' East Longitude. It has a population of 9,57,352 according to the census of India, 2011. The city is bounded on the north by foothills of Bhutan and Nalbari district, south by the state of Meghalaya, east by Nagaon and Darrang districts and in the west by Goalpara and Nalbari districts.

2.2 Free and open-source software:

FOSS systems have been used in this study to analysis the land use land cover (Sindhu et al., 2018) status of Guwahati city with respect to population expansion. Since the GEE (Gorelick et al., 2017), and SAGA (Cinmmery, 2007-2010) is the recent development in the field of GIS & Remote sensing, that can be accessible by the general people and proffer effective results. The satellite data has been gathered from the GEE application programming interface (API) script and run the supervised classification followed by accuracy assessment respectively (Figure 2.). The resulted .tif file of Land use/Land cover had composed in Quantum-GIS. The statistical analysis has been done with open-source software named SAGA.

2.3 Satellite Database:

In this study, we used the LANDSAT series of satellite imagery for the year of 2009, 2014, and 2019 containing 30m of resolution. The composition of multiband raster images process to as independent band for further analysis. The single-band raster with a number of categorical classes (Lu & Weng, 2007) relate to different types of land cover. In order to cover different time-periods, Landsat-8 OLI Top of Atmosphere (TOA) 16-day satellite sensor data collections available on GEE cloud for three years (2014&2019) were organized for Guwahati city (Teluguntla et al., 2018). But to get the 2009 satellite imagery Landsat-7 has been used.

2.4 Application programming interface script:

The satellite imageries of 2014 & 2019 were open with GEE API script *var image = ee. Image (ee. Image Collection ('LANDSAT/LC8_L1T_TOA'))* And satellite imagery of 2009 is open with *var image = ee. Image (ee. Image Collection ('LANDSAT/LC7_L1T_TOA'))*. In this study supervised classification (maximum likelihood algorithm) technique (Sisodia et al., 2014) has been used to analyze the land use land cover mapping of Guwahati city. The following code has been used for supervised classification:

```
//Train the supervised classifier (algorithm)
var classifier = ee.Classifier.cart().train({
  features: training,
  classProperty: 'landcover',
  inputProperties: bands
});
```

```
print(classifier.explain());  
//Run the classifier  
var classified = image.select(bands).classify(classifier);  
print(classified);  
//Display the supervised classification  
Map.addLayer(classified, {min: 0, max: 5, palette: ['blue', 'white', 'green', 'lightgreen', 'lightblue', 'red', 'yellow']});  
Before exporting the classified image accuracy assessment has been done in code editor with using following
```

code:

```
//Validation of landcover of against the classification result  
var testAccuracy = validation.errorMatrix('landcover', 'classification');  
//Print the error matrix to the console  
print('Validation error matrix: ', testAccuracy);  
//Print the overall accuracy to the console  
print('Validation overall accuracy: ', testAccuracy.accuracy());
```

The classified image has been exported to google drive for the further analysis in SAGA. The area of interest (AOI) has been uploaded in code editor to export the required area. The AOI has been drawn from the Toposheet of Survey of India. To export the classified maps the following code has been used:

```
//Export the classified image to my drive  
Export.image.toDrive({  
  image: classified,  
  description: 'RGB_Image',  
  scale: 30,  
  crs: 'EPSG: 4326', //wgs84  
  maxPixels: 1e12  
});
```

The land use and land cover types derived from digital image classification validated with data obtained from limited post-classification ground verification and using high-resolution Google Earth images (Hu et al., 2013). Further random reference point has been generated from the field-based knowledge and the GPS points for the accuracy assessment (Behera et al., 2000). Finally, change detection has been performed with the SAGA open-source software.

3. Result and Discussion:

The quantitative results and maps of land use and land cover assessment based on GEE for three different years 2009, 2014 and 2019 are shown in Table 1 and Figure 3 (a, b and c respectively) Each LULC map (2009, 2014 and 2019) contains 7 LULC classes, i.e., built up, forest, river, wetland, sand, degraded and agriculture. It has been found that the 159.18 km² of the area has been covered by a built-up area in 2019 prior to 89.51 km² in 2009 which represents 69.67 km² of built-up area has been increased in 10 years. It has been found that the massive decline of forest area 49.99 km² occurred between the periods of 2009 to 2019. Similarly, as the forest area has been decline the degraded forest has been increased and converted to built-up land. The overall accuracy assessments of LULC for the years 2009, 2014, and

2019 are 88.12%, 84.35%, and 91% respectively.

In the table.1 it shows that the built-up area of Guwahati city in 2019 covers 50.10 % of the total area of the land. From this study it divulged that the Guwahati city has been incessant growing the human foot print. It has been observed that only 14.40% of forest has been left in the city, and the 16% of land area has been covered by degraded forest. The agricultural land has been decreased by 17.79 km² from 2009 to 2019. During the 2014 and 2019 the net change area of forest has been decline by 29.39 km². Whereas during the period of 2009 and 2014 only 20.60 km² forest areas has been decline, it shows that the forest has been decline very rapidly from 2009. The analysis of LULC indicated substantial changes in built-up and forest areas. Out of the total geographic area, larger proportion was under forest area (30.13%) during the study period 2009-2014, whereas during 2019 larger portion of the total geographic area accounts for built-up area (50.10%) (Figure 4).

Change of LULC between 2009, 2014 and 2019 has been shown in the (figure 5 a, b, c) and transitional change of LULC has been shown in the (figure.6) with graphical representation. The graph shows the trend of transition from one land cover to another land cover. The larger portion of the forest has been transition to built-up area and forest has been converted to degraded area. The transition of the Forest area to River, Sand, and Built-up area has occurred gradually between the time period of 2009 and 2019. Similarly, the Degraded Forest area has switched to the Built-up area (Thakur, 2008), Sand, Wetland, and also has regenerated to the Forest area (Burton, 1989). The forest area was decreased maximum during 2014-2019 with 29.39 km². The overall decrease of the forest was recorded at a rate of 5.24% annually during 2009-2019 due to illegal encroachment and developmental activities. The increasing rate of population has tremendously changed in the land cover status of the city (Jain et al., 2016). Table.2. shows the error matrix table of land use and land cover.

The population is a prerequisite for development but excessive population leads to many unwanted problems in the city such as environmental issues, civic issues, and scarcity of potable water. The impact of rapid increase of human population on land use land cover change (National Research Council, 2009) in Kamrup (M) is the primary factors. The population in the urban area is always positive growth (Turok & McGranahan, 2013), which creates a pressure on wildlife that is living in the forest areas of the district. Increasing human population and unplanned legal and illegal settlements have exerted great pressure on the hills in the city (Haase et al., 2013).

The change of land use land cover mainly includes the built-up area (Mallupatu et al., 2013), agricultural land, and forest areas. These changes in the GMDA are mainly due to the natural factors as well as human impact over the forest areas of the city (Nitasha & Sanjiv, 2015). The natural factors which contribute to the land use land cover changes in Guwahati are erosion and the depositional process by river Brahmaputra. Table 2 the error matrix class from 2009 to 2019, which shows the pixel of a land class transferred to another land-use class.

4. Conclusion:

The use of free and open-source software (FOSS) is widely been used in the GIS study. The GEE and SAGA are the examples FOSS, therefore an attempt has been carried out to analyze the LULC of Guwahati city with respect to population expansion. The study reveals that significant loss of areas has occurred in the forest of the study site. It shows that 49.99 km² of the forest area has been lost and 21.93% of the built-up area has been increased during the period of 2009-2019. The transition of a large portion of the forest to the built-up area has been increased in the last 10 years. The

main cause of these transitions occurred largely due to anthropogenic activity. As the population has been expanded the development activities in the city attained every corner of the GMDA area. To minimize the increasing expansion of the population need to timely monitor the land cover status. Therefore the use of FOSS i.e, Google Earth Engine, and SAGA are the crucial tools to monitor the land cover with diminutive time period.

Credit authorship contribution statement:

Jyotish Ranjan Deka: Conceptualization, Data collections, Methodology, GEE Software, Writing. Kongseng Konwar: Conceptualization, Methodology, SAGA Software, Writing, Validation.

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Table . Trend of LULC of 2009, 2014 & 2019 and their net change

	LULC 2009		LULC 2014		LULC 2019		(2014-2009)	(2019-2014)
Class	Area in km ²	Area in %	Area in km ²	Area in %	Area in km ²	Area in %	Net Change	Net Change
River	17.41	5.48	19.61	6.17	14.61	4.60	2.19	-5.00
Forest	95.74	30.13	75.14	23.65	45.75	14.40	-20.60	-29.39
Agriculture	34.26	10.78	16.09	5.06	16.47	5.18	-18.17	0.39
Wetland	13.68	4.31	19.64	6.18	17.17	5.41	5.96	-2.47
Sand	7.13	2.25	3.99	1.26	7.35	2.31	-3.14	3.36
Built-Up	89.51	28.17	138.80	43.69	159.19	50.10	49.29	20.39
Degraded	59.99	18.88	44.46	13.99	57.19	18.00	-15.52	12.73
Total	317.73	100.00	317.73	100	317.73	100		

Table . Error matrix tables of land use land cover change from 2009-2019

LULC 2009	LULC 2019							
	Class	River	Forest	Agriculture	Wetland	Sand	Built-Up	Degraded
	River	10.08	0.42	0.13	1.28	2.35	2.64	0.51
	Forest	0.54	31.90	3.12	4.36	0.29	33.55	27.93
	Agriculture	0.37	0.97	5.79	1.43	0.95	21.33	3.42
	Wetland	0.40	1.49	0.31	4.21	0.23	4.94	2.11
	Sand	2.16	0.07	0.14	0.58	2.02	2.12	0.05
	Built-Up	0.77	2.99	3.93	3.21	1.21	62.25	9.21
	Degraded	0.29	7.91	3.06	2.10	0.31	32.36	1.40

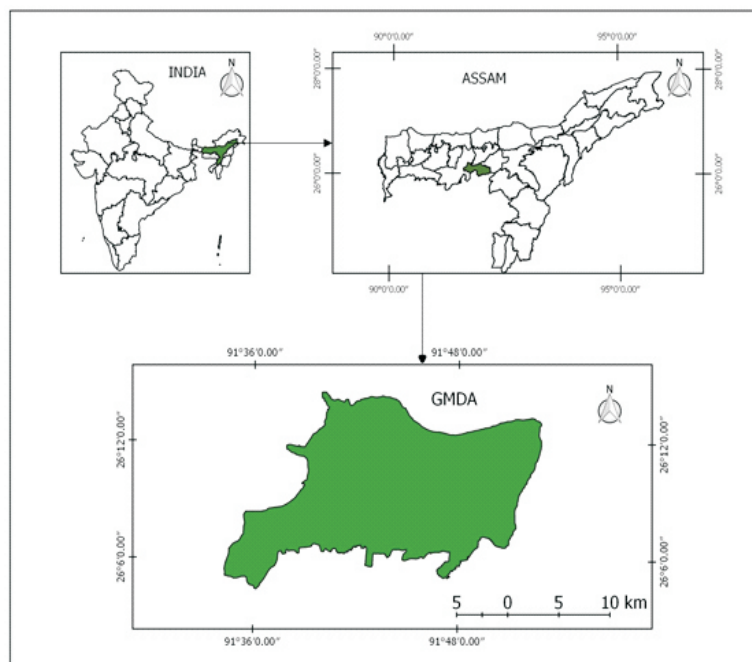


Figure 1. Location of the study area (Guwahati Metropolitan Development Authority)

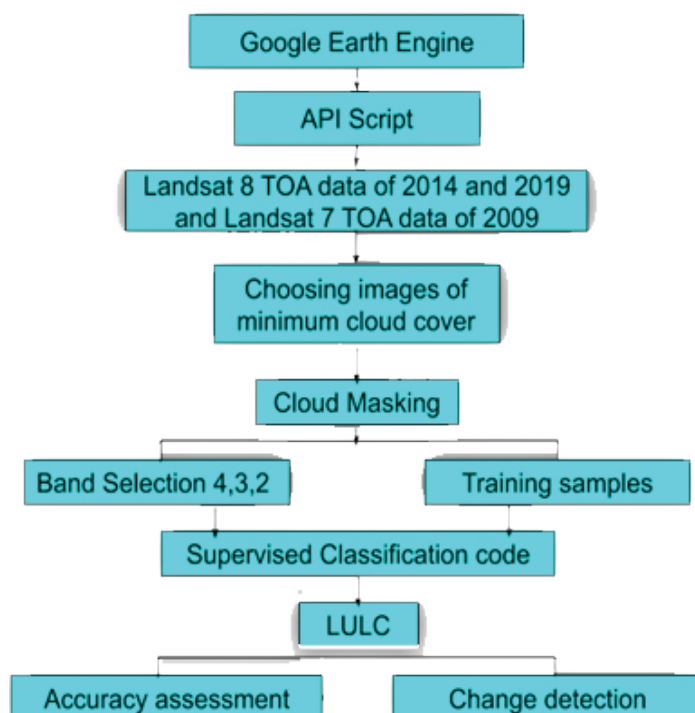
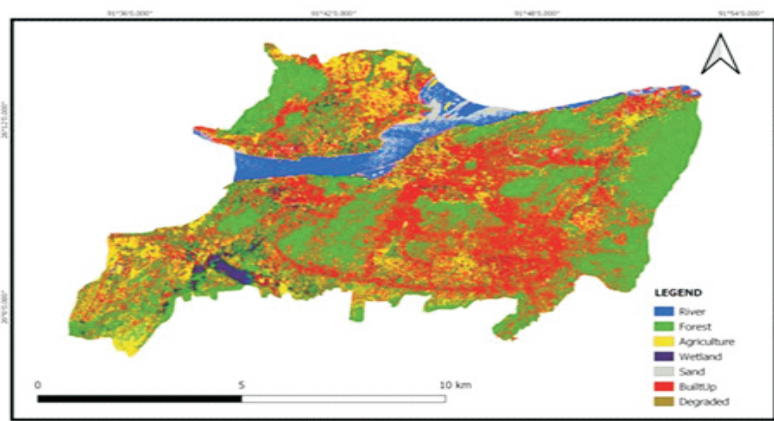
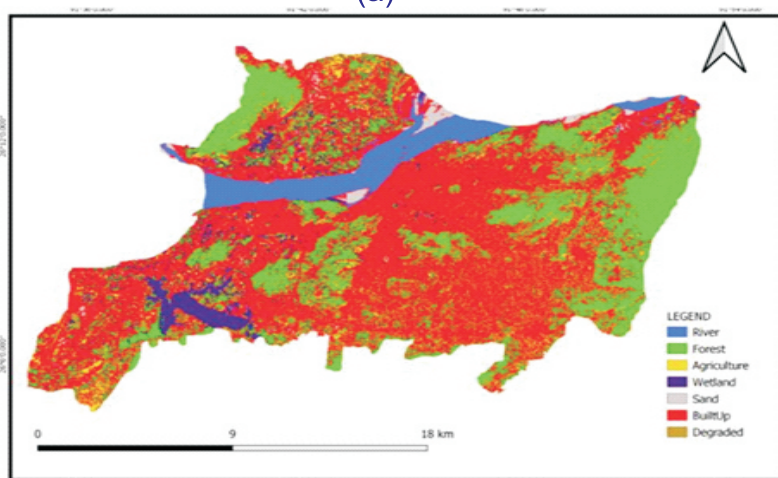


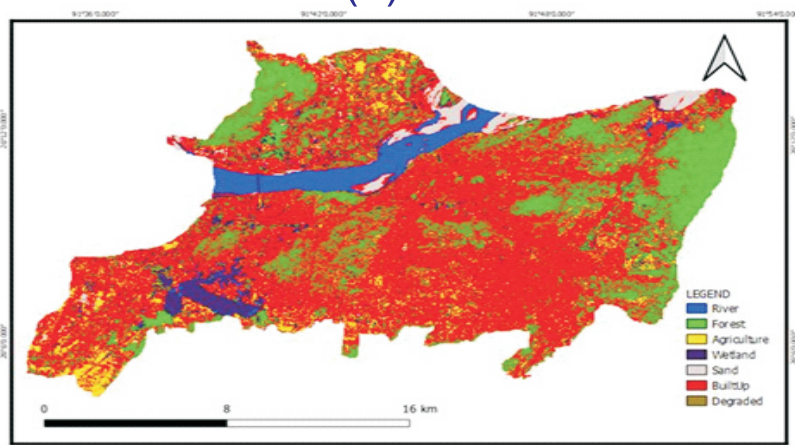
Figure 2. Methodology of the study using Google Earth Engine and SAGA software



(a)



(b)



(c)

Figure 3. Land use/Land cover Map of Guwahati Metropolitan Development Area for the year (a) 2009, (b) 2014 and © 2019

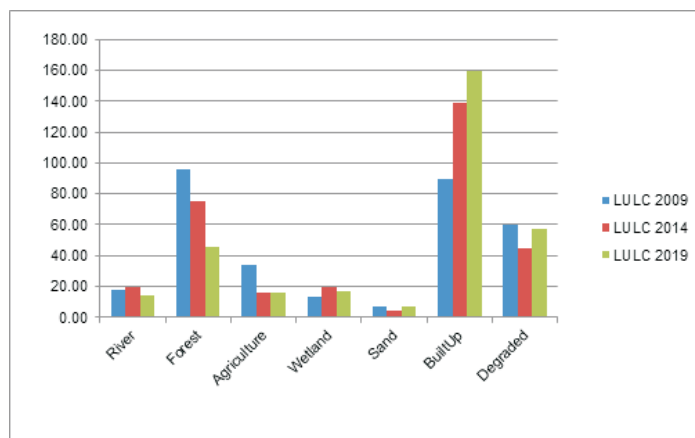
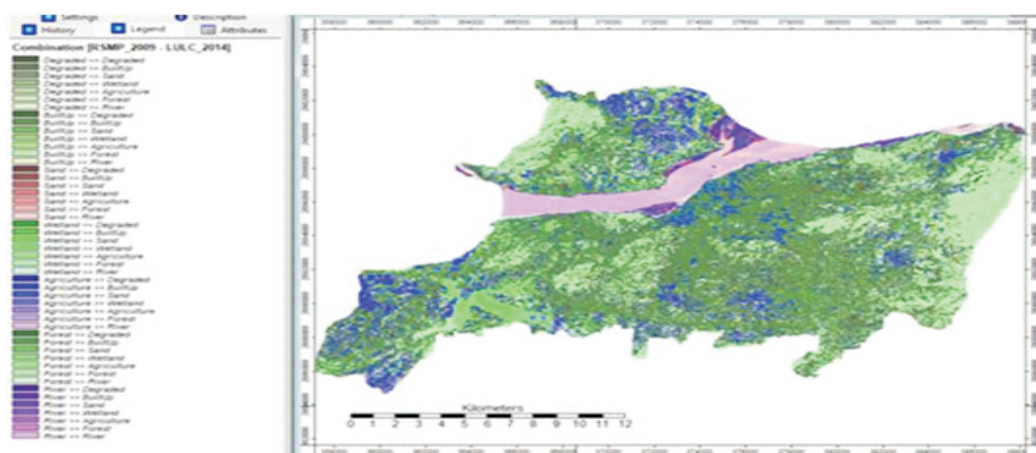
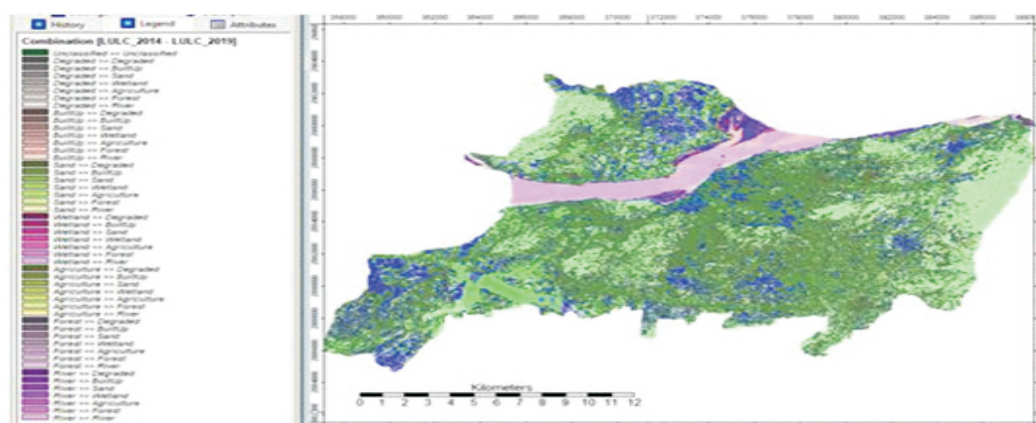


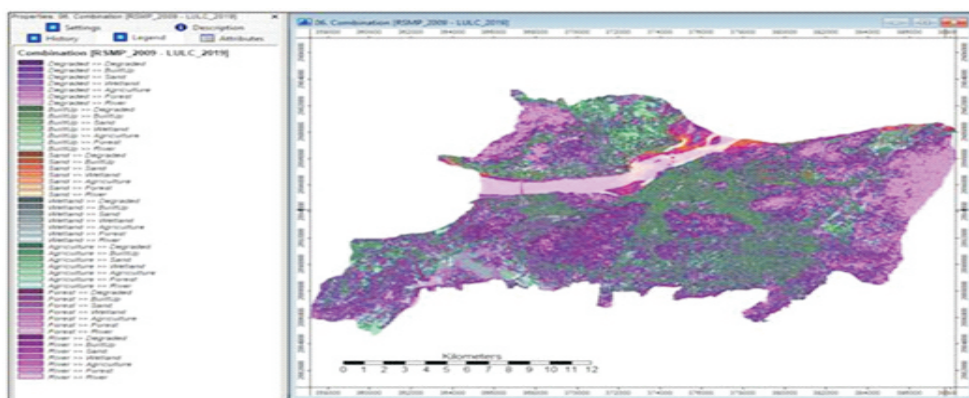
Figure 4. Graph showing the trend of land use and land cover status of GMDA (2009, 2014, and 2019)



(5 a)



(5 b)



(5 c)

Figure 5. Land use/Land cover Change map from class to class (a) 2009-2014, (b) 2014-2019 and © 2009-2019

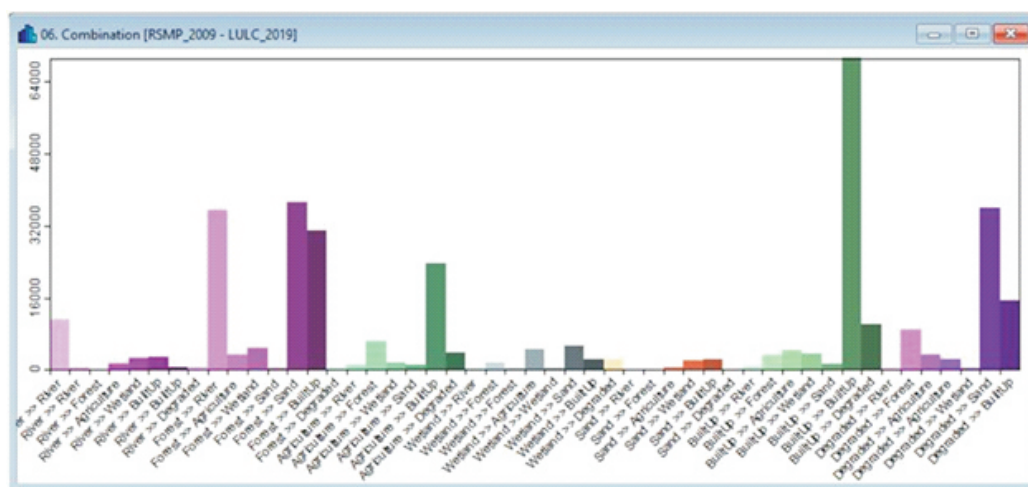


Figure 6. The trend of changes in Land use/Land cover (2009-2019)

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Commuting pattern of property offenders in Chennai City – A geospatial approach

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Abstract

Since the pattern of journey by offenders vary from one part of the city to another even for the same type of offense, the analysis of the spatial pattern of movement of offenders deserves closer attention. With the improvement in the quality of data, methodology and availability of GIS mapping techniques, this study aims at understanding the commuting pattern of property offenders in Chennai city. The analysis shows that the pattern of journey embarked in staging a crime is related to the physical and functional characteristics of different parts of Chennai city. In the localities where the environmental opportunity is low, the degree of commuting is relatively higher. In the commercial and high – income residential areas, on the other hand, the rate of occurrence of the property crimes is high owing to greater environmental opportunity and in such areas, the commuting of offenders is relatively lower. The Choropleth maps drawn with the help of GIS software identifies the areas of the high and low level commuting of Offenders. Such identification may help the Police in better law enforcement planning.

Keywords : Modus Operandi, Location preference, Commuting of Offenders, Origin, and destination of offenders, Environmental Opportunity.

1. Introduction

Since Geography is a spatial science, various location based analysis fall under it's ambit. The geography of crime encompasses the study of spatial and temporal distribution of criminal offenses and attempts to find a correlation between them which by doing so can provide valuable insights into patterns that were previously obscured to the naked eye and cognitive domain. This hidden relation between the two variables can be used for planning, mitigating and improving the existing scenarios for the betterment of peaceful co existence. The methodological and theoretical approaches developed in a variety of disciplines are often adapted to the study of crime and criminals and the field of geography and provides several analytical tools for Criminologists. The fields that make particular use of geographical techniques include the social ecology of crime, environmental criminology, situational crime prevention and geography of crime. For a crime to occur, a person who is motivated to commit an offense and an attractive target must intersect in time and space. At a broader geographical level, patterns of crime in Cities, Regions or Countries may relate to spatial flow of people, goods or employment (Brantingham and Brantingham, 1984, P.232).

1.1 Aim

The aim of this study is to map out the Crime prone areas by relying upon the loot worthiness of a place, a

Criminal's hideout/place of dwelling and his place of operation which on simpler terms is, to undertake an analysis of the spatial movement or mobility of Property offenders.

1.2 Objectives

- To compute the Commuting Index (CI) to gage the commuting pattern of Offenders.
- To compute the Relative Commuting Index (RCI) of Offenders with respect to offences committed in their own locality
- To find out the Correlation and Statistical significance between the Socio economic development and an Offender's keenness to commute out of an area of interest

2. Study Area

Tamil Nadu is the foremost state in the incidence of crimes among the Southern states of India. Chennai city, the capital of Tamil Nadu is one of the leading million cities in India. It is highly urbanized with the highest density of population and also records the highest number of crimes in Tamil Nadu. When compared to other Cities in Tamil Nadu, Chennai city recorded a greater number of crimes. Because of this conspicuous problem, it has been selected for the present study.

Further, Chennai city can be considered as a befitting example to understand Geographer Mark Jefferson's Law of Primate City (1938) which states that a City within a territorial limit would continue it's unchecked growth in demographic and economic aspects by depriving or stripping it's neighbouring counterparts' opportunities. A prolonged existence of the said phenomenon had paved the way for unabated immigrations from low income places in search of opportunities that eventually led to the development of Slums thereby making it's environment more hostile in a vigour to stay afloat sans poverty.

3. Materials and Methods

As per the Police station records, Chennai city has recorded 7450 incidences of property crimes during the year 2007(Figure 1).The police station wise data pertaining to the place of occurrence or scene of the crime (destination) and place of residence (origin) of Property offenders along with the charged offense have been collected from the CRB (Crime Record Bureau) for 70 police stations in Chennai city for the year 2007.

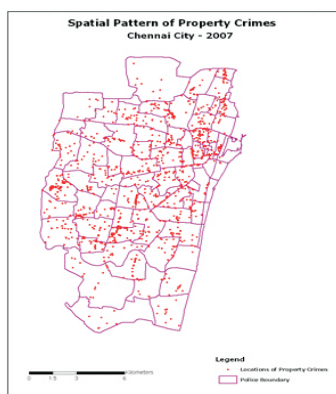


Fig. 1 Spatial pattern of Property crime -2007

A map of Chennai city was collected from EICHER maps and scanned using Deskan flatbed scanner upon which georeferencing technique is performed in ArcGIS 9.3 software using Ground Control points (GCP) of prominent places that were acquired in and around the City. An accurate depiction of Chennai City boundary was arrived at using the georeferenced map which aided in demarcating the Police boundary within it. Boundaries were constructed by onscreen digitizing in Arc View 9.3 and topology constructed in Arc GIS 9.3. To our chagrin, there was no police boundary map with the office of the Chennai Police Commissioner. However, a police boundary map for the state of Tamil Nadu which was available in the article published by Sivamurthy(2005), (A study of spatial mobility of property offenses, the Indian Police Journal) was used for the current study. The map was, traced out and redrawn to obtain the Police boundary accurately (Figure 2). Finally, the base map consisting of police station boundaries and police stations was created.

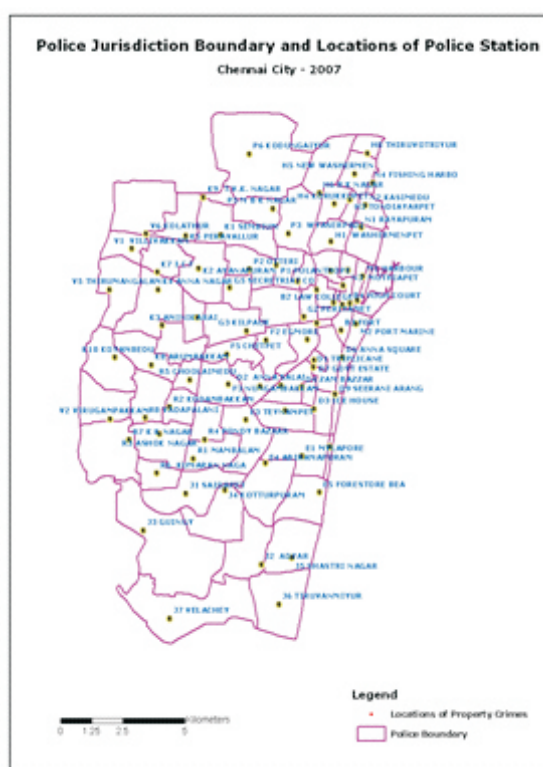


Fig. 2 Police stations location with Jurisdiction -2007

The scene of Crime locations were plotted using ArcGIS 9.2 (Figure 1). Then, X, Y coordinates were generated for Property crimes (Theft, House burglary, Pocket-picking, Cycle theft, Automobile theft, and Chain Snatching) and unique IDs were created for every individual property offenses. Next, Criminals' residences were plotted in a similar manner, subsequently, the origins and destinations of trips by the Offenders have been identified. The analysis of origin and destination reveal much of the spatial dynamics of movements and interactions in a City. In order to analyze the

attractiveness of the area in terms of movement of offenders, a Commuting index (CI) was calculated. It is assumed that commuting of an individual from one area to another is owing to a lack of opportunity in his own area. A Commuting index has been computed in the following manner for each of the 70 Police station jurisdictions.

Total no. of Offenders living in the police station jurisdiction (B)

Commuting Index: ----- (i)

Total no. of Offenders who live and commit a crime in the same police jurisdiction (C)

The higher value of Commuting Index shows that there is a lack of opportunity in the area and therefore outward commuting is prevalent among offenders.

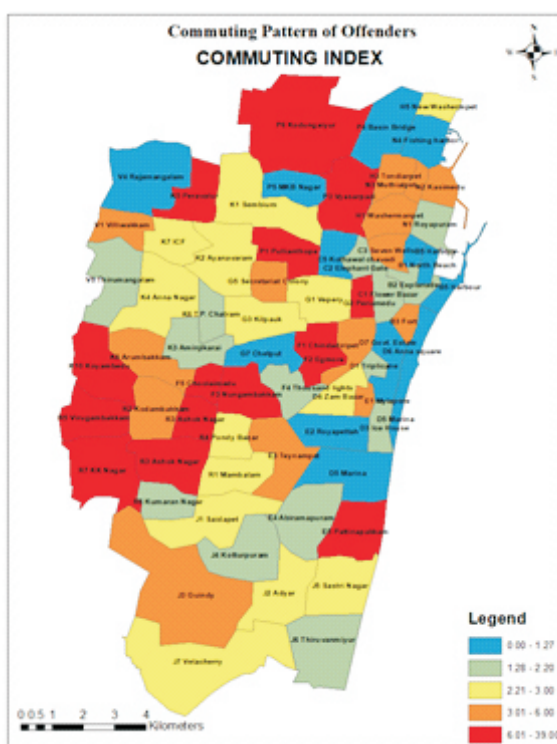


Fig. 3 Commuting Index (CI)

The Commuting Index value indicates Jurisdiction limits in the likes of P6 Kodungaiyur, P3 Vyasarpadi etc which were quite high denoting thereby denoting increased inclination to explore out while others like G7 Chetpet, E2 Royapettah etc are on the other side of the spectrum.

However, tracking mere outward movement of Criminals alone would not paint a bright picture in terms of analytical usefulness which thereby has prompted us to further the cause of pattern extraction by incorporating an index namely, the Relative Commuting Index (RCI). RCI, is just an enhanced version of CI where it's already obtained value for a particular area is divided by the number of crimes committed in it for which offenders are known. While the

Commuting index is solely based on the number of offenders who live and commit crimes in an area locally, Environmental opportunities which influence them to pick and choose select areas must be taken into account which can be gauged by culling out the occurrence of Crime events in each Jurisdiction. RCI faithfully tries to incorporate this factor so that a holistic commuting behavior of an Offender can be mapped. The Police department were able to discern and relate crime activities with alleged offenders which proved to be a boon in arriving at the RCI values for different areal units. Therefore, a Relative Commuting Index is another variant of commuting index that is expressed as a proportion of total crimes committed in the area for which offenders are known. It is derived as below.

Commuting Index (B)/(C)

Relative commuting Index: ----- (ii)

Total crimes for which offenders are known (A)

Since it may be difficult to comprehend the usefulness of RCI , a simple example has been used here to relate with it's importance in the current analysis.

Say for instance we have two areas namely A and B. Let's say the number of Criminals residing in A and B are 100 respectively. Of the total lot (100) only 50 of them operate inside A while 80 of them in B. From this we arrive at the CI values which are 2 and 1.25 for A and B respectively. It is obvious from CI that criminals in area B are reluctant to move out of their zone of dwelling while it is the other way around in area A. Now that the CI is computed, RCI comes into play which relies upon a Criminal's Modus Operandi. Since the number of native criminals who operate in A (50) tend to be much less than B (80), the number of crimes committed by them in A (say 25) would by all means be significantly lower when compared to B (say 50). By taking these values into account,

RCI for A = $2/25 = 0.08$

RCI for B = $1.25/50 = 0.025$

A lower RCI value for B has further cemented it's chance in proving that it's environmental worthiness or scope for opportunities are way above A.

4. Limitations

The scope of this paper is to primarily focus on the behavioural pattern of Offenders by analyzing their inclination towards committing crimes outside their area of residence and statistically correlating the reasons behind it in a socio economic context. The analysis is confined within the broad definition of crime rather than delving deep into it's segregation into different categories which would have had it's share of influence on the outcome.

5. Results and Discussion

As mentioned earlier, the Relative Commuting Index (RCI) is the level of commuting expressed as a ratio of Commuting Index and Total crimes committed in the area. By treating Police stations jurisdictions as areal units, Choropleth maps were prepared to show the spatial pattern of commuting by using GIS software ArcGIS 9.3. The lower value of the index indicates that the area depends very little on outward commuting since the area itself is rich in environmental opportunity. Conversely, the higher value shows the lack of opportunity in the area and therefore the outward commuting is necessary for offenders. A comparison of the pattern of occurrence of property crimes (Figure 1)

with the pattern of commuting of Offenders (Figure 2) reveals that the areas which record greater degree of commuting of Offenders are characterized by a lower rate of incidences of property crimes. In other words, the areas which record a higher rate of incidence of property crimes are assumed to have greater environmental opportunities and therefore, the degree of commuting of offenders is low.

Table 1:
Jurisdiction wise data

S. No	AREA	A	B	C	CI	RCI	SED
1	H5 New Washernmpet	22	24	10	2.40	10.91	25.99
2	N4 Fishing harbor	7	1	1	1.00	14.29	25.01
3	N2 Kasimedu	8	19	6	3.17	39.58	28.94
4	N3 Muthialpet	13	6	1	6.00	46.15	30.94
5	H3 Tondiarpet	29	36	9	4.00	13.80	30.05
6	P4 Basin Bridge	5	1	1	1.00	20.00	27.75
7	P6 Kodungaiyur	24	69	10	6.90	28.75	30.86
8	N1 Royapuram	25	22	11	2.00	8.00	29.97
9	P3 Vyasarpadi	15	102	10	10.20	68.00	27.06
10	H1 Washermanpet	9	55	11	5.00	55.56	29.97
11	K1 Sembium	47	33	12	2.75	5.85	30.90
12	V4 Rajamangalam	1	0	0	0.00	0.00	31.76
13	V5 Thirumangalam	75	69	35	1.97	2.63	34.81
14	K2 Ayanavaram	70	24	10	2.40	3.43	31.43
15	K4 Anna Nagar	28	9	4	2.25	8.04	32.66
16	K8 Arumbakkam	33	23	6	3.83	11.62	32.32
17	F5 Choolaimedu	11	14	1	14.00	127.27	34.72
18	G5 Secretariat Colony	27	5	1	5.00	18.52	34.14
19	C2 Elephant Gate	31	23	15	1.53	4.95	27.42
20	C3 Seven Wells	44	35	7	5.00	11.36	29.32
21	G7 Chetput	1	0	0	0.00	0.00	36.79
22	G1 Veperiy	39	20	9	2.22	5.70	32.49
23	F2 Egmore	27	9	1	9.00	33.33	34.09
24	F4 Thousand lights	55	33	22	1.50	2.73	36.79
25	R2 Kodambakkam	18	15	3	5.00	27.78	34.46
26	R3 Ashok Nagar	60	9	1	9.00	15.00	34.59
27	R9 Valasarawakkam	2	1	1	1.00	50.00	32.24
28	F3 Nungambakkam	41	8	1	8.00	19.51	34.94
29	R4 Pondy Bazar	49	3	1	3.00	6.12	38.35
30	R1 Mambalam	95	39	16	2.44	2.57	34.72
31	E3 Teynampet	26	25	7	3.57	13.74	33.12
32	R6 Kumaran Nagar	16	6	3	2.00	12.50	32.48

33	J1 Saidapet	27	40	15	2.67	9.88	29.45
34	J4 Kotturpuram	26	8	4	2.00	7.69	29.45
35	E4 Abiramapuram	52	18	12	1.50	2.88	34.23
36	J7 Velacherry	48	71	31	2.29	4.77	33.83
37	J6 Thiruvannamiyur	56	52	26	2.00	3.57	35.27
38	J5 Sastri Nagar	16	3	1	3.00	18.75	36.33
39	E5 Pattinapakkam	4	39	1	39.00	975.00	32.89
40	D5 Marina	9	1	1	1.00	11.11	35.29
41	D3 Ice House	19	22	10	2.20	11.58	28.29
42	K10 Koyambedu	69	9	1	9.00	13.04	32.36
43	R5 Virugambakkam	21	39	1	39.00	185.11	32.36
44	R7 KK Nagar	11	8	1	8.00	72.73	30.72
45	F1 Chindadripet	33	61	16	3.81	11.55	30.88
46	D1 Triplicane	66	44	22	2.00	3.03	39.56
47	D7 Govt. Estate	5	1	1	1.00	20.00	39.56
48	D4 Zam Bazar	11	6	2	3.00	27.27	33.48
49	D5 Marina	9	1	1	1.00	11.11	28.39
50	B3 Fort	3	4	1	4.00	1.33	32.24
51	B5 Harbour	1	0	0	0.00	0.00	30.18
52	D6 Anna square	8	1	1	1.00	12.50	30.63
53	B5 Harbour	1	0	0	0.00	0.00	30.63
54	B1 North Beach	15	8	7	1.14	7.62	30.63
55	K6 T.P. Chatram	24	12	9	1.33	5.56	31.98
56	G2 Periamedu	24	8	1	8.00	33.33	28.07
57	C1 Flower Bazar	44	22	16	1.38	3.13	25.78
58	B2 Explanade	20	9	7	1.29	6.43	32.24
59	V1 Villiwakkam	46	75	24	3.13	6.79	32.40
60	K7 ICF	14	3	1	3.00	21.43	30.69
61	P1 Pullianthope	21	83	7	11.86	56.46	30.05
62	C5 Kothawal chavadi	24	1	1	1.00	4.17	29.18
63	E2 Royapettah	45	19	15	1.27	2.81	36.50
64	E1 Mylapore	37	37	12	3.08	8.33	31.73
65	J2 Adyar	43	29	11	2.64	6.13	36.69
66	P5 MKB Nagar	16	1	1	1.00	6.25	28.88
67	J3 Guindy	22	82	14	5.86	26.62	29.19
68	K3 Aminjikarai	132	47	36	1.31	0.99	34.18
69	K5 Peravalur	15	19	2	9.50	63.33	33.44
70	G3 Kilpauk	36	17	7	2.43	6.75	35.31

Table 1 contains the Number of Crimes for which Offenders are known (A), Number of Offenders residing in an Area (B) and out of them who commit crimes locally (C). To corroborate the rationality behind narrowing their choices down to select areas and to statistically test them, Socio Economic Development (SED) indicator is taken into consideration. SED values represent how socially and economically sound an area is in percentage terms. A spatial and statistical approach is needed to prove the strong connection between SED and RCI

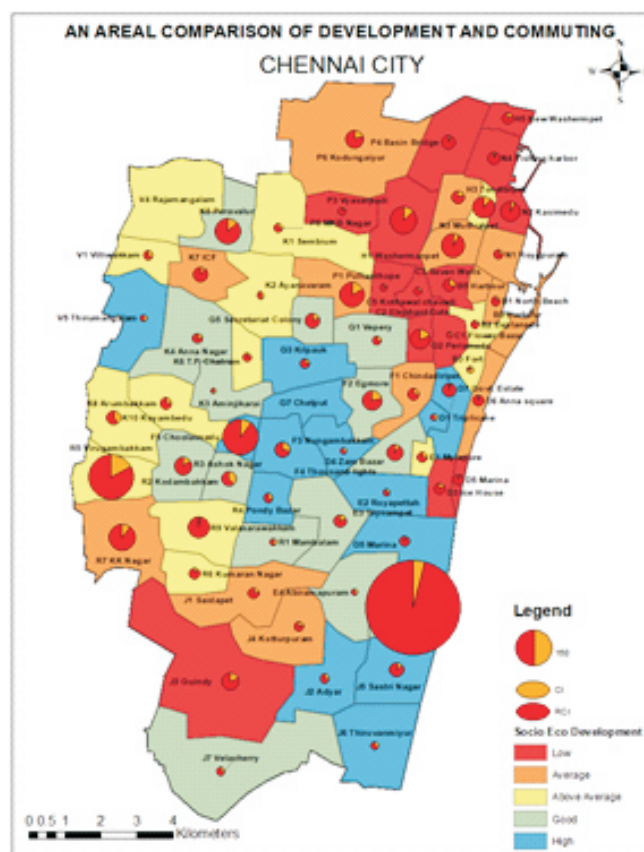


Fig. 4 Comparing SED with Commuting preference

The positive and negative correlation can be observed between CI, RCI and SED, RCI respectively with some notable exceptions in Table 1 and Figure 3. Since CI is a function of RCI, it tends to be directly proportional to the latter with the major difference between them being the crude willingness of an Offender to explore out (CI) and the environmental opportunities that influence his decision (RCI). As evident from the proportional representation of pie symbol in Figure 3, majority of regions having low development tend to have high degrees of commuting and vice versa. Noteworthy exceptions like E5 Pattinapakkam and F5 Choolaimedu are the causal effects of factors like frequent Police patrolling and presence of VIP residences.

Least to Low preference for commuting is noticed in Figure 4 in limits like Aminjikarai (K3), Pondy Bazaar (R4) and Anna Salai (D2) in Central Chennai, Thirumangalam (V5) and Ayanavaram (K2) in the West: Triplicane (D1) in the East: Harbour (B5) and Flower Bazaar (C1) in the North: and Adyar (J2) in the South. The lower degree of commuting of Offenders on these areas indicate that the majority of Offenders commit crimes in their own area. It is observed that these areas, especially, Pondy Bazaar and Anna salai in Central Chennai: and Flower Bazaar in North Chennai is essentially characterized by commercial and service functions. The other areas, namely. Aminjikarai in Central Chennai, Thirumangalam in the West and Adyar in the South are mainly the high- income residential areas. These areas also provide

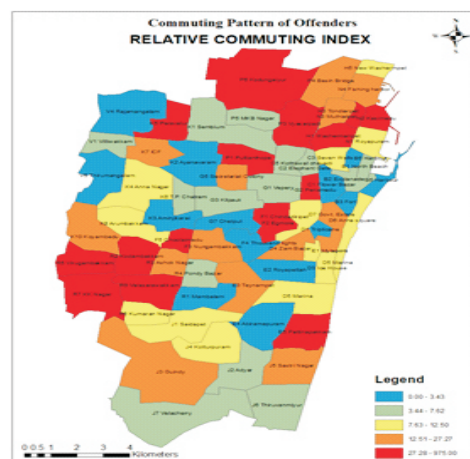


Fig. 5 Relative Commuting Index (RCI)

a great environmental opportunity for property offenders. A relatively lower percentage of commuting is also found in the peripheral parts of Southern Chennai that is characterized by industrial and high-income functions.

The concentration of high degree of commuting (Hotspot like feature) is found distinctly in the North and North East Chennai. The distinct locations are expressed visually on the Surface map.

Further, from Figure 4 it is evident that majority of Offenders prefer their home turf (areas where they reside) to foreign counterparts with some notable exceptions in Northern parts of Chennai. While the former observation may be due to the existence of elite communities, the latter conspicuously indicates the dearth of opportunities thanks to low quality of living standards.

Taking cue from this, Pearson's Correlation coefficient analysis is performed between the Development indicator (SED) and RCI using NCSS Statistical software and further it is tested for statistical significance.

Upon interpreting the results (Figure 5), there is an obvious downward progression of the Regression line which is bound by 10% Confidence Intervals on both sides showing definite Negative correlation between them. Some notable outliers (say for instance, Pattinapakkam (E5)) were ignored in the best of interests to arrive at a factual conclusion.

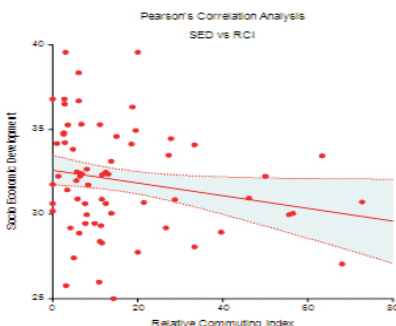
Further, Null(H_0) and Alternative hypothesis(H_a) were formulated and the data is tested for significance at Probability value($\alpha=0.1$) where H_0 denotes no significant correlation i.e the variables are random and H_a disproves it.

Pearson Correlation Test Section

$H_0: \rho = 0$

Alternative Hypothesis	Pearson Correlation	Count	df	T-Value	P-Value	Reject H_0 at $\alpha = 0.1$?
$\rho \neq 0$	-0.2051	67	65	1.6897	0.0959	Yes

Source: NCSS Statistical Software



Since the obtained P- Value (0.0959) is less than the assumed probability value ($\alpha=0.1$), H_0 is rejected and the existence of a significant correlation between SED and RCI is further reestablished.

6. Conclusion:

The analysis shows that the pattern of the journey to crime is related to the physical and functional characteristics of different parts of Chennai city. In the localities where the environmental opportunity is low, the degree of commuting is relatively higher which can prove to be vital in monitoring the movements of recorded suspects in RCI high valued areas while at the same time beefing up the security levels in RCI low valued counterparts. It must be noted that in the commercial and high-income residential areas commuting is relatively lower owing to greater environmental opportunities within itself but it is important to take cognizance of some exceptions as well which are due to obvious causative factors. Thus the Study helps us to understand the relationship between the mobility pattern of property offenders and the characteristics of the areas. The Choropleth maps drawn with the help of GIS software also identify the areas of significantly high and low commuting pattern of offenders. Such identification may help the police department in law enforcement planning. Additionally, the usage of Commuting indices in analyzing the behavioural aspects of Offenders is quite uncommon in crime related literatures barring few like A study of spatial mobility of property offences, Sivamurthy (2005), the Indian Police Journal in which Ward centric suggestive and mitigative measures were advised to the Coimbatore City Police department based on Commuting pattern of Offenders post the infamous riot events that shook the City.

Moreover, from a Geographer's perspective apart from just a mere spatial portrayal of events, this Study has employed Statistical techniques to ascertain the factors of influence as it is quintessential to cull out the root cause, say for instance analyzing the push and pull factors that prompt these malicious occurrences. Push factors are the ones that force a person to commit crimes in the likes of poverty and unemployment which can be noticeably recognized in areas of low Socio economic development especially in northern parts of the City and Pull factors which expresses the magnetic pull some of the areas in central parts of the City have on people who are gullible to commit offences due to socio economic disparities and increasing capitalistic environment. Thus mitigating crime not only demands stringent laws and punishments but an increased emphasis on Push and Pull factors and accordingly an apt allocation of resources which are concerned with equity in regional developments and living standards. Though the former method may prove to be effective in the short run there always exists an eerie uncertainty about it's worthiness in the near future.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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