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SPATIAL AUTOCORRELATION TECHNIQUE FOR LANDSLIDE HOT-SPOT ANALYSIS IN THE UPPER RAVI RIVER CATCHMENT, CHAMBA, HIMACHAL PRADESH

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Abstract

Landslide is one of the most frequent disasters in the Himalayan Mountains that cause destruction to human lives, property and infrastructure. The Upper Ravi river catchment of Himachal Pradesh is one such area where potential to slope failures is associated with complexity of geo-tectonic processes, extreme climatic events and anthropogenic activities. These spatial processes make this hilly terrain susceptible to landslides. This paper attempted to examine landslide hot-spots and associated spatial processes. Geospatial technology has been used to delineate landslide sites and preparation of landslide inventory. The technique of spatial autocorrelation was used to identify landslide clusters using Global Moran's Index. The analysis reveals two major statistically significant landslide hot-spots located in the eastern and western margins of the study area.

Keywords: Geospatial Technology, Landslide, Spatial Processes, Spatial Auto-Correlation, Hot-Spot Analysis.

Introduction

Mountains are destined to be scarred by disasters; every year multiple disasters cause destruction in mountain environment. Landslide is one of them; the slope failure is ranked second most frequent hazard in the Himalayan state of Himachal Pradesh. Among all the districts of state, Chamba is one of the worst affected by landslides (Kahlon, Chandel and Brar, 2014). This catastrophic slope failure process shows its presence in Himalayan mountains and claim human lives, causes loss to property and infrastructure (Chandel and Brar, 2011; Chandel, Brar and Chauhan, 2011). The entire Upper Ravi river catchment falling in Chamba and parts of Kangra districts of Himachal Pradesh is vulnerable to multiple geo-tectonic hazards. This region has potential to various types of slope failures due to its weak geological structure, complex geomorphological processes, active river cutting and increasing anthropogenic meddling with the slopes. The occurrence of extreme climatic events (Chandel and Brar, 2010a; Thakur and Chandel, 2016) and active seismicity (Chandel and Brar, 2010b) further adds to the misery caused by slope failure and landslides.

Himalayan mountains are prone to landslides of severe to high intensity. The identification of locations of frequent sliding is an important aspect of mitigating landslide hazard. The spatial arrangement of such geographic phenomenon reflects patterns that could help in determining whether such events form clusters or distributed randomly. Such patterns also help understanding spatial dependency and the nature of a particular region since distribution and arrangement of landslides/slope failure is dependent on local geological and geomorphological processes. Besides, there are many more interrelated factors like topography, climate, environment and anthropogenic activities that directly or indirectly modify susceptibility conditions of an area. Every slope failure has different characteristics based on underlying natural processes; the spatial patterns are true representative of such processes operating in the region(Chou, 1995). An appropriate modelling of observed landslide sites to examine such patterns is a very significant step for understanding hazard potential and geospatial technology facilitates to explore spatial relationships between diverse locations of landslides in an area.

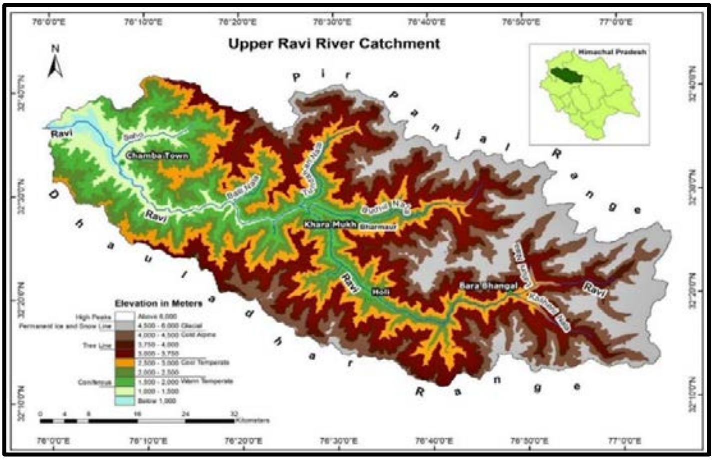

Fig. 1. Location of Study Area

Landside hot-spot analysis using geospatial technology has provided with very useful tool to interpret an area's potential for landslide hazard. The hot-spot mapping identifies the statistically significant spatial clusters; the higher values indicate hot-spots whereas low values denote cold-spots. Also, the hot-spot mapping of landslides may serve as reference for undertaking extensive field studies that has application in initiating future developmental plans. Spatial autocorrelation and hot-spot analysis has applications in explaining distributional patterns of geographical entities (Wong and Lee 2005) and has been used in different studies, for instance, traffic safety (Moons et al., 2008), crime analysis (Eck et al., 2005; IACA, 2013) and detection of slow moving landslides (Lu et al., 2009; Holbling et al., 2018). This research paper attempted hot-spot analysis for landslide hazards assessment using geospatial technology in a mountainous environment.

Study Area

The study area comprises of upper Ravi river catchment situated between the Dhauladhar and the Pir-Panjal mountain ranges of the Lesser Himalayas. The elevation in this mountainous landscape ranges from 700-6,200 metres above mean sea level. Such large altitudinal variations have produce different climate types that varies from semi-tropical to temperate to alpine type (Figure 1). The topography is highly rugged which is carved out by river Ravi and its tributaries. The study region covers an area of about 3232 km². The rocks of Proterozoic times that specifically belong to Vaikrita group are found here; slate and phyllite with minor quartzite dominates the lithology. Unconsolidated rock material cause instability and make region susceptible to mass movement and slope failure. The District Disaster Management Plan (DDMP, 2016-2017) of Chamba district reported that 33.28 per cent and 60.10 per cent of the total area has severe and high risk to landslides, respectively. Moreover, the area is undergoing massive transformation under new development policies and plans. New infrastructure is being created here; activities such as construction of highway, link roads to villages, widening of existing and construction of new roads to facilitate hydropower projects has impacted heavily on mountain slopes making landscape instable and vulnerable to slope failures.

Data Sources and Methods

The study is based on geospatial technology and spatial statistical tools wherein spatial autocorrelation technique has been applied to identify spatial pattern of landslide concentration. Specifically, the Moran's I index and incremental spatial autocorrelation were calculated to determine whether or not hot-spot analysis is statistical significant.

- *Landslide Inventory:* The first step for hot-spots analysis is the preparation of landslide inventory of the study area. A total of 473 landslides were traced from satellite imageries and high-resolution image using Google Earth Pro. Different types of slope failure sites were identified, most of which belonged to debris slide, rock fall, slump and wedge failures. The initially marked polygon features representing landslide sites were then transformed into point data using GIS tool.
- *Spatial Auto-correlation:* Spatial autocorrelation finds patterns in the distribution of geographical entities such as landslide by utilising their location and attribute information as input point data to determine the clusters or dispersion of landslide locations with the reference to their attribute values (Wong and Lee, 2005). In case of nearest neighbourhood analysis and quadrat analysis, it is difficult to distinguish each point feature from other point features as both methods analyse only the locations of point data. The advantage of spatial autocorrelation tool is that it helps to generate clusters with similarity in terms of their attribute values (Positive Autocorrelation) and dissimilarity of attribute values (Negative autocorrelation) (Legendre, 1993).

In this paper, spatial autocorrelation between landslide locations has been examined using Global Moran's Index. This index measures autocorrelation based on feature locations and feature values to determine whether pattern is clustered, dispersed or random. The spatial autocorrelation tool calculates values such as Moran's index value, expected index, variance and gives z-score and p-score that accounts for the significance of Index. The positive Moran's index value shows clustering whereas negative values denotes tendency towards dispersion (ESRI, 2018). The Moran's index values are calculated using the following equation:

Moran's Index Statistic for Spatial Auto-Correlation

$$\mathbf{I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2}}$$

z_i=Deviation of an attribute for feature i from its mean$(x_i - \bar{x})$,
$w_{i,j}$= Spatial weight between Feature i andj.
$n =$ Total Number of Features,
S_0= Aggregate of all the spatial weight,

$$S_0 = \Sigma_{i=1}^{n} \Sigma_{j=1}^{n} w_{i,j}$$

Equation to find $zI -$ score:

$$\mathbf{z_I = \frac{I - E[I]}{\sqrt{V[I]}}}$$

Where,

$$E[I] = -1/(n-1)$$
$$V[I] = E[I^2] - E\,[I]^2$$

- Moran's index is based on null hypothesis, which states that attributes are randomly distributed in the study area. Statistically significant test decides whether to reject or accept the null hypothesis (ESRI, 2018). Moran's index tool calculates expected and observed values and then compared the both. The z-score and p-score are calculated by taking into account the total number of point features in the dataset and their variance. Moran's index can be classified as positive, negative or no spatial autocorrelation. Positive spatial autocorrelation exists when Moran's index is close to +1.0 and negative spatial autocorrelation occurs when index value is close to -1.0, whereas absolute 0 index value shows no spatial autocorrelation (GIS Geographer, 2018). Moran's Index value should fall between -1.0 and +1.0, as this range is assumed to be statistically significant.

Table 1. Interpretation of p-value and z-score

Non-significant p-value	Null hypothesis cannot be rejected. The possibility exist that spatial distribution is the result of random spatial processes.
Statistically significant p-value and positive Z-score.	Reject the Null hypothesis. The spatial distribution is more spatially clustered.
Statistically significant p-value and negative Z-score.	Reject the Null hypothesis. The spatial distribution is more spatially dispersed.

- *Incremental Spatial Autocorrelation Tool:* Global Moran's I tool computes statistically significant z-score and p-values derived from a given dataset. However, there are certain things which are required for hot spot analysis such as appropriate scale for analysis where distance band indicating maximum spatial autocorrelation (peak value) is measured using incremental spatial autocorrelation tool (Basu, 2015). This tool measures spatial autocorrelation for a series of distance and optionally develops a line graph showing z-score with several peaks. The highest peak with corresponding value of z-score represents maximum spatial autocorrelation as compare to other peaks with their respective z-scores. This distance serves as the ideal distance for further analysis while running hot-spot tool.

- *Hot-Spot Aanalysis:* Mapping of landslide clusters in the study area is based on hot-spot analysis (Getis-ord Gi*). The z-score and p-values derived from spatial autocorrelation analysis represent landslide location that has high values (hot-spots) and low values (cold-spots). However, in order to be designated as a hot-spot, it is necessary that a landslide location has a higher value along with the surrounding landslide features having high values as well. Getis-ord Gi* statistic was calculated to identify such hot-spots using following algorithm:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)\right]}{n-1}}}$$

Where,

x_j=Attribute value for feature j,

$w_{i,j}$= Spatial weight between feature i and j,

n= Total number of features.

To calculate value of $\bar{X}$ and S:

$$\bar{X} = \frac{\sum_{j=i}^{n} x_j}{n}$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n}} - (\bar{X})^2$$

- *Inverse Distance Weights (IDW):* The calculated hot-spot values were interpolated using Inverse Distance weight (IDW) interpolation techniques in ArcGIS software. This IDW technique is based on an assumption that the influence of mapped variable diminishes with increasing distance from the sampling location. Hence, this technique gives higher weightage to variables located in the close proximity to sampled location and vice versa.

Results and Discussion

The present research paper attempted to find statistically significant landslide hot spots in the Ravi river catchment by extracting information from the satellite data and processing the information using spatial analysis tools in GIS environment. Using satellite data and Google Earth Pro, a total of 473 landslide sites were extracted which were then transformed into point feature class. The spatial auto-correlation (Global Moran's I) was performed on the point data inventory to test the significance level of various patterns spread throughout the study area. Table 2 shows Moran's I index value is (0.350673) is falling between desired range of -1.0 and +1.0 thereby indicating a statistically significant patterns. Since the p-value (0.000000) is zero, it means spatial patterns are not an outcome of random process. As a result, the null hypothesis stands rejected (Table 1). Also, the z-score value (5.721330) that actually represents standard deviation is positive and much higher than +2.5, therefore, it shows a strong presence of landslide clusters. These values derived from Moran's index clearly reject the null hypothesis and signifies the presence of clustered pattern in the spatial distribution of landslides and hence makes the analysis statistically significant and verified.

After checking the significance level of values derived from point data on landslide locations, the next step was to generate the distance band (incremental spatial autocorrelation). Finding such appropriate scale for analysis ensures that all point features have at least one neighbour. The analysis shows a peak having maximum spatial autocorrelation at the distance of 15,046.07 metre with corresponding z-score of 4.846973 (Figure 2). Since spatial autocorrelation is high at this distance, this value deemed as appropriate distance band for Hot-spot analysis tool. The hot-spots (Getis-ord Gi*) analysis calculated landslide hot-spots and cold-spots locations with confidence levels of 90 %, 95% and 99% (Figure 3) along with non-significant locations in the upper Ravi river catchment. The landslide hot-spots (clusters in red dots) in the extreme eastern and western margins of study area show a high degree of confidence which is statistically significant whereas cold-spots (blue dots) represents dispersed pattern of landslide occurrence. The remaining dots show random distribution of landslides.

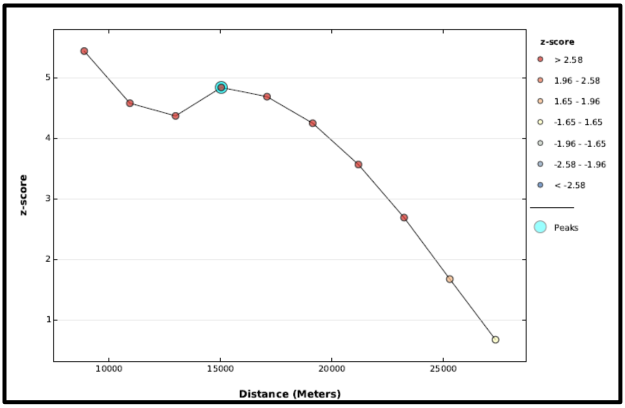

Fig. 2. Spatial Autocorrelation by Distance

Table 2. Spatial Autocorrelation Analysis

Moran's I	Expected Index	Variance	z-score	p-score
0.350673	-0.011111	0.003999	5.721330	0.000000

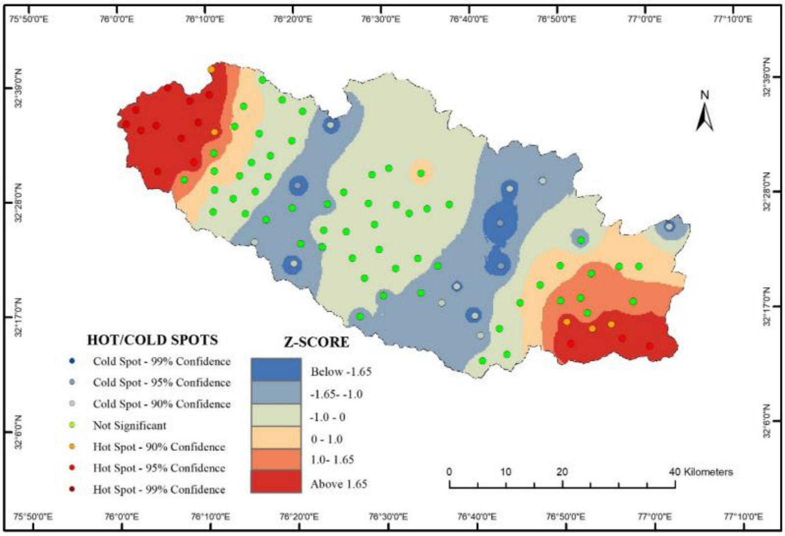

Fig. 3. Landslide Hot-Spots and Cold-Spots

The analysis further examined the major spatial processes that are responsible for landslide hot-spots. Landslide is a site-specific hazard persistent to certain specific locations and these locations are governed by the geological and geomorphological processes, land use/land cover, proximity to rivers and streams, proximity to roads, lineaments and infrastructure development activities. Correlating these factors helps in understanding as to why hot spots are persistent in certain locations and what mechanism makes certain sites highly vulnerable to landslides. Landslide hot spots (Fig. 3) in the western margins represent areas of Chamba town and its surroundings that have high population concentration. Since human activities are more dominant in this part, the slope failure can be attributed to anthropogenic activities. On contrary, the eastern hot-spot occupy a remote area of Bara Bhangal where landslides and slope failure activities are chiefly governed by geo-tectonic factors.

Within the physical factors, slope is one of the most important causative factors of landslides; landslide hot-spots in the study area comprise of critical slope angles between 30-35 degree and higher. The slopes of such nature have tendency to collapse during high intensity rainfall and even by minor earthquake, which are regular phenomena in this area. Geomorphological control over slope failure is very dominant. Highly dissected hills and valley covers 76 per cent of total area and hot-spots coincide within this geomorphological class which is highly susceptible to collapse anytime under the influence of excessive rainfall and seismic activity. The geology of this area is dominated by Slate, Phyllite, Quartzarenite, Limestone and Meta-basics that occupy nearly 64 per cent of the total area. These rock types are highly susceptible to landslides and the hot-spot zones are associated with these types.

The high degree of drainage density and dissection index appears to be another trigger for landslides in this area. Not only the hot spots but other randomly distributed landslides location in the study area has a close affinity with major streams and their tributaries. Despite a major role played by geo-tectonic factors, there is an active anthropogenic influence on slope failure and landslide occurrence. Till very recently only about 5.06 per cent of the total area in Chamba had been under direct human use as revenue area. More recently, extensive anthropogenic activities have taken place in the form of settlement expansion, construction of new roads and widening of existing ones to facilitate hydro power projects and tourism. Such areas are exposed to landslides and hence represent hot-spots with high degree statistical significance. It is to note that the eastern landslide hot-spot zone has no-visible sign of anthropogenic activities and has deciduous forests; scrubland and barren rocky patches as dominant land cover type. However, the western hot-spot zone has human dominated land use. The road construction has taken place extensively in this zone, which has resulted in slope instability and failure. Additionally, the areas where landslides are randomly distributed show a strong correlation with road alignment. Hence, the occurrence of landslides in such locations is more influenced by anthropogenic actions.

Conclusion

It is quite evident from the analysis that multiple factors, both natural and anthropogenic, are responsible for triggering landslides in study area. The role played by a combination of various geo-tectonic causative factors such as geology, geomorphology, drainage and slope is clearly visible, especially in the eastern hot-spot zone where anthropogenic activities are minimum. However, human induced landslide risk in the area is equally significant as evident from western hot-spot zone where land use, road building and related human activities are the key player in triggering landslides. The increasing risk of landslides was also found along the roads as majority of slope failure occur in their vicinity. It can be concluded that detection of spatial pattern and landslide hot-spot analysis is a very innovative approach to determine the landslide risk areas wherein geospatial technology provides a robust tool for statistical measurement of landslides, their distributional patterns and associated spatial process.

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REMOTE SENSING AND GIS BASED STUDY ON LANDCAPABILITY ASSESSMENT FOR SUSTAINABLE CROP DEVELOPMENT IN SARADA BASIN, VISAKHAPATNAM DISTRICT, ANDHRA PRADESH

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Abstract

The study seeks to assess land capability across all 62 micro-watersheds of Sarada river basin in Visakhapatnam District of Andhra Pradesh, India using Remote sensing and GIS technology for suitable crop development. The study takes into account various contributory factors include landuse, soil type, slope, drainage density, geology and rainfall for integrated analysis. IRS-P6 Resourcesat-1, LISS-III image data has been used for interpreting and mapping the distribution of land resource in the watershed area. LIDD-III image with 23.5 metres resolution is best suited for classifying the land resource across the watershed. Meteorological factors like rainfall and humidity have also been considered as they influence the seasonal productivity of the crop. Integration of these factors were accomplished through a real-time multi-criteria model which functions based on corresponding weights of the factors to identify and map areas having varied potential for crop growth. A schema was designed to categorise these potential areas into eight diversified classes and finally regrouping them into high, moderate and low priority areas. The evaluation reveals that climatic limitations are prevalent in the study area. The resultant map indicates 61.82% of basin with potential for agricultural development. This include land with 'high' and 'medium' potential accounting for 39.48% and 22.34% and found suitable for crops like paddy, sugarcane, sesame, maize, arhar and chillies. The 'low' priority areas (hilly and deep slope) are not considered for crop development as this category does not satisfy the needs of agricultural practices and crop development.

Keywords: Land Suitability Assessment, Sustainable Agricultural Development, Remote Sensing and GIS, Sarada River Basin

Introduction

Rapid growth in population continues to insert pressure on natural resource, especially on agricultural land, thus warrants a sustainable approach. This is only possible through intensification and expansion of agricultural practices in the limited land, which effectively combats increasing demand for farm output.

This essentially calls for understanding and identification of potential constraints and implementing appropriate landuse measures through land capability assessment studies. Land capability assessment is the process of classification of a land resource into distinctive categories depicting their potential and suitability for a particular landuse activity (Alshuwaikhat and Nasef, 1996). The process was first introduced in the USA (especially that of the Soil Conservation Service of the U.S. Department of Agriculture) and successfully being implemented in many countries at various scales, keeping in view the characteristics of local landuse activities (Helms and Douglas, 1992). The specific objectives of landuse mapping and land capability assessment are to obtain up-to-date information about current landuse activities, to assess the availability of existing land resource and physical constraints.

They relate them to land capability which help develop a plan for subsequent evaluation of land capability class based on weighted multi-criteria evaluation methods. The idea is to limit the land for the proposed landuse type for better yield. An economic definition of suitability can be based on defined metrics of economic values, e.g., predicted gross margin, net present value, internal rate of return, benefit cost/ratio.

Land capability evaluation also makes it possible to predict the performance of the land, so that it can be utilized properly over a period of time. These predictions are then used to guide strategic landuse decisions. A landuse system can therefore be defined as a specific landuse practiced during a known period on a known and contiguous area of land with reasonably uniform land characteristics.

Land capability is a spatial attribute which changes in space and time, therefore the study needs to conduct surveys to gather information pertaining to environmental variables pertinent to land quality. The variables include soil, geology, geomorphology, landuse, land cover, slope and climate. Hence, land capability studies are intensive in terms of data gathering and analysis. Of late, land capability assessment has become essential in agricultural applications as they enormously help farmers to make informed choices about the land, thus contributes for a sustainable utilization of land resource in a way which is optimal.

Advent of Remote Sensing and GIS technologies paved way for inordinate progress in land capability assessment for agriculture, in terms of ease and performing complex analysis in a shorter time frame. Remote Sensing data is of great advantage in mapping landuse/land cover scenario while updating the existing repository of information like soils, geology, geomorphology etc. GIS acts as a platform for extracting and storing spatial information in a format amenable to complex analysis like overlay, proximity, suitability etc. Therefore, GIS has high significance in land capability assessment where multi-criteria evaluation is an essential requirement (Nooka Ratnam et al. 2013).

Quite a number studies attempted to evaluate the land capability through different approaches. According to Rossiter (2001) land suitability is the fitness of a given type of land for a specified landuse type and obliges the study of land properties and land use to determine the adequacy of compounded requirement of landuse to the compounded properties of land. This essentially takes into account the important factors like, physical, socioeconomic and environmental aspects for optimum utilization and conservation.

The need for optimum use of land has never been felt so strongly as in current times, when rapid population growth and urban expansion are making the agricultural land, a scarce commodity. The increasing demand for intensification of existing cultivation and the opening up of new areas of land can only be satisfied without damage to the environment if the land is classified according to its suitability for different kinds of use (FAO, 1983).

The comparison of relevant landuse requirements with associated land characteristics or qualities is essence of the analysis of landuse systems. The outcome of this matching procedure forms the basis for assessing the suitability which is meant to describe the adaptability of land to a specific landuse (Driessen and Konijin, 1992).

Methods for Assessment of Land Capability

Land evaluation is a multi-disciplinary approach involves an integrative and iterative process. The methodology requires expert knowledge of landuse planners, agronomists, research scientists, farmers and socio-economists. For optimum results, the land evaluator shall undertake to extract information from the concerned experts and transform it into a format compatible with the FAO land evaluation methodology.

Land evaluation deals with three major aspects like physical, climatic and demographic. Physical aspects include topography, soil, geology, geomorphology, slope, whereas climate and socioeconomic aspects include farm size, management level, available manpower, market position and other human activities. The former are considered to be relatively stable, while the latter are more variable and dependent on social and political decisions (Sys et al., 1991).

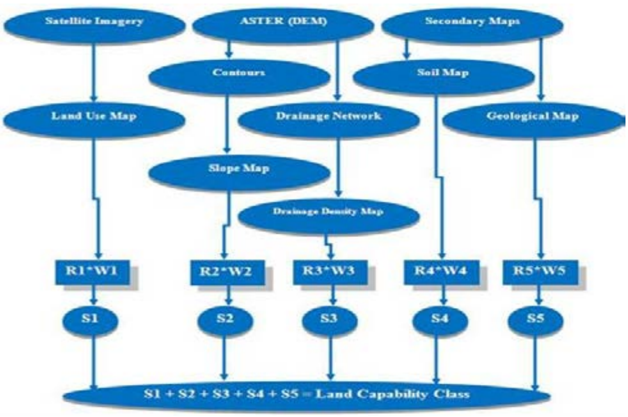

Fig. 1. Workflow for the Integration of Various Themes for Land Capability Classification

Data collected from different sources are classified into static and dynamic data. Static data elements are those which do not change over time, like soil data, surface, water resource, elevation/slope, geology and drainage density. Dynamic elements are those which changes over time, like, land use/land cover, cropping patterns, demography etc. These parameters as information layers were used to classify the spatial units based on the degree of their differentiation. Subsequently, all these map layers were integrated for further analysis in GIS environment which resulted in a composite layer of multiple units or classes. The work flow involved in the study is shown in Figure 1.

Land use Characterisation

Driessen and Konijn (1992) further elaborated the landuse system as a combination of a land unit with one utilization type (one set of landuse requirements). As such, land relations between landuse and land give estimates of required inputs and projected outputs. In order to study the performance of landuse, it must be the basic entity of descriptions (De Bie et al., 1996). However, the definition of a landuse system mentioned above differs from the one given by Food and Agriculture Organization (FAO, 1983), which defines a landuse system as a specific use type practiced on a given land unit and associated with inputs, outputs and possibly land improvements.

As required land use/land cover phenomena is mapped for the year 2015. The area statistics generated suggests that rain-fed agriculture is the predominant landuse type in the study area accounting for about 53.38% of the total land. Each class in all the respective themes was given a subjective rank with a range of 1 to 10 based on its priority within the theme. Similarly, each class has been assigned with a weight factor, which varies within a range of 1 to 10, but indicates the overall priority of the class within the integrated map composite. Multiplying the ranks and weight factors of each class in the integrated map composite resulted in a unique score for each class (Table 1) indicating its importance, which will be taken as the basis for recognizing most or least favorable zones for agricultural practice. These final scores are again categorized into 8 major classes, i.e., from I to VIII, where, class I shows a high degree of favorability and class VIII shows a low degree of favorability for agriculture. The score is simply used as the measure of suitability for cultivation. Accordingly, the entire land was classified into 8 classes as per its ability to support agriculture activity in the given area on the basis of soil characteristics, associated land features and environmental factors. The chief soil character taken into consideration is texture. The important associated land features are slope, erosion, soil, drainage and frequency of overflow. From the overlay of landuse/land cover, soil, geology, slope and drainage density maps, a land capability map was produced. Land classes are shown with different colors indicating the intensity of suitability and non-suitability for cultivation.

Criteria for Classification of Land Capability

Land capability classification is a systematic approach, where each unit of land is classified according to its capability of producing the crop output and its vulnerability to risk which may have the potential to damage (National Institute of Hydrology, 1999).

This classification is made primarily for agricultural purposes and enables the farmer to use the land according to its capabilities and treat it according to its characteristics (Lynn et al., 2009). Land is arranged in various capability classes by considering a number of soil characteristics and associated land features (landuse/land cover, soil and geology) and environmental factors (climate). The chief soil characteristics to be taken into account are texture, depth, salinity and alkalinity of soil and subsoil. The important associated land features are slope of land, the effect of past erosion, landuse/land cover, terrain, geology, geomorphology etc.

Table 1. Rank, Weightage and Score for Land Capability Analysis

Rank (R)	Data Layer / Theme	Weightage (W)	Overall Class Score (R*W)
A	**Landuse/ land cover Classes**		
2	Rural Settlement	1	2
1	Urban Settlement	1	1
9	Agricultural Crop Land	9	81
8	Agricultural Fallow Land	9	72
1	Aquacultures	1	1
3	Forest	4	12
1	Rocky/Barren Land	1	1
1	River / Tanks / Reservoir	1	1
B	**Soil Type**		
5	Red Clayey Soils (125, 127, 134, 135, 136 and 130)	5	25
3	Red Loamy Soils (128)	5	15
2	Red Gravelly Clay (131)	4	8
4	Brown Gravelly Loam Soils (139, and 140)	6	24
6	Sandy Soils (199)	7	42
1	Red Coastal Clayey Soils (209, and 212)	3	3
1	Saline-Sodic Clayey Soils (213)	2	2
C	**Slope Type**		
9	Plain Area	9	81
7	Low Slope	8	56
6	Low-Moderate Slope	7	42
4	Moderate Slope	6	24
3	High-Moderate Slope	4	12
1	High Slope	2	2
D	**Drainage Density**		
9	Very Low	9	81
8	Low	7	56
5	Moderate	4	20
3	High	2	6
1	Very High	1	1
E	**Lithology / Rock Type (Geology)**		
9	Alluvium	9	81
2	Charnockites	3	6
1	Granite Gneisses	2	2
3	Khondalites	4	12

By combining the thematic information generated in previous steps using GIS, it is possible to handle multiple information layers and the complex connections between these, simultaneously. Figure 2 shows a schematic illustration of various input data layers that are each multiplied using a weighting factor and subsequently added together into a land capability measure. This methodology is commonly applied for agricultural land capability.

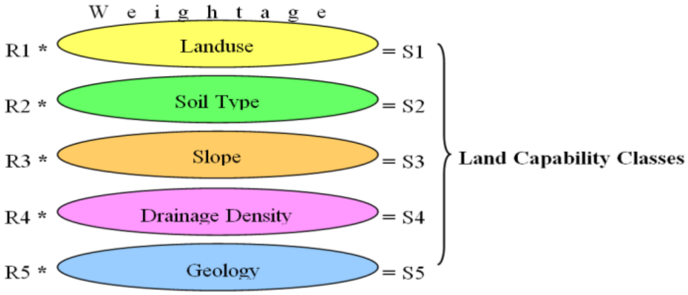

Fig. 2. Spatial Themes with Ranks (R), Weights (W) and Scores (S) used for Land capability Analysis

Land Capability Classification

According to the Land Capability Classification standards developed by the University of Minnesota (2009) the land is divided into eight broad classes based on their capability. These classes take into account the degree of erosion and the intensity of limitations for use. The classes are numbered in Roman numerals from I to VIII (Jacks, 1946) and assigned a standard color. These classes are grouped into two landuse suitability groups i.e., 'the land suitable for cultivation and other uses (Class I to IV)' and 'the land not suitable for cultivation but suitable for other uses (Class V to VIII)'. Land under 'Class I' is considered the best as it can be farmed easily and has no impact of hazards or limitation on its use. While land under 'Class VIII' may or may not be having economic value in terms of agricultural use, but need to be protected and conserved with best management practices for other value added practices and river basin management whichever it belongs to (Table 2).

Land capability information enables an identification of development opportunities and over-developed areas. For instance, actual grassland areas in very high land capability areas considered as high potential areas for development as they can support high intense agriculture. On the other hand, agricultural land located in areas with severe land capability constraints can be considered as being over-developed.

Results and Discussion

The study endeavors to evaluate the potential and suitability of land resource for agricultural development. The land capability assessment was carried out in GIS environment by integrating the thematic inputs such as, landuse/land cover, soil, geology, slope, drainage density and geology, with units representing a class assigned with a rank, weight and score on the basis of being most or least favorable for agricultural practice. Score for each category has been derived by multiplying the rank and weightage of range from 1 to 10 for each unit (Table 3) which was further grouped into major classes i.e. I to VIII.

Table 2. Land Capability Classes with Descriptions.

Capability Class	Description
Class I	The best and the most easily farmed land. It has a few limitations that restrict its use.
Class II	Land has moderate limitations that reduce the choice of crops. It needs simple soil and water conservation practices and requires some attention to soil management.
Class III	Land has severe limitations for use; hence, it needs intense soil and water conservation treatment and requires careful soil management. Graded terraces are made on moderate slopes.
Class IV	Land generally suits very low to moderate impact land uses. Includes some of the best grazing in the area.
Class V	Land is generally suitable for moderate to low intensity grazing. Significant limitation for high impact land uses. Suitable for very low to moderate impact land uses such as direct drill cropping and grazing.
Class VI	Not Capable of Supporting high or medium impact land uses due to extreme difficulty in removing or reversing degradation and associated off-site impacts. Low productivity agricultural land capable of light grazing or natural conservation.
Class VII	Land should remain under native vegetation due to high soil erosion hazard and extreme site limitation. The land is best utilized under forest and native vegetation.
Class VIII	Other lands not suitable for any type of landuse apart from native timber (commercial plant) and nature conservation due to soil and landforms limitation, and restrict their use for recreation, wildlife or water supply or to esthetical purpose. Examples: rock outcrops, sandy beaches, marshes, deserts, land along river banks, mine tailings etc., which do not give any economical return.

Source: Jacks (1946) and University of Minnesota (2009)

Table 3. Land Capability Classes and Their Areal Extents in the Sarada River Basin

S. No.	Land Capability Class	Area (km^2)	Area (%)
1	Class – I	262.53	9.97
2	Class – II	382.50	14.52
3	Class – III	394.93	14.99
4	Class – IV	221.76	8.42
5	Class – V	366.68	13.92
6	Class – VI	443.46	16.84
7	Class – VII	387.59	14.71
8	Class – VIII	174.77	6.63
	Total	**2,634.22**	**100.00**

Land capability assessment identifies most of the study area under Class II, III, V, VI and VII, with 14.52%, 14.99%, 13.92%, 16.84% and 14.71% area respectively (excluding area of Class-I). On the other hand, Class I, IV and VIII account for only 9.97%, 8.42% and

6.63% area (Table 4). The final land capability map (Figure 3) is shown in a color gradation range from red to green. Where green represent land which is most capable and suitable for agriculture while the red denotes the least.

Table 4. Land Capability classes with priorities in the Sarada River Basin.

S. No.	Land Capability Classes	Priority
1	Class – I	High
2	Class – II	
3	Class – III	
4	Class – IV	Moderate
5	Class – V	
6	Class – VI	Low
7	Class – VII	
8	Class – VIII	

In order to demarcate priority areas for agricultural practices and to map the crop development areas all the eight land capability classes described in Table 4 are regrouped into three. A composite map is generated overlaying different parameters influencing agricultural characteristics and reclassifying them into three priority categories such as ‘high’, ‘moderate’ and ‘low’ based on their suitability for agriculture practices as shown in (Table 4) and (Figure 4).

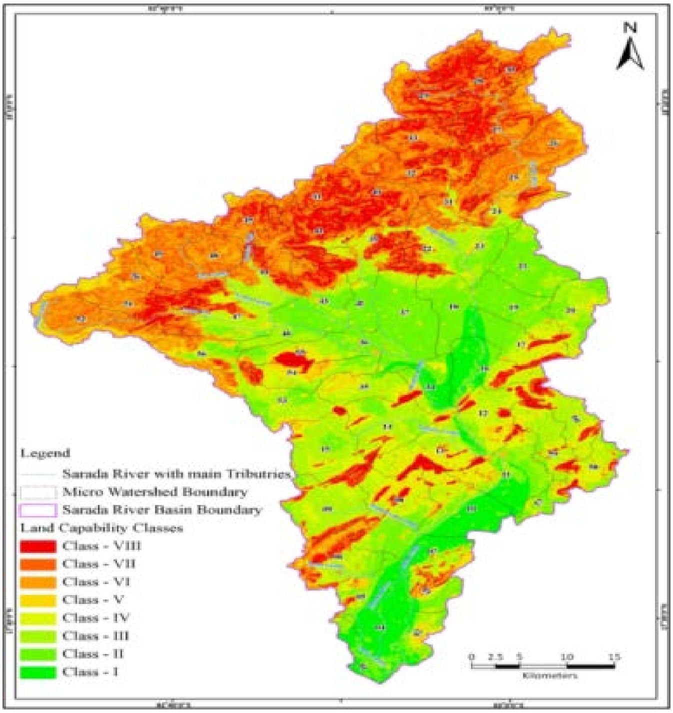

Fig. 3. Land Capability Class of Sarada Basin Mapping of Priority Zones for Agricultural Development

It is noticed that, a total of 61.82% area in the basin has the potential for agricultural development. A major part of the study area is covered by land capability classes with priority as ‘high’ and ‘medium’ accounting for 39.48% and 22.34%, respectively. The ‘low’ priority areas are not considered for development, as the category does not satisfy the needs of agricultural practices and crop development. The ‘high’ and ‘medium’ priority area is suitable for the crops like rice, sugarcane, sesame, maize, arhar and chillies.

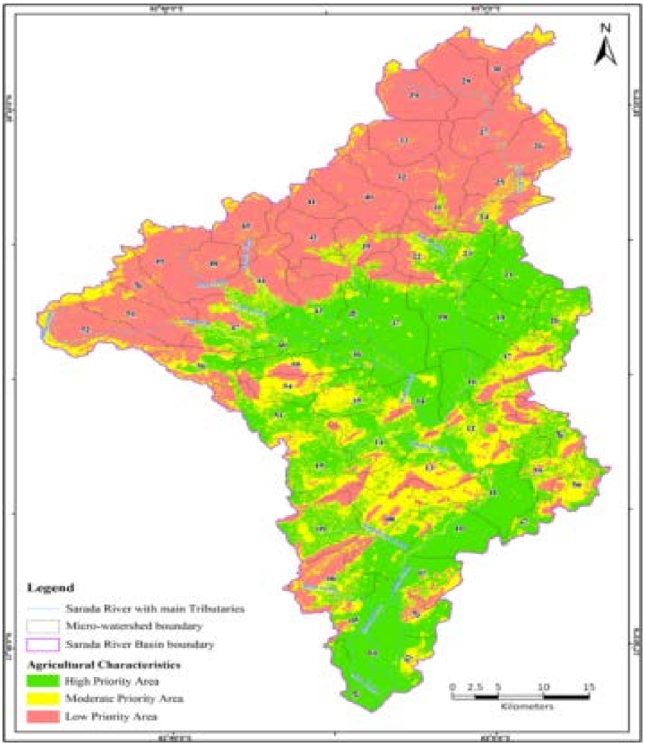

Fig. 4. Prioritisation of Land Capability Classes for Agricultural Development

Land Suitability Mapping

Since, agricultural land could not be discriminated into individual cropping units at the scale of mapping adopted for the study; they all were collectively grouped together as one. However, over 61.82% of the total agricultural fields as shown in the land suitability map (Figure 5) are identified as suitable for growing agriculture crops, such as, rice, sugarcane, sesame, maize, arhar and chillies.

Rainfall and climate are also considered as important factors in the land suitability analysis. The seasonal productivity of the field depends on the amount of rainfall and the humidity or dryness of the environment. Accordingly, the agricultural crop is chosen for the area. A generalized evaluation of the land suitability map (Figure 5) shows that climatic limitations are prevalent in the study area. Land with good or high suitability for irrigation covers only an area of about 1,406.33 km^2, which is 53.38% of the total land area.

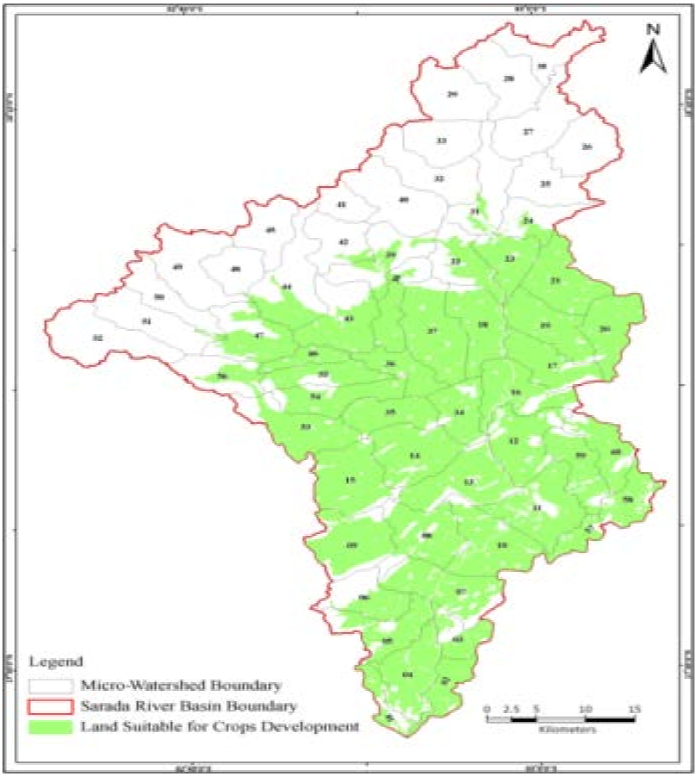

Fig. 5. Land Suitability for Crop Development

Conclusion

The results obtained from this study indicate that a combination of technologies like Remote Sensing, GIS and multi-criteria evaluation models could provide a superior database at micro level on suitability of land as a guide map for decision makers for crop land substitution for achieving better agricultural production. The study clearly shows that the spatial distribution of crop land derived from Remote Sensing data in conjunction with evaluation of biophysical variables of soil, geological, climatic, and topographical information integrated and modeled using GIS is helpful in crop vs. land management options for intensification as well as diversification. Superimposing of cadastral map over land capability map of the basin could help the planners and authorities to impost at field level.

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SITE SUITABILITY ANALYSIS FOR SOLID WASTE DISPOSAL USING REMOTE SENSING AND GIS - A COMPARISON OF KNOWLEDGE GUIDED FUZZY, INDEX OVERLAY AND AHP MODELS

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Abstract

Dumping of Municipal Solid Waste (MSW) in unsuitable areas have resulted in adverse effect on human health as well as on the environment. Studies on the selection of a suitable site for MSW disposal have gained considerable importance in recent years to ensure minimum damage to the environment and human health. The main objective of the study was to find a suitable site for Solid Waste Disposal (SWD) using Remote Sensing (RS), Geographic Information Systems (GIS) and Multi-Criteria Evaluation (MCE) technique for Visakhapatnam, Andhra Pradesh, India for better urban planning. In this study, a comparison is made by applying three different models such as multi-class weighted overlay, fuzzy overlay and Analytical Hierarchical Process (AHP) to the same set of GIS database to find out the suitable areas. The high suitable areas derived using three different models were compared and the common areas showing high suitability were field verified to find out the best possible site for SWD. The present study demonstrated the use of RS and GIS in decision making process for urban planning.

Keywords: Site Suitability, Solid Waste Disposal, AHP, Multi-Class Overlay, Fuzzy Overlay.

Introduction

A huge amount of solid waste has been generated on a daily basis by large cities all over the world. Because of rapid urbanisation, Municipal Solid Waste Management (MSWM) is a challenging task in many developing countries in the world (Khan and Samadder 2015). India is second most populated (1.2 billion) country in the world, having 17.5% of world population. As per the census of India 2001, 25.73% population resides in urban cities, which has been going to rise to 33 % in next 15 years (Sumathi et al. 2008). National Environmental Engineering Research Institute (NEERI) had conducted survey through Central Pollution Control Board (CPCB) during the year 2004-05, and estimated that 39,031 tons of Municipal Solid Waste (MSW) had generated per day in 59 cities and Central Institute of Plastics Engineering and Technology (CIPET) had conducted survey for same 59 cities during the year 2010-2011and had estimated that 50,592 tonnes of MSW generated per day (Status report on MSWM, CPCB, 2012). Unscientific disposal of MSW causes adverse impacts on all aspects of the environment and human health (Rathi, 2006). A scientific management of MSW includes source reduction, collection, segregation, processing, transfer and the final disposal of MSW in an appropriate way by taking environmental, aesthetical, engineering, economic, public health and social factors into consideration (Islam et al. 2018; Sharholy et al. 2008). Final disposal of MSW can be done in many ways, but landfill is considered as one of the common and appropriate process for waste disposal (Rahmat et al. 2017). Municipal authorities encounter various problems while selecting a suitable site for the MSW disposal.

Many researchers attempted to find out a suitable site for solid waste disposal for different cities across the globe by applying various techniques. Babalola and Busu (2011) used analytic network process (AHP) with Geographical Information Systems (GIS) to identify landfill site for Damaturu town, Nigeria. Sahani et al., 2014 used weighted overlay analysis to select suitable solid waste disposal site for Madanapalle Municipality, Andhra Pradesh. Gorsevski et al. (2012) standardized environmental and economic factors using fuzzy membership functions and combined by integration of AHP and ordered weighted average techniques for identification a landfill site for Polog Region, The Republic of Macedonia. Moeinaddini et al., (2010) used weighted linear combination and AHP in GIS environment to find out suitable landfill site for Karaj city, Iran.

Selection of MSW disposal site is complex task and it requires multi-criteria inputs from environmental, social and economical aspects (Şener et al. 2011). Remote sensing (RS) and GIS together acts as effective tools in Multicriteria Evaluation (MCE) for different kind of studies for regional as well as global level problems. GIS combines spatial data with other quantitative, qualitative and descriptive information databases (Nishanth et al., 2010). GIS reduces time and cost of site selection and helps in monitoring of site in future (Sumathi et al. 2008). RS and GIS databases have been becoming a handy tool for integrated analysis to understand the scenario of a particular location for site selection analysis.

Our study aimed at deriving a set of criteria and analysing them in a model based GIS environment to find out best suitable areas surrounding the Visakhapatnam city for solid waste disposal. Three knowledge-guided methods were tried and tested in the present study for their suitability to delineate the sites for solid waste disposal. Weighted Overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Weights have been assigned to each input parameters depending on its importance and same way suitable scores have been given to each class in individual input parameters. Fuzzy overlay combines different rasters, which are created using fuzzy membership functions. AHP provides a hierarchical structure by reducing multiple sets of parameters into a pairwise comparison method for suitability analysis either individual or group decision-making and allows the use of quantitative (objective) and qualitative (subjective) information (Gorsevski et al., 2006; Saaty, 1980).

Study Area

Visakhapatnam is the largest city in the Indian state of Andhra Pradesh. Visakhapatnam municipality is the headquarters of Visakhapatnam district and the headquarters of the Eastern Naval Command of the Indian Navy. Hence it has a large floating population from nearby towns and villages. It is a coastal, port city, often called 'The Jewel of the East Coast', located on the eastern shore of India, and nestled among the hills of the Eastern Ghats and facing the Bay of Bengal to the east. The study area has the areal extent of 12,44.4 sq. km. It lies between 17°29' N to 17°57' N latitudes and 82°58'E to 83°29'E longitudes. Visakhapatnam population is 14.35 lakhs (Census, 2011) including Anakapalli and Bhimli crossing 20 lakhs and population density is around 384 persons/sq.km. Greater Visakhapatnam Municipal Corporation (GVMC) is a fast growing city and it has population in-flow from nearby villages, towns, and other cities. GVMC built-up area occupies an area 19.66% of the total study area. In Visakhapatnam city, 334 tonnes per day municipal solid waste was generated during the year 2010-11 (Status report, CPCB, 2012). The average temperature range is 21°- 32.6°, average rainfall is 955 mm and elevation 54 m. The location map of the study area shown in Figure 1.

Site Characteristics and GIS Database

In this study, conventional methods have been used in selecting open areas away from the habitations for the disposal of solid wastes. With Remote Sensing (RS) and other allied methods of investigation including Geographic Information System (GIS) are available, finding a suitable site for solid waste disposal is more accurate, cost and time effective. In addition, RS and GIS can consider a number of factors/ parameters that have a direct/indirect bearing on the criteria for selection of suitable sites for solid waste disposal.

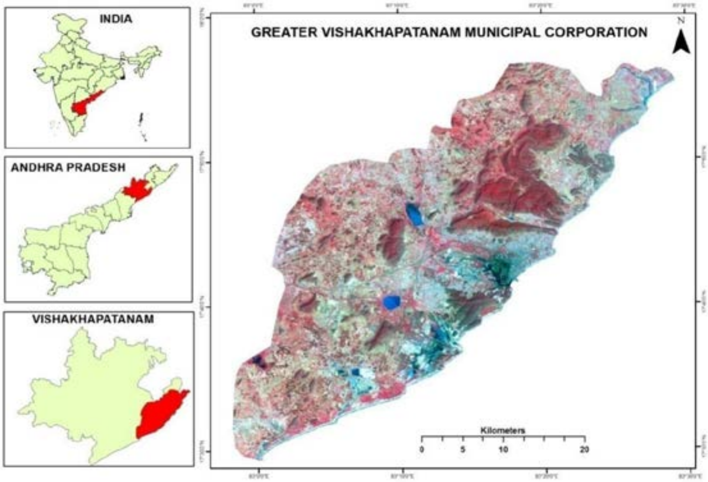

Fig. 1. Location of Study Area - Visakhapatnam, Andhra Pradesh

Taking into consideration the suitability factors for solid waste disposal and realizing the importance of scientific understanding of the causative factors, 10 parameters have considered for the study. Lithology map, overburden thickness map, landuse map, settlements buffer map, slope map, permeability map, Geological structures buffer map, Road buffer map, Water bodies buffer map and water-table map have been considered in the present study for optimizing the suitable site.

All the layers have been created from different sources in the GIS database environment. Disposal site should be away from settlements. As per CPCB guidelines, at least 500 meter distance should maintain from the settlement area to select new landfill site. Fractures and lineaments in the rocks act as a conduit for movement of groundwater. The water mixed with the waste material will lead to pollution of groundwater. Hence 0.5 km buffer zone has been extracted around major lineaments to avoid those areas for solid waste disposal. The area is dominated by settlements and fertile agriculture land. Forest area occurs in scattered blocks mostly limited to hills. Fallow lands and scrublands are limited in the area and occur in patches. Wetlands and water bodies along with sandy patches occur towards the coast. Geologically, the area is a hard rock terrain mostly dominated by Khondalite, which is a variety of gneissic rock. Granitoid gneiss is the second dominant rock type and alluvium occurs in patches within the extent of the study area. The overburden thickness map has been derived by co-interpreting the combined geomorphology, soil and slope classes and the knowledge of the geology of the study area. Low and moderate overburden thickness material is observed in hills and hill slopes as a result of low weathering, steeper slope gradient, and thin soil cover. High or thick overburden material is observed in relatively flat areas, alluvial and coastal sandy plains. The permeability map has been derived using lithology map, overburden map, soil map and permeability values of each rock type. Qualitative permeability classes have made based on the nature of the soil and various types of rocks present in the area. Low permeability has generally observed in clay-rich soil and areas with a thin cover of weathered material whereas moderate permeability has observed in loamy soils and high in sandy soils with varying overburden thickness. The road buffer map has derived using distance criterion from the road by creating buffer. Different buffers have created both sides of the major roads present in the area. Proximity to the road is used as a criterion for understanding the suitability of the solid waste disposal sites. The slope map has derived from DEM and classified into a number of slope categories keeping in mind the objective of the study. Flat and gentle slope dominate plain areas. Steeper slopes limited hilly regions. The water bodies get polluted by mixing up with waste materials. Areas away from the water bodies are suitable for solid waste disposal. A 200-meter buffer has been extracted around the large water bodies and streams to avoid those areas for solid waste disposal. The water table map has been derived by interpolating depth to water table information collected from field. The deeper water table is preferred for solid waste disposal along with many other factors. However, the area is mostly dominated by the moderately deep water table. All the parameters have been shown in Figure 2. After preparing the all the input thematic layers, the scores for each class of the input maps and weight factors have assigned to each map considering their overall significance for the suitability of landfill sites. The procedure followed to assign the scores has explained in the methodology section.

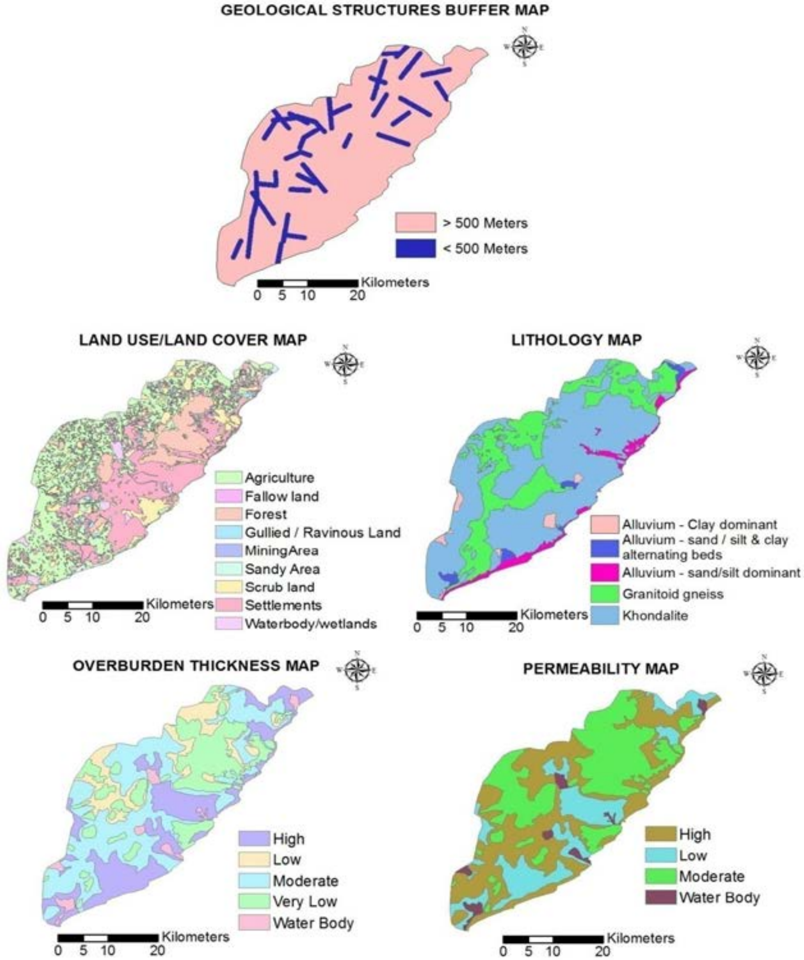

Fig. 2A. Input Layers

Methodology

Earlier worker attempted MSW landfill site suitability study based on implementation of different MCE methods like weighted overlay analysis (Pandey et al. 2012; Sashikumar and Lalwin 2013), fuzzy overlay (Ekmekçioĝlu et al. 2010; Khorram et al. 2015), AHP and simple additive weighting (Chabuk et al. 2017) and AHP (Islam et al. 2018; Kumar and Shaikh 2013; Yıldırım and Güler 2016). The present study compares three knowledge guided methods such as weighted index overlay fuzzy overlay analysis (Bonham Carter 1994) and AHP for solid waste disposal site selection. The same set of input maps has used in all three models to compare the outputs of one model with another model.

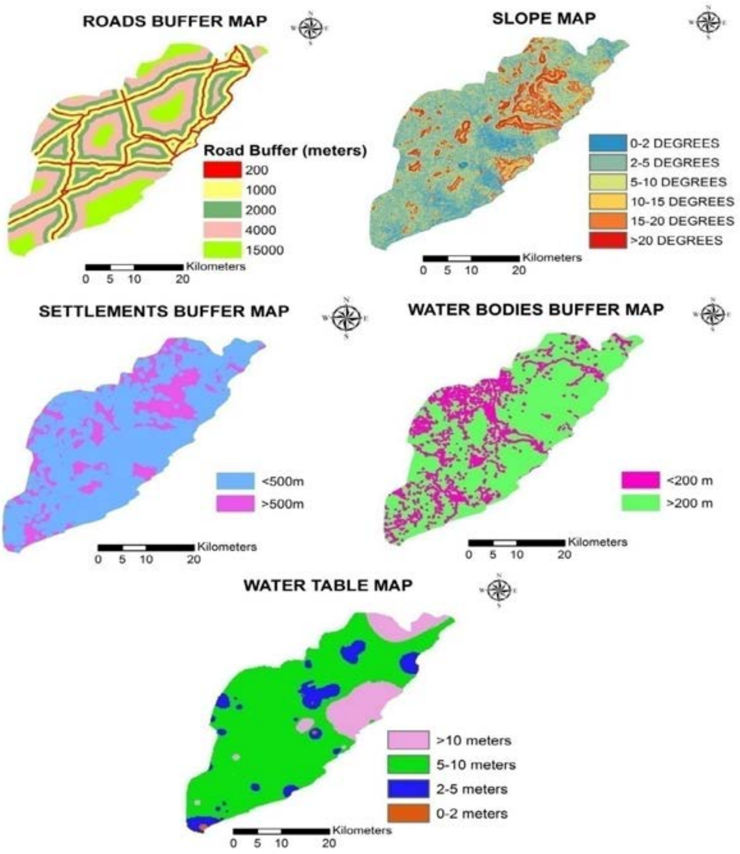

Fig. 2B. Input Layers.

Weighted Overlay

A systematic procedure has been adopted to assign weights and scores, to each map and each class of different input maps respectively. Different scores have been assigned to different classes of the maps based on their overall importance towards suitability of the class for solid waste disposal. The procedure adopted to assign scores to each class of different input maps have been based on the heuristic criteria for quantifying the significance of each class for the suitability of solid waste disposal. A weighted index overlay analysis has been carried out for deriving the normalized score (S) for suitability classification.

$$S = \frac{\sum_i^n S_{ij} W_i}{\sum_i^n W_i}$$

Where,

W_i is the weight assigned to i^{th} input map and S_{ij} is the score for the j^{th} class of the i^{th} input map

Fuzzy Overlay

Fuzzy overlay combines different rasters, which have been created by using fuzzy membership functions. The selection of a suitable membership function for a fuzzy set is one of the most important criteria in the fuzzy logic method. Linear fuzzy membership function has been used in present study applies a linear function between the user-specified minimum and maximum values. Anything below the minimum has been assigned 0 and anything above the maximum were assigned 1. A value of 1 indicates full membership in the fuzzy set, with membership decreasing to 0, indicating it is not a member of the fuzzy set. In this study, fuzzy gamma function has used for site suitability analysis. Fuzzy Gamma is an algebraic product of fuzzy product and fuzzy sum and it is a compromise of the increasing effect of Fuzzy Sum and the decreasing effect of Fuzzy Product.

$$\mu(x) = (\text{Fuzzy Sum})^{\gamma} * (\text{Fuzzy Product})^{1-\gamma}$$

Analytical Hierarchy Process (AHP)

In the present study, Analytic Hierarchy Process (AHP) is used to analyze selected multiple factors. AHP is one of multi-criteria decision-making method that was originally developed by prof. Thomas L Saaty 1980. AHP is widely used to determine the weight of criteria based on pairwise comparisons of parameters according to their relative importance towards the objective of the study (Kumar and Hassan 2013). Pair-wise comparison of the layers has shown in Table 2. The ratio scales were derived from the principal Eigenvectors, and the consistency index (CI) is derived from the principal Eigenvalue.

$$\mathrm{CI} = \frac{\lambda\mathrm{max} - \mathrm{n}}{\mathrm{n} - 1} \;\&\; \mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$$

A perfectly consistent decision maker should always obtain CI=0, but small values of inconsistency may be tolerated {(CR= CI/RI) <0.1)} the inconsistencies are tolerable, and a reliable result may be expected from the AHP. If the value of Consistency Ratio (CR) is smaller or equal to 10%, the inconsistency is acceptable. If the CR is greater than 10%, we need to revise the subjective judgment.

Analysis, Discussion and Results

For weighted overlay and fuzzy overlay analysis, scores has been assigned on a scale of 1-9. Highest significant classes have assigned with the score of 9 and insignificant classes have assigned with the score of 1 (Table 1). Same way in AHP, high suitable classes has given relatively high importance value of 9 to highly suitable classes on 1 to 9 scale (Saaty, 1980; Kumar and Shaikh, 2013). While assigning scores to each class guidelines of Central Pollution Control Board, and Central Public Health & Environmental Engineering Organization (CPHEEO 2000) have been followed. For lithology map, high importance has given to clay dominant alluvium and low importance to sand/silt alluvium. For khondalite and granitoid gneiss classes, based on their significance towards suitability for solid waste disposal moderate importance has given. Similarly, for overburden-thickness map high importance has given to low overburden thickness classes and very low, moderate and high overburden thickness classes have assigned importance in descending order. In permeability map, high importance has given to low permeability class and very less importance to high permeability classes. In landuse-land cover category, scrublands and fallow lands have given high importance whereas agricultural lands have assigned moderate importance. Settlements and waterbody areas have given very less importance to avoid those for MSW disposal. Gullied / ravenous lands, mining and forest areas have been assigned relatively moderate to low importance. In road buffer map first 200 meters of both sides has given low importance (CPHEEO 2000).

The area which has come in 200-1000 meters range has given high importance. For slope classes, 0°-2° slope class has given the highest importance followed by 2°-5° with score 8 as flat and gentle slopes are significant for landfill site suitability. Further steeper slope classes 5°-10°, 10°-15°, 15°-20° and >20° have been assigned fewer scores of 6, 4, 2 and 1 respectively. For settlements buffer, lineaments buffer and water bodies buffers the areas which have fallen inside the buffer has given a very low importance to avoid those for solid waste disposal and the areas outside buffer has given very high importance. Shallow water table areas (0-2 meters) have not suitable for MSW disposal (CPHEEO 2000) so that less importance has given to shallow water table class and high importance to the deep water table class. The assigned scores for different classes from different inputs have showed in Table 1.

Table 1. Input Layers, Classes, Suitability Scores and Area (%)

Input Layers	Input Layer classes	Suitability Score	AHP Score	AREA (%)
Geological Structures Buffer Map (in meters)	<500	1	0.1	14.42
	>500	9	0.9	85.58
Settlements Buffer Map (in meters)	<500	1	0.1	77.81
	>500	9	0.9	22.19
Landuse / Land Cover Map	Agriculture	5	0.1	38.75
	Fallow land	9	0.31	4.66
	Forest	2	0.05	10.95
	Gullied/ Ravinous Land	7	0.13	1.46
	Mining Area	3	0.06	0.38
	Sandy Area	1	0.03	1.17
	Scrubland	9	0.27	11.11
	Settlements	1	0.02	26.72
	Water Body	1	0.02	4.79
Lithology Map	Alluvium - Clay dominant	9	0.48	1.59
	Alluvium - Sand/silt dominant	5	0.09	4.70
	Alluvium - Sand / silt & clay alternating beds	5	0.09	1.93
	Granitoid gneiss	7	0.17	26.56
	Khondalite	7	0.17	65.22

Overburden Thickness Map	Very low	8	0.31	22.70
	Low	9	0.46	12.10
	Moderate	7	0.14	37.31
	High	3	0.07	25.04
	Waterbody	1	0.03	2.84
Permeability Map	Low	9	0.52	20.54
	Moderate	8	0.31	34.81
	High	5	0.13	41.81
	Waterbody	1	0.16	2.84
Roads Buffer Map (in meters)	200	1	0.03	8.41
	1000	9	0.45	26.56
	2000	7	0.30	23.55
	4000	5	0.16	26.87
	>4000	3	0.06	14.60
Slope Map (in Degrees)	0-2	9	0.43	33.52
	2-5	8	0.26	29.10
	5-10	6	0.15	17.27
	10-15	4	0.08	8.44
	15-20	2	0.05	6.73
	>20	1	0.03	4.94
Water Bodies Buffer Map (in meters)	<200	1	0.1	34.90
	>200	9	0.9	65.10
Water Table Map	0-2 meters	1	0.05	10.67
	2-5 meters	3	0.12	83.01
	5-10 meters	7	0.28	6.23
	>10 meters	9	0.56	0.09

After finalizing the scores for each class of the different input maps, weight factors have assigned to each map considering their overall significance for the suitability of landfill sites. All input maps have converted to rasters and overlay analysis has carried out using ArcGIS spatial Analyst tool. For same set of input parameters, pair-wise comparison has done and relative weights have obtained for each input layers and each sub-class of the input layer (Table 2).

Table 2. Pair-Wise Comparison of Input Layers

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
LULC (**A**)	1	2	1	3	1	5	1	5	1	4
Settlements (**B**)	1/2	1	1/2	2	1/2	5	1/2	5	1/2	1/2
Slope (**C**)	1	2	1	3	1	5	1	5	1	4
Roads (**D**)	1/3	1/2	1/3	1	1/3	2	1/3	2	1/3	2
Overburden (**E**)	1	2	1	3	1	5	1	5	1	4
Structures Buffer (**F**)	1/5	1/5	1/5	1/2	1/5	1	1/5	1	1/5	1/3
Lithology (**G**)	1	2	1	3	1	5	1	5	1	4
Waterbody Buffer (**H**)	1/5	1/5	/5	1/2	1/5	1	1/5	1	1/5	1/2
Permeability (**I**)	1	2	1	3	1	5	1	5	1	4
Water Table (**J**)	1/4	2	/4	1/2	1/4	3	1/4	2	1/4	1

All the input maps have converted to raster format and final suitability map has prepared by following formula (Kumar and Shaikh 2013). Final weights for all the individual parameters have showed in Table 3.

Table 3. Final Weights for Each Input Map

Layer	Final Weights	
	WI and Fuzzy Overlay	AHP
LULC	12	0.15
Settlements	11	0.09
Slope	12	0.15
Roads	9	0.05
Overburden	12	0.15
Structures Buffer	6	0.03
Lithology	12	0.15
Waterbody Buffer	6	0.03
Permeability	12	0.15
Water Table	8	0.05

Suitability Map = $\sum[criteriamap * weight]$

Suitability Index = {(0.03 * Geological structures) + (0.05 * Water table) + (0.015 * LULC) + (0.03 * Waterbodies buffer) + (0.015 * Litholoogy) + (0.15 * Overburden Thickness) + (0.015 * Permeability) + (0.05 * Roads) + (0.15 * Slope) + (0.09 * Settlements Buffer)}

An index overlay analysis has been carried out for all the weighted maps for deriving the normalized score (S) for landfill suitability. In the final map output, three classes of landfill suitability have been generated with classes high (2.68%), moderate (73.29%), and not suitable (24.04%) shown in Fig. 3. Fuzzy overlay analysis has been carried out for same inputs used in weighted overlay method. All the input layers converted to rasters using suitable scores. All these rasters further converted to membership rasters using linear membership function. All linear membership rasters having value on the same scale of 0 to 1, 0 indicating least membership and 1 indicating maximum membership in site selection. All this linear membership rasters have been integrated using fuzzy overlay tool in ArcGIS spatial Analyst extension. In the final map three suitable classes have been identified as not-suitable (56.90%), moderate (40.88%) and high (2.22%) for MSW disposal (Fig. 3).

Using suitability index equation AHP analysis has done. Final suitability map classified into three classes as not-suitable (33.92%), moderate (64.47%) and high (1.61%). While comparing the results of the most suitable area from all the models it has observed that very less area is suitable for the MSW disposal, which have depicted in all the models as high suitable. Settlements, agricultures lands and forest have covered majority of the study area. From the three models, common high suitable candidate sites have been extracted for final site selection. Five major sites have been observed towards north and northeastern side of the city.

The site near to the Kalavanipalem village having 106 land and easily accessible by metal road that is connected to highway is the first choice for solid waste disposal of GVMC, Andhra Pradesh. The site near to the pallavanipalem village having 56 hectares land and located between two small hills, also found suitable for MSW disposal. The sites which have marked 3 and 4 are not easily accessible because of poor road network. The site located between Akkireddipalem and Gandigudem is very near to highway but surrounded by agricultural lands. So this site can't be preferable for solid waste disposal. The high suitable sites have been marked on satellite image shown in Figure 4.

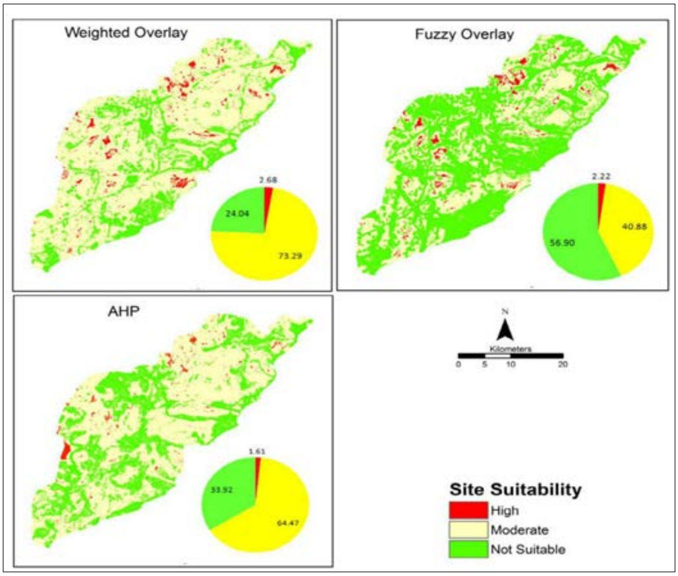

Fig. 3. Final Outputs from Different Models for MSW Disposal

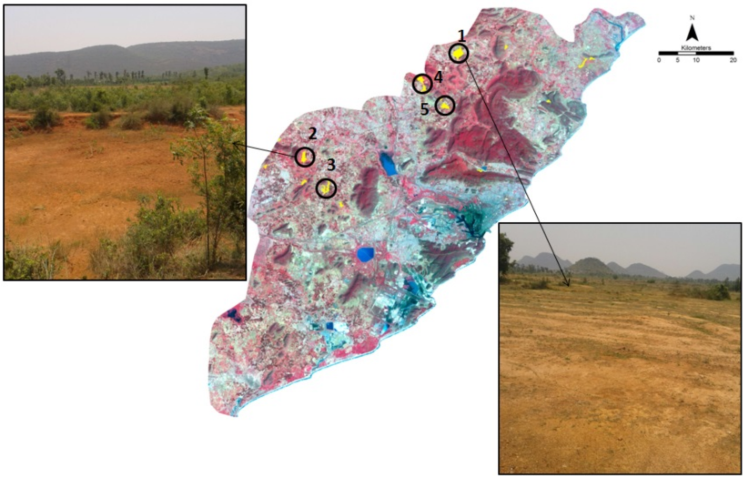

Fig. 4. Final Sites Marked on Satellite Image of GVMC, Andhra Pradesh

Conclusion

Solid waste consists of different kind of materials generated from houses, industries, markets and other sources. Improper collection, transportation, and dumping will cause health problems. In the present study, an attempt has been made to find out suitable disposal sites for solid waste in Greater Visakhapatnam Municipal Corporation, Andhra Pradesh, India based on several factors. Weighted overlay fuzzy overlay and AHP analysis have been carried out in GIS environment. The final maps have been categorized into very low, low, moderate and high classes. High suitable areas have been observed in many places around the city. However, looking at the future growth perspective and other developmental activity around the mega-city, it can be considered that the suitable site should be out of Greater Visakhapatnam Municipal Corporation (GVMC) boundary as well as should be away from Special Economic Zones (SEZ) which was demarcated for future urban growth. In addition, it should be away from major water bodies and away from flood zones.

The high suitable areas derived using three different models were compared and the common areas showing high suitability were field verified to find out the best possible site for SWD. The field verified images have been shown in Figure 4. The present study demonstrated the use of RS and GIS in decision-making process for urban planning

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GEOSPATIAL ANALYSIS OF LAND USE / LAND COVER CHANGE WITH SPECIAL REFERENCETO ENVIRONMENT IN ANDAL, WEST BENGAL - A CASE STUDY

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Abstract

The study investigates the land use / land cover (LULC) changes in Andal, Burdwan district of West Bengal from 2005 to 2015. The urbanisation, industrialisation and expansion of coal mining have accelerated the land transformation and become a hot-spot since last decade. The study revealed that, due to expansion of coal mine, 58.43% of the agricultural lands were converted followed by scrub land (31.61%), water body (5.44%), tree clad (4.18%), rural built-up (0.20%) and wetland (0.15%). Whereas, 40.13% of the cultivable lands were converted for the development of D.V.C thermal power plant, followed by scrub land (11.42 %) and vegetated area (4.14%). Similarly, the concentric development around Andal airport has occupied 72.06% of the cultivable lands towards the development of the aerotropolis. This study proposes technical ideas and methods to take a fresh look and optimize land evaluation, land allocation, land-use planning and help the decision-makers to imply environmental management.

Keywords: Geospatial Analysis, LULC, Hot-spots, GIS, Environment, Industrialisation, Aerotropolis.

Introduction

India is endowed with vast natural resources. No natural resources remain unaffected by human impacts. The intensity and spatial distribution of these anthropogenic threats is currently expanding to levels unprecedented in human history. Although, the importance of landscape change, both temporally and spatially, has been addressed in a number of studies (Su et al,. 2010; Solon, 2009; Pauliet et al., 2005; Blaschke, 2006; Schneeberger et al., 2006; Zomeni et al., 2008; Antwi et al., 2008; and Kim and Ellis, 2009), but it is also essential to understand causes and effects of such changes on the environment in both developed and developing countries, at both micro and macro levels. Hence, identification and monitoring of LULC change hotspots with time becoming prime importance for natural resource management.

According to Lambin and Ehrlich, (1997) land cover change hotspot can be perceived at three levels- (i) high rates of land cover change which are observed at present, Such studies illustrate the causes and effects as well as recommendations on integrating the findings into plans and policies under a sustainability goal, as confirmed by the study of Musacchino and Coulson and Brunckhorst et al.

Change of landuse patterns to urban, industrial and mining areas has become a major problem resulting from economic and population growth, especially in developing countries (Ruiz and Montes, 2008; Nigal *et al.,* 2008; Thapa and Muriyama, 2008; Beardsley *et al*., 2009; Su et al., 2010). The urbanization process which has resulted from both direct and indirect influences is multi-directional and differentiated in time and space (Solon, 2009). People transform natural habitats into man-made landscapes of residential, commercial, institutional and industrial areas as well as supporting infrastructure (Moorman *et al.,* 2006). Simultaneously, to meet the need of increasing energy requirement in the developing countries, like India, resulting in over exploitation of natural resources due to activities like deforestation, mining and industrialization for meeting the increasing demand for food, fuel and fibre.

Remote sensing and Geographical Information Systems (GIS) are important tools for studying landuse/ land cover patterns and their dynamics. A number of studies related to landuse planning have been carried out, using Geographic Information Systems (GIS). Although GIS can be applied to spatial aspects, an analytical mechanism depends on the purpose of application and spatial settings (Swangjang and Iamaram, 2011). Studying changes in LULC pattern using remotely sensed data is based on the comparison of time-sequential data. Change detection using satellite data can allow for timely and consistent estimates of changes in landuse/ land cover trends over large areas, and has the additional advantage of ease of data capture into a GIS.

In this study, the hypothesis is set that the dynamics of LULC has been initiated by the development of multiple mega projects which acts as the main driving force to become a hotspot. Contribution ratio of urban, industrial and mining growth which may affect the areas of ecological interest as a result of the change of natural landscape is also pinpointed. Characteristics of the change of other landuse patterns to ‘urban sprawl’, ‘industrial’ and ‘mining’ are also important in terms of environmental sustainability. During the last ten years, development of land for Domestic Airport, Steel plat and expansion of mining activity has dramatically increased. Not only transportation networks are developing to support the development, but also rapid property development projects and village rehabilitation programme in various forms to serve the demand of new communities are one of the challenges.

Keeping the above in view, an attempt was made to evaluate the change of LULC as a result of the mega project development. In this paper LULC changes are considered from both spatial and temporal aspects. The characteristics of the changes will support the measures to conserve the environmental capability according of each LULC potential.

Study Area

The present study area is situated within the Andal area of Burdwan district of West Bengal, is confined between latitudes $23^{o}\ 32^{/}\ 54^{//}$ N and $23^{o}\ 43^{/}\ 44^{//}$ N and longitudes $87^{o}\ 7^{/}\ 55^{//}$ E and $87^{o}\ 19^{/}\ 51^{//}$ E (Figure 1). This study area has been selected because it has gone through many land transformations since last decade. The study area has a long and diverse mining history which involves both open cast and underground mining spanning over a century. Unplanned mining of coal, conversion of agricultural land for the development of Aerotropolis and expansion of thermal power plant has led to severe environmental degradation in and around the area.

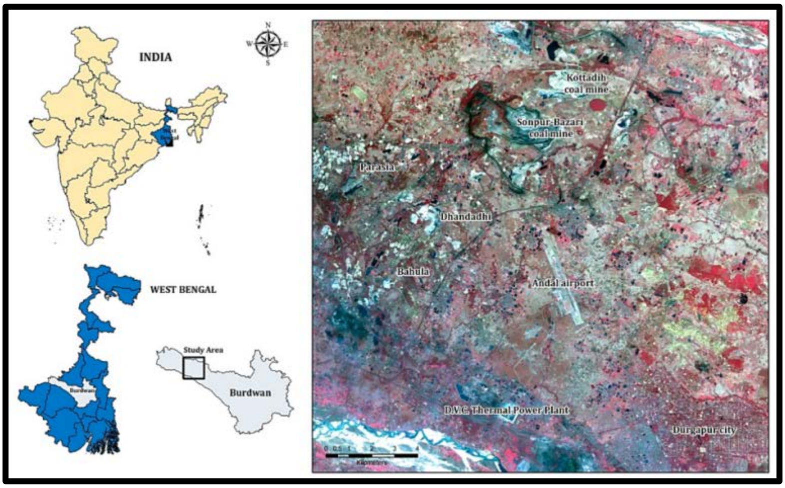


Fig. 1. Location of the Study Area

Geomorphology

The study area with its varied tectonic elements and riverine features is a transitional zone between the Jharkhand plateau in the west and Ganga-Brahmaputra alluvial plain in the north and east. The Ajoy-Damodar inter-stream tract is made up of several stows consisting of vales and low convex spurs which run in almost all directions except north-east and thus lends a very complicated character of local relief. Geomorphological units of the study area reveals that most of the part of the study area is a Pediplain which has been characterised by buried pediplain in the central part of the study area whereas the coal and quarry belt of the study area has been found in weathered pediplain. The eastern part is a lateritic plain. The north-eastern and south-western part of the study area is known as flood plain as both the river Ajay and Damodar flowing through respectively.

Lithology

The study area of Burdwan district of West Bengal is overlain by a thin alluvial cover and forms a transition zone between hard rock and flat gently sloping alluvial terrain. The western part of the study area comprising the Raniganj coalfield is characterised by the sandstones with shale and contains valuable coal deposits. The eastern part of the study area is characterised by laterite (ferricrete) whereas, southern part of it's dominated by shale with sand stones. Likewise, the north western part of the study area is dominated by sandy shale. The sedimentary framework is suggested to be mainly continental, with a marine transgression during Oligocene-Miocene times.

Soils

Different types of soil are encountered in different topographical, biological and hydrological as well as geological condition within the study area. In the western part, soils formed due to weathering of pigments, quartz veins, conglomerates and sand stones. Towards the east, alluvial soil attains an enormous thickness in the low level plains to the east. This alluvial soil is formed of alluvium brought down by the Ajoy and Damodar.

Problems of the Study Area

Central Pollution Control Board has identified 24 problem areas in the country where industrial and anthropogenic activities are concentrating and cause rigorous environmental degradation. The present study area (Asansol-Durgapur) region is one of those 24 problem area. It is an integral part of the Damodar river valley resource region and is one of the most important urban industrial zones of Eastern India located in West Bengal. Firstly, the environmental concerns in the region are large-scale mining activities (collieries of the region produce about 95% of the total coal output of West Bengal) in the area and the pollution caused to river Damodar due to discharge of mining/industrial and domestic wastewater (CPCB, 2001). Secondly, the development of Andal airport is of prime concern for the following reasons: there are a great number of development projects within the area; the area was originally a green belt; and local people's way of life, i.e., mainly farmers. Thirdly, the development of four industries namely, Durgapur Steel Plant (DSP), Durgapur Projects Ltd. (DPL), Durgapur Thermal Power Station (DTPS) and Hindustan Fertilizer Corporation Ltd (HFCL) are of another concern as these industries consume the maximum water supplied both for industrial and their townships, and treated and untreated effluents and Sullage drain into Tamla nala, which ultimately joins river Damodar (CPCB, 2001).

Materials and Methods

Data Used

IRS P6 LISS-4 MX of 2005 and IRS Resourcesat-2 LISS-4 MX images of 2015 have been used for identification and delineation of areas of major change. Details of the data used are given in Table 1.

Table 1. Satellite Image Specifications

Satellite	Sensor	Date of Pass	Spatial Resolution	Spectral Resolution	Radiometric Resolution
IRS P6	LISS-4	29 Jan, 2005	5.8 m	3Bands (2,3,4)	8 bit
IRS Resourcesat-2		12 Jan, 2015			16 bit
		03 Feb, 2016			

Field Data

Ground data collection for the study area has been carried out to check and validate LULC change which was used to create a vector layer. These data, coupled with the 2011-2012 surveys, formed a database that was vital for validating the classification and change areas.

Methodology

Semi-automated approach has been adopted to realize the objectives of the current study which are detailed into three broad categories - Classification, change detection and spatial statistical analysis.

Classification Approach

Segmentation

Image segmentation is a classification operation that allows the scene to be divided into uniform regions using consistency criteria based on characteristics such as uniformity, reflectance and texture. A threshold is set by the operator to limit growth of the region (scale). Hence, by choosing different values for the "threshold", different levels of segmentation are generated, forming a hierarchal object network. In this network, each object is related to its neighbours, its sub-objects (objects from lower levels) and its super-objects (objects from higher levels).

Onscreen Data Interpretation

Assessment of the results of segmentation should be based on a visual assessment of the shapes and contents of the objects created. So, the optimal triplet must ensure that each derived object contains a unique category of pixels (Despinoy, 2007).

Integration of Object and Onscreen Classification Technique

The workflow given in Figure 2 shows the steps required for preparing a LULC map that includes the combination of the object-based and onscreen LULC classification techniques and its validation.

Change Detection

Following the classification of imagery from the individual years, a multi-date post classification comparison change detection field was used to determine changes in LULC between 2005 and 2015/2016. This is perhaps the most common approach to change detection (Jensen, 2004) and has been successfully used by NRSC/ISRO (2011) to monitor LULC changes at 1:50,000 scale in all over India. The post-classification approach provides ''from–to'' change information and the kind of landscape transformations that have occurred can be easily calculated and mapped (Yuan et al., 2005). A change detection map with 56 combinations of 'from–to' change information were derived for 2005 - 2015 map.

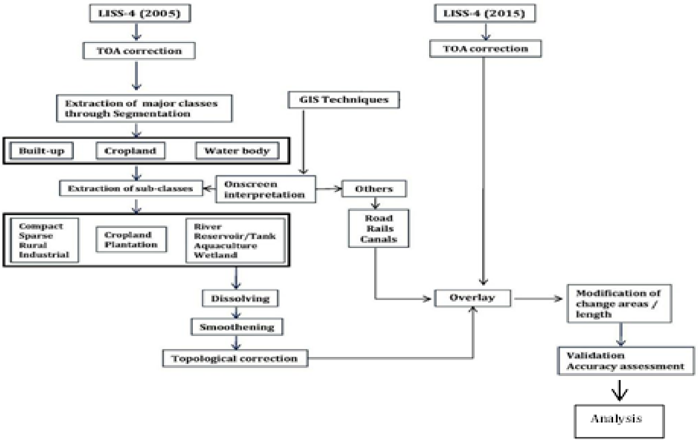


Fig. 2. Conceptualised Framework of the Study

Classification and Change Detection Accuracy Assessment

Assessments of the classification accuracy of the LULC maps were conducted by comparing samples of the classified layer and reference layer following Congalton, (1991). 303 reference points were verified by field visits, and 25 reference points were verified through comparison with recent Bhuvan imagery dated between 2005 and 2015/2016. The class and overall accuracies, which provide an indication of the classification agreement between two maps (the classified and the ground-truthed maps) that is not attributable to chance, were calculated and are presented as error matrices. The change detection accuracy was obtained by randomly sampling the study area to calculate an error matrix for the classification (Fuller, Smith and Devereux, 2003; Yuan, Sawaya, Loeffelholz and Bauer, 2005). Classification of the polygons as 'change' and 'no change' in the resulting LULC change layer was conducted. A total of 12,821 polygons were used in the change detection assessment: 3,596 polygons for the 'change' and 9,225 for the 'no change' category. All reference polygons were validated through field visits and an inspection of Bhuvan imagery.

Results and Discussions

Results of the Accuracy Assessment

The results of the classification accuracy assessment are showed in Table 2. The resulting maps produced the overall accuracy values of 96.98% for 2015 with a Kappa accuracy of 0.934, showing that the classification agreement between images ranged from good to very good. These results show that the extraction and merging of the best-classified classes from object-based and onscreen methods produces a LULC map with an improved accuracy in comparison to the individual object-based or pixel based classification methods.

Table 2. Land use / Land cover Classification Accuracy

Level-1	Level-2	Class accuracy
Built-up	Compact	100
	Sparse	100
	Vegetated	96.15
	Rural	100
	Industrial/ Mining	89.47
Agricultural land	Cropland	100
	Fallow land	84.62
Forest	Tree clad	100
	Forest plantation	100.00
Wasteland	Scrub land	93.55
	Sandy areas	100.00
Water body	Water body	100.00
Overall accuracy	96.98%	
Kappa statistics	0.934	

Land use / Land cover Change Analysis

The LULC maps depicting fifteen LULC classes (Figure 3) were prepared for the two period viz. 2005 and 2015. The change matrix provided the area covered under each of the classes and the inter-class transformations

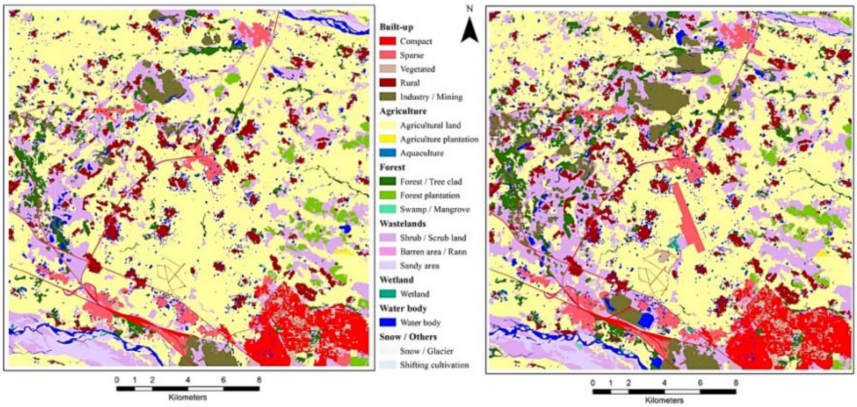


Fig. 3. Land use / Land cover Change from 2005 to 2015

Three major classes viz., agricultural lands (cropland and fallow land), built-up (mining and industries) and wastelands (scrub lands) were identified as most dynamic classes throughout the study area (Figure 4). It was found that north-western and western part of the study areas were mainly covered by tree clads and forest plantation while surrounding of those mining and abandoned mining areas were mostly covered by scrub lands. It has also been observed that there is a remarkable increase in wasteland (4.888%), as the advancement of Sonpur-bazari and Kottadih coal mines towards the eastern part of the study area have converted large portion of the agricultural lands into wastelands. The plains and the low lands were dominated by cropland and fallow land. The south-eastern part of the study area, mainly known as Durgapur area is an urban unit. A substantial change in LULC has been observed in the centre of the study area which is mainly characterised after the development of Andal airport, 5.5 km away from the Durgapur city. It has been noticed that 4.593 km^2 area of agricultural land was occupied for the development of the airport. It has also been observed that the proposed area for the development of the Aerotropolis around the Andal airport is going to transform a large amount of agricultural land (72.06% of the proposed area which is around 3.895 km^2) to urban built-up (Figure 5).

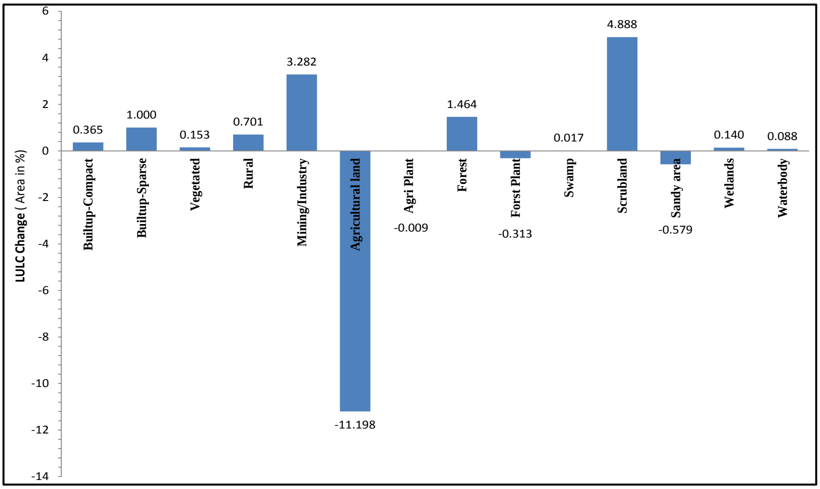
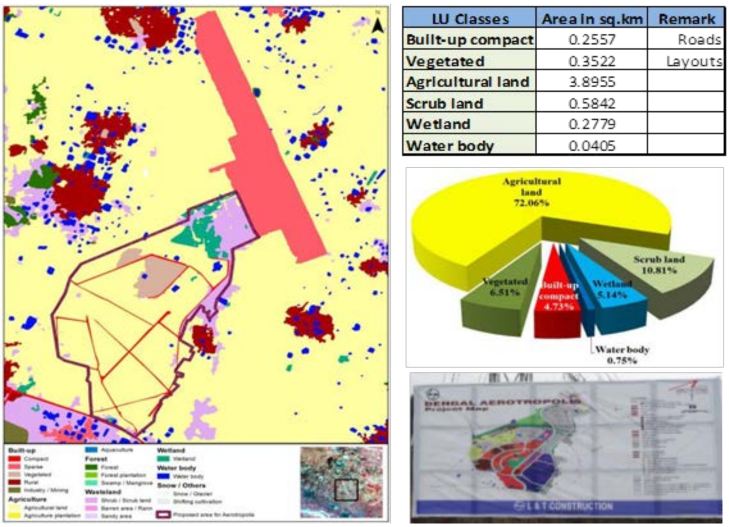


Fig. 4. Land use / Land cover Change Statistics



LU Classes	Area in sq.km	Remark
Built-up compact	0.2557	Roads
Vegetated	0.3522	Layouts
Agricultural land	3.8955	
Scrub land	0.5842	
Wetland	0.2779	
Water body	0.0405	

Fig. 5. Land Transformations due to Development of Andal Airport

An increase in rural population has also been noticed which accounts 0.701% of the study area from 2005 to 2015. Results showed built-up density has been increased from 28.24 to 39.35. Durgapur saw its first township with the development of the D. V. C.

Thermal Power Station at Durgapur. In this present study it has been observed that an area about 4.93 km^2 has been converted for industrial development from 2005 to 2015.

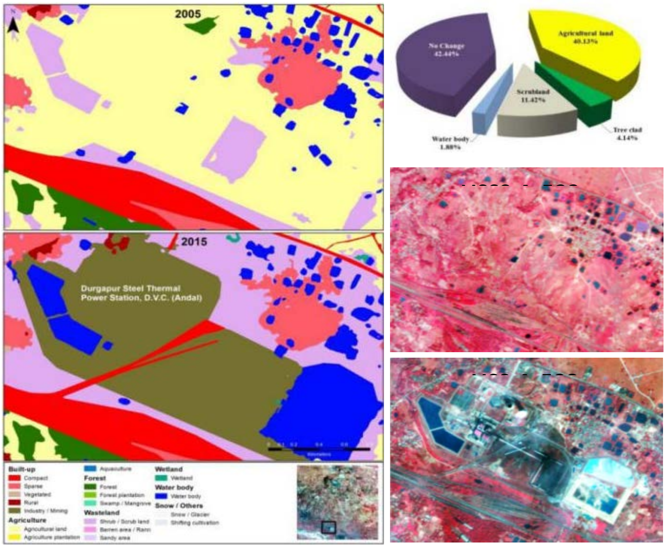


Fig. 6. Industrial Development (Development of D.V.C. Thermal Power Plant)

Figure 6 shows that there is about 42.44% of land within study area remains industrial land from 2005 to 2015, but it has also been noticed that mostly cultivable land (40.13% of the study area) has been converted for industrial development compare to wasteland-scrub land (11.42%). The natural vegetation in Andal area has also suffered a subsequent amount of loss (4.14%) due to this developmental process. The area under mining / quarry increased significantly from 5.731 km^2 in 2005 to an area of 15.909 km^2 in 2015.

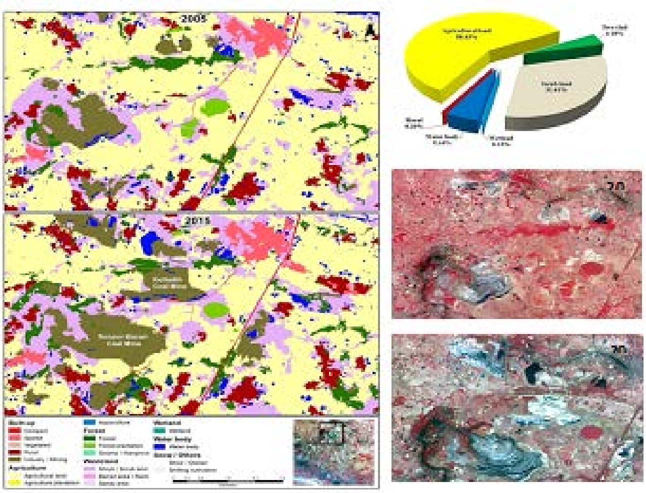


Fig. 7. Changes in Land use /Land cover due to Mining

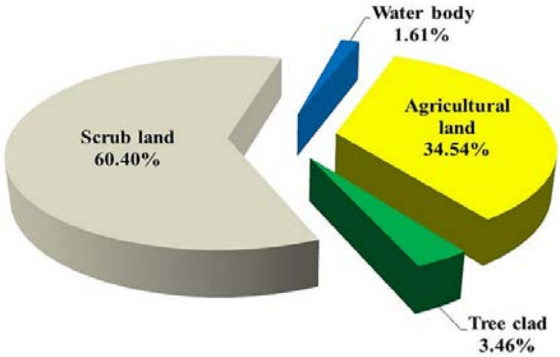


Fig. 8A. Changes in Land use /Land cover due to Quarries

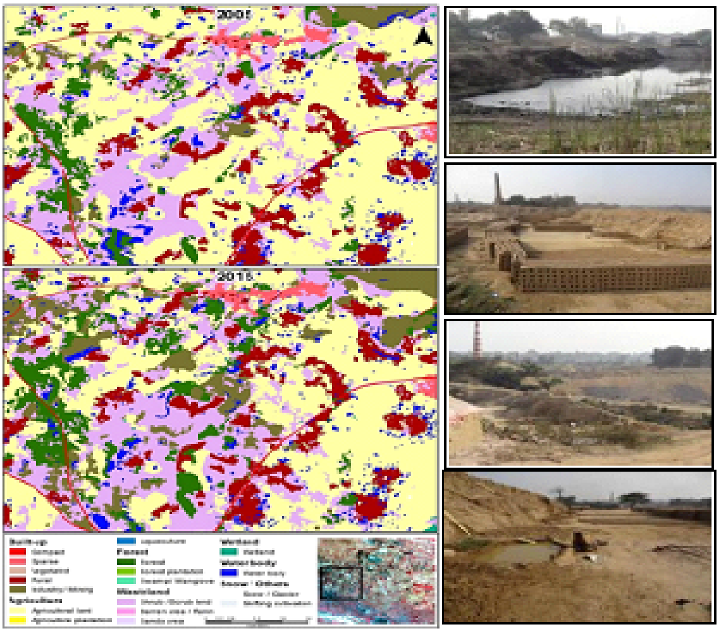


Fig. 8B. Changes in Land use /Land cover due to Quarries

Systematic mining / quarry activities led to growth of human population with a corresponding increase in built-up areas and cropland. On the other hand, illegal and unsystematic mining / quarry activities led to environmental degradation. It has been noticed from 2005 to 2015, the advancement of the Sonpur-Bazari coal mine towards east of the study area and the newly formed Kottadih coal mine has brought substantial changes in different LULC classes. Figure 9 showed that due to mining / quarry activities 58.43% of the change areas were transformed from agricultural land followed by scrub land (31.61%), water body (5.44%), tree clad (4.18%), Rural (0.20%) and wetland (0.15%).

An intensive observation has also been made to identify the quarries along the mining belt separately. It has found that, many places like, Bahula, Dhandadhi, Parasia, Banshra and Topsi and its surroundings were experienced high rate of land transformation from 2005 to 2015.

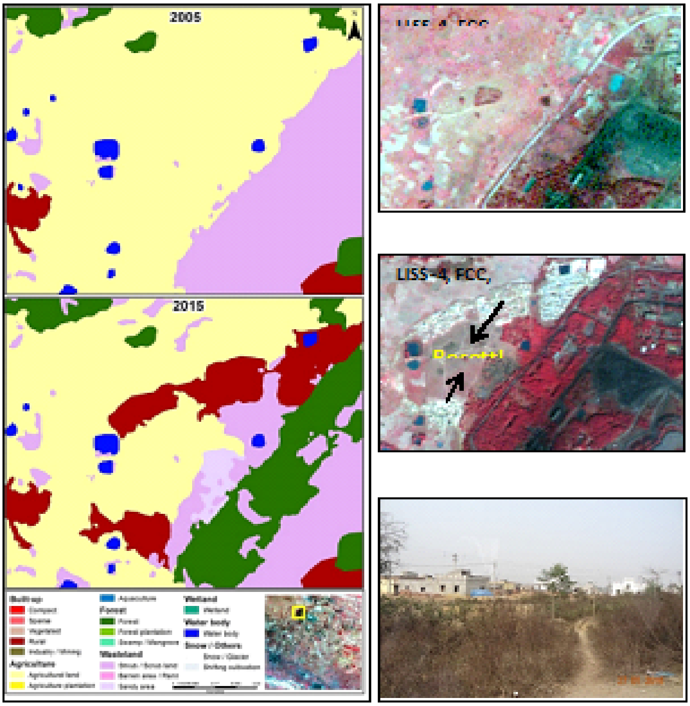


Fig. 9. Resettlement due to Expansion of Sonpur-Bazari Mining Activity

It has been noticed about 60.40% of quarries have generated from the scrubland and agricultural land (34.54%), Figure 7 and Figure 8.Apart from the spatial observations, an attempt has also been made to point out the socio-environmental impacts of the mining industry on the study area. One of the social challenges for the local industry is the problem of mining- induced displacement and resettlement in the study area. Due to exploration activities, almost every day all scheduled villages in the study area are facing new environmental as well as socio-economic problems. In the present study rehabilitation of villages within Sonpur-Bazari coal mining area has been observed between 2005 and 2015, where, 19.3 ha. of agricultural lands were acquired for rehabilitation near Dahuka village (Figure 9). Similarly, due to the expansion of newly developed Kottadih coal mine another resettlement process has been observed.

Conclusion

The present study has revealed that considerable landuse / land cover changes have taken place in Andal of Burdwan district during 2005 to 2015. The region has undergone three major changes viz. Development of Durgapur Thermal Steel Plant (D.V.C), Development of Andal airport and Aerotropolis, and expansion of coal mining areas. It has been observed that, DVC power plant was developed utilising the wasteland and just beside the river Damodar to access the water for industry. LULC change in association with urban sprawl is a crucial factor to be considered during the set-up of measures to maintain environmental sustainability.

Development of the Andal airport is one step towards the amelioration of Durgapur city as the major communications and accessibility in terms of railway (Howrah station) and airway (Kolkata airport) is 200 km away from city. The proposed Aerotropolis around the Andal airport will enrich the living status high. Although, about 5 km^2 area was converted for the development of the airport but it is creating ample of scope for local people and outsiders and many employment opportunity in near future. On other hand, the negative impacts of airport and aviation include land take, noise, air pollution, climate change, water use, and effects on the social structures of local communities should be addressed carefully. Before the start of expansion of the coal mining and other industrial activities the region was covered with agricultural land. Coal mining operation on large scale has significantly changed the pre-mining environment scenario. The mining shows increase of 10.178 km^2 during ten years which is due to the rapid increase in the coal production, tree clad areas are decreasing but the plantations at overburden dumps under reclamation schemes have also been going on. In addition to mining activity, the industrialization especially thermal power plants in the surrounding have also adversely affected the landuse/land cover, air and water quality of the study area due to the discharge of waste products in the form of ash, smoke and chemical effluents. It may be concluded that the landuse/land cover change in the Andal region has taken place due to the rapid expansion of urban, industrial and mining activity during the period 2005 to 2015.

The study highlights the capability of remote sensing and GIS in analysing the change dynamics of LULC. Likewise the approach will be useful in planning, management and utilization of land and other natural resources to trace the future impacts of aerotropolis and airport development, industrial and mining activity. It can utilised as an effective tool at research level, policy formulation level and policy implementation level, which will help in proper management of landscapes and natural resources, thus leading to sustainable development.

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CONJECTIVE USE OF ASTER DEM, LANDSAT (ETM PLUS) SATELLITE DATA AND TOPOGRAPHIC MAPS FOR MORPHOMETRIC ANALYSIS OF JAMUNA WATERSHED, KOPILI RIVER, ASSAM

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Abstract

Watershed is a natural 'geo-hydrological' unit characteristic with topography, streams and land cover. Morphometric study is a logical choiceto understand the hydrologic and geomorphic processes occurring within thewatershed. Systematic analysis of morphometric parameters is a proven and viable method of characterizing the behavior of 'land -water' interface in a watershed. In the present study, the Jamuna watershed of Assamhaving extension $25^0 41'$ N to $26^0 27'$N latitude and $92^0 32'$ E to $93^0 41'$ E longitude, has been chosen. The terrain, relief and hydrologic parameters of the watershedis accomplished using topographic maps, in conjunction with ASTER DEM and remote sensing satellite data of LANDSAT-7 Enhanced Thematic Mapper Plus (ETM +) sensor in a GIS environment.

Keywords: Jamuna Watershed, Landsat ETM, ASTER DEM, Morphometric Analysis, GIS Environment

Introduction

In recent years, watershed is considered to be an ideal unit for the management of natural resources. The study of hydrological characteristics of a drainage basin is pre-requisite for any basin management scheme. It involves a detailed morphometric analysis of the basin. Morphometry is defined as the measurement and mathematical analysis of the configuration of the earth surface and the shape and dimension of its landforms (Clarke, 1966). Morphometric analysis of river basin provides a quantitative description of the drainage system, which is an essential aspect of the characterization of a basin (Strahler, 1964). Morphometric analysis of drainage basin is very much important for its planning, since it gives an idea about the watershed characteristics in terms of slope, topography, soil condition, runoff characteristics, surface water potential etc. This analysis is done successfully through measurement of linear, areal, relief, gradient of channel network and contributing ground slope of the basin (Nautiyal, 1994; Nag and Chakraborty, 2003; Magesh et al. 2012 and Rai et al. 2017).

Morphometric analysis in basin of a river is also significant to assess the hydrological characteristics and flood potential of the river (Aravinda and Balakrishna, 2013;

Withanage et al. 2014). Hydrologic and geomorphic processes occur within the watershed, and morphometric characterization at the watershed scale reveals information regarding formation and development of land surface processes (Singh 1992, 1995; Dar et al. 2013). Drainage characteristics of many river basin and sub-basins in different parts of the globe have been studied using conventional methods (Horton, 1945; Strahler, 1957, 1964; Krishnamurthy et al., 1996).

Geographical Information System (GIS) and Remote Sensing techniques are used as convenient tool for morphometric analysis. Remote Sensing and GIS-based drainage basin evaluation has been carried out by number of researchers for different terrain and it is proved to be a very scientific tool for generation of precise and updated information for characterization of drainage basin parameter (Das and Mukherjee, 2005; Pankaj and Kumar, 2009; Rai et al., 2014; Nag and Lahiri, 2011). The Digital Elevation Model (DEM) such as SRTM and ASTER is used for generating the stream network and other supporting layers (Magesh et al., 2011; Evangelin Ramani Sujatha et al., 2015; Pande and Moharir, 2014; Rai et al. 2014; Banerjee et al., 2015).

Study Area

The Jamuna watershed lies in an area between $25^{0}41'$ N to $26^{0}27'$ N latitude and $92^{0}44'$ E to $93^{0}40'$ E longitude (Fig. 1). It is a principal tributary of Kopili river. The river Jamuna, draining through an area of 3903 sq. km from its source to its confluence with the river Kopili. It flows through Hojai and Karbi Anglong district of Assam. Out of the total geographical area of the watershed; 753.6 sq km (20 percent of the entire basin) area lies in Hojai district and remaining 3149.4 sq km area (80 percent of the total geographical area of the watershed) in Karbi Anglong district of Assam. It originates at Khumbaman hills of Diphu sub-division at an elevation of 1360 meters above mean sea level located at 26°8' N and 93°30' E longitude and descends to about 60 meter above mean sea level before meeting Kopili river at Jamunamukh. With a total length of 172.8 km, Jamuna is one of the significant perennial river systems of Karbi Anglong district.

Jamuna flows southwards from its source region for about 32.4 km, then joins Dilai river near Manja and flows westwards until it meets Kopili river at Jamunamukh. The Mikir hills located to the north of the river Jamuna, forming the northern boundary of the watershed. The Nambor Reserve Forest and Dhansiri Reserve Forest are situated to the eastern and southern side of the basin, while the Kopili river forms the western boundary of Jamuna watershed. A significant portion of the study area is hilly and comprises of hills with plain area in the south-western part of the basin. The plain area is minimal in comparison to the upland. The population concentration is very high only in the small plain area of the basin.

Methodology

The Jamuna watershed is automatically extracted from ASTER DEM having 30 metres resolution, with the help of different geo-processing techniques in ArcGIS 10.2

software and is further rectified using Survey of India toposheets of 1 : 50,000 (83B/12, 83B/15, 83B/16, 83C/13, 83F/3, 83F/4, 83F/7, 83F/8, 83F/11, 83F/12, 83G/1, 83G/5, 83G/6, 83G/9) following water divide line. The entire drainage segments are digitised as lines separately for each order from SOI toposheets and LANDSAT 7 satellite images (Strahler, 1952). All the sixth ordered sub-basins are delineated following surface water divide. The morphometric parameters for each basin were directly computed from the vector data extracted from the topographic maps (basic parameters). The data in the first category includes area, perimeter of the watershed, maximum order of the streams, number of streams in each order, length of streams etc. The other morphometric parameters such as bifurcation ratio, stream length ratio, drainage density, stream frequency, drainage texture, length of overland flow, constant of channel maintenance, form factor, circulatory ratio, elongation ratio etc are computed by the formulae suggested in Table 1. For computation of relief aspects of the watershed ASTER DEM of 30 metre resolution has been used.

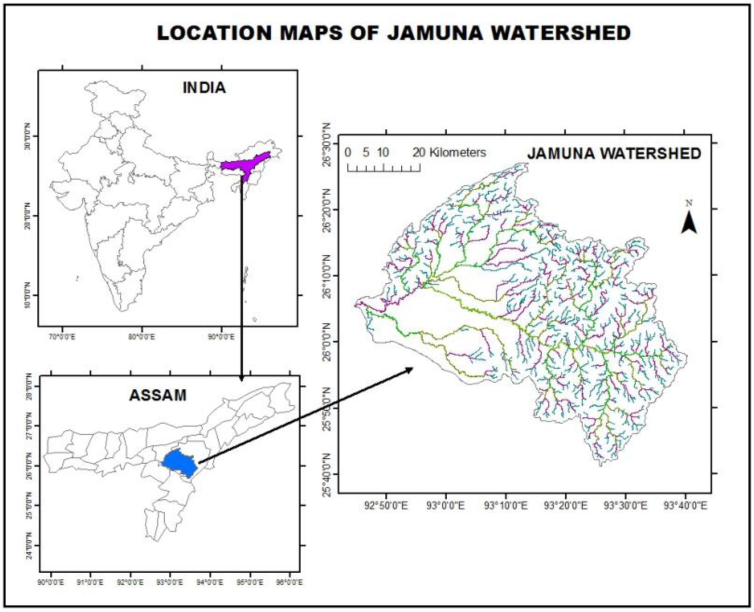

Fig. 1. Location of the Study Area

Results and Discussion

Linear Aspects: Stream Order and Stream Number

Stream order is defined as a measure of the position of a stream in the hierarchy of tributaries (Leopold et al. 1964). Various methods of stream ordering have been put forward by different scholars like Gravelius (1914); Horton (1945); Strahler (1952) and Schideggar (1970). Strahler's system which is a slight modification of Horton's has been followed because of its simplicity. In this method, headward streams which receive no tributaries are designated as first-order. Where two first-order streams are confluent, they form a second-order stream. The confluence of two-second order streams forms third order stream and so on. When two channel of different order joins the higher order is maintained. Stream order is raised only when two- streams of the same order converge. (Figure 2).

Table 1. Formulae Adopted for Computation of Morphometric Parameters

Morphometric Parameters	Formulae	References
	Linear Aspects	
Stream order (μ)	Hierarchical order	Strahler(1964)
Stream length ratio (R_L)	$R_L=\bar{L}_\mu/ \bar{L}_{\mu+1}$ (Average stream length of any order to the average stream length of the next lower order)	Horton (1945)
Bifurcation ratio(R_b)	$R_b=N_\mu/N_{\mu+1}$ (Total no of stream segment of a given order to the no of stream segments of next higher order)	Horton (1945)
	Areal Aspects	
Drainage density(Dd)	$Dd=L_\mu/A$ Where L_μ=total stream length of all orders, A= area of the watershed	Horton (1945)
Stream frequency (Fs)	$Fs=N_\mu/A$ Where N_μ= total no of streams of all orders, A=area of watershed	Horton (1945)
Drainage texture (Dt)	$Dt= N\mu/P$ Where Nμ=total no of streams of all orders, P= perimeter of the watershed	Horton (1945)
Form factor (Rf)	$Rf=A/Lb^2$ Where A=area of watershed, Lb=length of watershed	Horton (1932)
Elongation ratio(R_e)	$R_e=(2\sqrt{A/л})/Lb$ Where A=area of watershed, л=3.41, L_b=length of watershed	Schumn (1956)
Circularity ratio (R_c)	$R_c=4лA/P^2$ Where A=area of watershed, л=3.41, P=perimeter of watershed	Miller (1953)
Length of overland flow (L_g)	L_g= ½ Dd	Horton (1945)
	Relief Aspects	
Basin relief (R)	R=vertical distance between the highest and the lowest point of watershed	Schumn (1956)
Relief ratio (R_r)	$R_r=R/Lb$ Where R=basin relief, Lb= length of watershed	Schumn (1956)

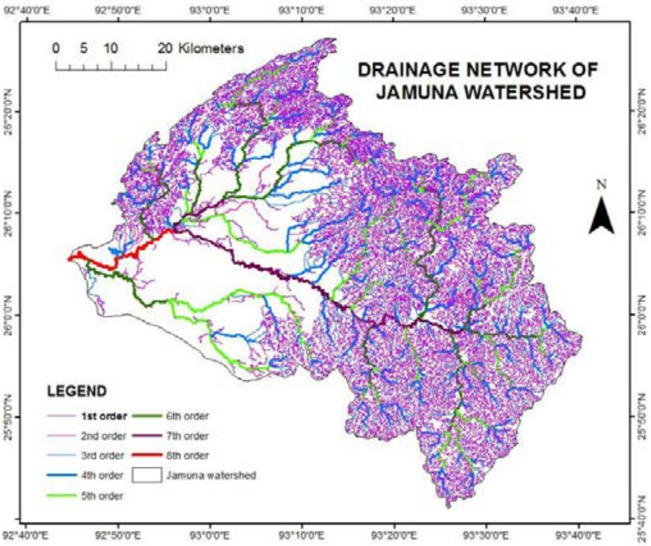

Fig. 2. Stream Network of Jamuna Watershed

The maximum frequency (order) of streams is observed in the 1st order stream, and this frequency decreases gradually as the stream order increases (Table 2).

Table 2. Linear Parameters of Jamuna Watershed

Stream order	Number of streams frequency	Total stream length (km)	Mean stream length (km)	Length ratio (R_L)	Bifurcation ratio (R_b)
1	12,160	5,896.24	0.484	-	4.34
2	2,804	2,004.66	0.714	1.475	4.26
3	657	1,027.58	1.564	2.190	4.03
4	163	589.50	3.616	2.312	4.40
5	37	371.83	10.049	2.779	3.70
6	10	269.42	26.942	2.681	5.00
7	2	125.63	62.815	2.331	2.00
8	1	32.78	32.780	0.521	-
Total	15,834	10,317.64	-	-	-

The higher amount of stream order indicates lesser permeability and infiltration (Arunachalam and Sakthivel, 2014). Horton's law of stream number (1945) states that the number of stream segments of each order forms an inverse geometric sequence against the plotted order. Most drainage networks show a linear relationship with small deviation from a straight line. Plotting the logarithm of the number of streams against stream order shows a straight line which affirms the number of streams usually decreases as the stream order increases (Figure 3).

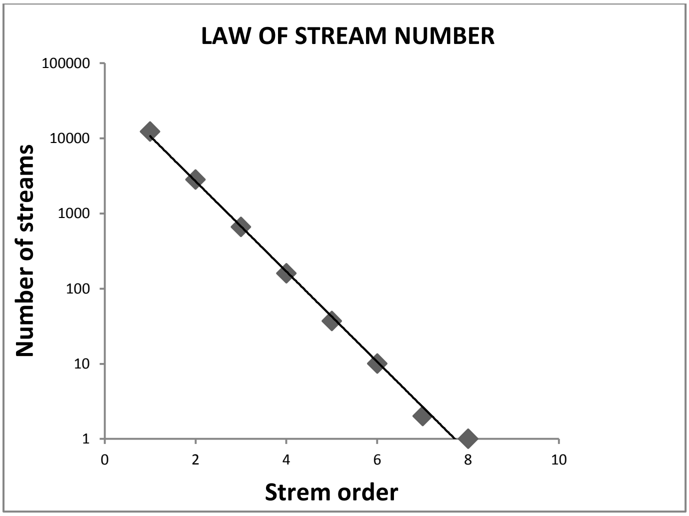

Fig. 3. Semi-log Plots of Stream Number v/s Stream Order of Jamuna Watershed

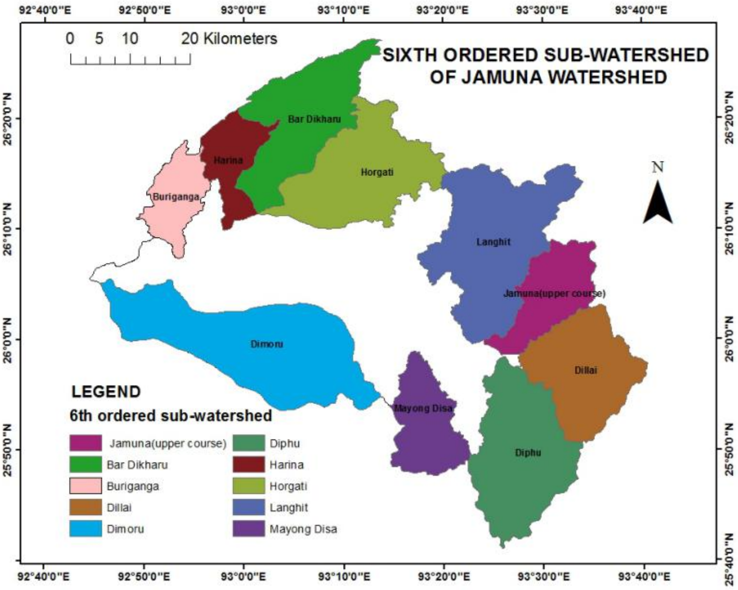

Fig. 4. Sub-Watersheds of Jamuna River Stream Length (Lµ)

All the sixth ordered sub-watersheds have been delineated from Survey of India toposheets following water divide line for detailed morphometric analysis. There are ten sixth ordered sub-watersheds within Jamuna basin (Figure 4).

Stream length is indicative of the contributing area of the basin for a given order (Horton, 1945). It is the quantification of hydrological characteristics of bedrock and the drainage extent. When bedrock is of permeable character then only subtle numbers of relatively longer streams are formed in a well-drained basin area. On the other hand, when the bedrock is less permeable then a large number of smaller length of streams in the basin are produced (Kulkarni, 2015). The length of stream segment is high for first-order streams and it decreases as the stream order increases. Streams with relatively short lengths are representative of areas with steep slopes, and finer texture; whereas longer lengths of stream generally indicate of low gradients (Strahler 1964). The total stream length of Jamuna watershed is 10,317.64 km (Table 3). Stream length of all the sub-watersheds has been presented in Table 4. Maximum stream length (1639.48) is observed in Langhit sub-watershed, and minimum stream length (269.11) is observed in Harina sub-watershed.

Table 3. Linear Parameters of Jamuna Watershed

Stream order	Number of streams	Total stream length (km)	Mean stream length (km)	Length ratio (R_L)	Bifurcation ratio (R_b)
1	12,160	5,896.24	0.484	-	4.34
2	2,804	2,004.66	0.714	1.475	4.26
3	657	1,027.58	1.564	2.190	4.03
4	163	589.50	3.616	2.312	4.40
5	37	371.83	10.049	2.779	3.70
6	10	269.42	26.942	2.681	5.00
7	2	125.63	62.815	2.331	2.00
8	1	32.78	32.780	0.521	-
Total	15,834	10,317.64	-	-	-

Mean Stream Length (L_{um})

Mean stream length of a stream channel segment of order 'u' is a dimensional property revealing the characteristic size of components of a drainage network and its contributing basin surface (Strahler, 1964). It is obtained by dividing the total length of the stream of an order by the total number of segments of that particular order. Mean stream length reveals the size of the component of drainage network and its contributing surface (Strahler.1964). It is directly proportional to the size and topography of drainage basin.

Stream Length Ratio (R_l)

Stream length ratio is defined as the ratio of the mean length of one order to the mean length of the next lower order (Horton, 1945).Stream length ratio for all the sub-watersheds has been calculated, and it is presented in Table 4. The values of R_L in the sub-watershed vary from 0.61-11.95 (Table 4). R_L values between successive stream orders vary due to differences in slope and topographic conditions and have a positive relationship with the surface flow discharge and erosional stage of the sub-basin (N.S. Magesh and N. Chandrasekar, 2012).

Bifurcation Ratio (Rb)

Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio of the number of streams of any given order to the number of streams in the next higher order in a drainage basin (Schumm, 1956). It is a dimensionless property and shows the degree of integration prevailing between streams of various orders in a drainage basin (Schumm, 1956). Rb shows a small range of variation for different regions or different environments except those where the powerful geological control dominates. The mean bifurcation ratio of Jamuna watershed is 3.96. The values of Rb vary from 2 – 5.13 in different stream order in the sub-watersheds, whereas mean bifurcation ratio ranges from 3.08 – 4.65 for the sub-watersheds (Table 4). It is noted that the Rb values fluctuates from one order to the next order. These fluctuations depend upon the geological and lithological development of the basin (Strahler, 1964). The higher value of Rb indicates a strong structural control in the drainage pattern whereas, the lower value indicates that the sub-basin is less affected by structural disturbances (Strahler, 1964).

Table 4. Sub-Watershed Wise Linear Morphometric Parameters of the Study Area

Sub-Watershed	Stream Order	No of Streams	Stream Length (km)	Mean Stream Length (km)	Length Ratio (R_L)	Bifurcation Ratio	Mean Bifurcation Ratio
Bar Dikharu	1	1,212	657.04	0.54	----	4.39	4.19
	2	276	191.87	0.69	1.28	4.6	
	3	60	99.18	1.65	2.38	5	
	4	12	46.71	3.89	2.35	4	
	5	3	28.37	9.46	2.43	3	
	6	1	37.77	37.77	3.99	---	
Dimoru	1	413	240.26	0.58	---	4.21	3.45
	2	98	96.97	0.98	1.69	3.92	
	3	25	49.91	1.99	2.02	3.12	
	4	8	26.95	3.37	1.68	4	
	5	2	80.55	40.27	11.95	2	
	6	1	35.37	35.37	0.87	---	
Dillai	1	1,080	533.71	0.49	---	4.23	4.08
	2	255	193.98	0.76	1.54	4.11	
	3	62	103.12	1.66	2.19	4.42	
	4	14	47.49	3.39	2.04	4.66	
	5	3	22.45	7.48	2.20	3	
	6	1	19.39	19.39	2.59	---	
Diphu	1	1,526	693.44	0.45	---	4.62	4.40
	2	330	240.34	0.73	1.60	4.58	
	3	72	111.10	1.54	2.11	3	
	4	24	56.32	2.35	1.52	4.8	
	5	5	41.33	8.27	3.52	5	
	6	1	27.83	27.83	3.36	---	
Harina	1	246	144.80	0.58	---	4.03	3.08
	2	61	47.64	0.78	1.32	3.21	
	3	19	31.37	1.65	2.11	3.16	
	4	6	22.19	3.69	2.24	2	
	5	3	6.80	2.26	0.61	3	
	6	1	16.28	16.28	7.17	---	

Mayong Disa	1	734	349.47	0.47	---	4.17	3.80
	2	176	123.41	0.70	1.47	4.75	
	3	37	53.87	1.45	2.07	4.11	
	4	9	30.40	3.37	2.32	3	
	5	3	11.46	3.82	1.13	3	
	6	1	15.75	15.75	4.11	---	
Horgati	1	1,031	480.85	0.46	---	4.52	4.06
	2	228	156.08	0.68	1.46	4	
	3	57	86.20	1.51	2.21	3	
	4	19	66.76	3.51	2.32	3.8	
	5	5	18.08	3.61	1.02	5	
	6	1	42.81	42.81	11.83	---	
Buriganga	1	608	263.15	0.42	---	4.47	3.77
	2	138	82.44	0.59	1.40	4.6	
	3	30	36.44	1.21	2.03	4.28	
	4	7	26.80	3.82	3.15	3.5	
	5	2	6.31	3.15	0.82	2	
	6	1	23.63	23.63	7.48	---	
Langhit	1	2,155	991.13	0.45	---	4.27	4.65
	2	504	317.54	0.63	1.40	4.46	
	3	113	151.67	1.34	2.12	5.13	
	4	22	92.28	4.19	3.12	4.4	
	5	5	44.98	8.99	2.14	5	
	6	1	41.85	41.85	4.65	---	
Jamuna (upper Course)	1	705	368.66	0.52	---	5.10	3.89
	2	138	115.20	0.83	1.59	4.31	
	3	32	48.75	1.52	1.83	3.55	
	4	9	37.96	4.21	2.76	4.5	
	5	2	22.98	11.49	2.72	2	
	6	1	8.74	8.74	0.76	---	

Areal Aspects

The aerial aspects include various morphometric parameters like drainage density (Dd), drainage texture (T), stream frequency (Fs), elongation ratio (Re), the circulatory ratio (Rc), form factor (Rf), and length of overland flow (Lg). The total area of Jamuna watershed and ten sub-watersheds are computed from the topological polygons that are created by delineation of the basin from the toposheets and ASTER DEM in ArcGIS 10.2. The basin area, basin length and perimeter of Jamuna watershed along with its ten sub-watersheds are presented in Table 5.

Drainage Density (Dd)

Drainage density (Dd) is one of the important indicators of the landform element and provides a numerical measurement of landscape dissection and runoff potential (Chorley, 1969). It is the computation of the total length of the entire stream segment in the watershed to the area of the watershed. Dd is a measure of fluvial dissection and depends on various factors like climate, slope, rock types, vegetation cover, soil texture, and runoff intensity (Verstappen, 1983). It helps in determining the permeability and porosity of the watershed. Higher drainage density is associated with the basin of weak and impermeable subsurface material, sparse vegetation and high relief. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture, high runoff and erosion potential of the basin area (Strahler 1964). Drainage density of each sub-watershed is given in Table 7. Higher drainage density (3.81) is identified for Langhit watershed, while low drainage density (1.04) is found in Dimoru watershed

Table 5. Basic Area Parameters of Jamuna Watershed along with its Sub-Watersheds

Watershed / Sub-Watersheds	Basin Area (sq km)	Basin Length (km)	Perimeter (km)
Jamuna	3902.7	94.53	375.40
Bar Dikharu	308.3	34.21	112.20
Dimoru	507.3	50.33	123.69
Dillai	280.0	23.47	79.14
Diphu	355.3	31.79	97.19
Harina	124.2	20.41	66.96
Mayong Disa	171.5	21.12	69.57
Horgati	347.4	32.57	116.87
Buriganga	119.8	19.68	63.13
Langhit	429.5	33.91	128.07
Jamuna (Upper course)	171.5	24.20	75.98

Stream Frequency (Fs)

Stream frequency (Fs) is the total number of stream segments of all orders per unit area (Horton, 1932).It depends upon the basin lithology and indicates the texture of the drainagenetwork. Stream frequency density serves as a tool in establishing the erosional processes operating over an area; to be more specific, the same about the stream orders and their characteristics provides data which can throw light even on the sequences of relief developments and the degree of ruggedness in the area (Singh 1980). Reddy et al. (2004) stated that low values of stream frequency indicate the presence of a permeable subsurface material and low relief. The Fs values of the sub-watershed of the study area are presented in Table 7. It is noted that the values of Fs vary from 1.05 – 6.64 (Table 7). It is also observed that the stream frequency values for the sub-watersheds exhibit a positive correlation with drainage density values of the area indicating that there is an increase in stream population concerning the increased drainage density.

Drainage Texture (Dt)

Horton (1945) defined drainage texture as the total number of stream segments of all order in a basin per perimeter of the basin (Table 1). The drainage texture depends upon many natural factors such as climate, rainfall, vegetation, lithology, slope, infiltration capacity, and stage of development (Smith, 1950). Smith (1950) has classified drainage texture into five different textures, i.e., very coarse (<2), coarse (2 to4), moderate (4 to 6), fine (6 to 8) and very fine (>8). The values of drainage texture of all the sub-watersheds are presented in Table 7 and it varies from 4.42 (in Dimoru sub-watershed) to 21.86 (in Langhit sub-watershed). The value of Dt shows moderate to very fine drainage texture in all the sub-watersheds of the study area.

Length of Overland flow (Lg)

According to Horton (1945), the length of overland flow is the length of water over the ground before it gets concentrated into specific stream channels. It approximately equals half the reciprocal of the drainage density and inversely relates to the average slope of the channel and is entirely synonymous with the length of sheet flow to a significant degree (Horton 1945). It significantly affects the quantity of water required to exceed a certain threshold of erosion. The value of Lg varies from 0.52 in Dimoru sub-watershed to 1.90 in Langhit sub-watershed (Table 7).

Constant of Channel Maintenance (C)

Constant of channel maintenance is the inverse of drainage density (Schumm, 1956). It depends on the slope of a basin, nature of rocks and the duration of erosional activity. Generally, the higher C values of basin indicate the higher permeability of rocks and vice versa (Pakhmode et al. 2003; Rao 2009; Kumar et al.2011). The C value of Jamuna watershed is 0.38 (Table 6) and it varies from 0.26 to 0.96 in all the sub-watersheds (Table 7). Most of the sub-watersheds with low values of constant of channel maintenance are categorised as the region with close dissection whereas the large value of C signifies higher infiltration rate and mature to old stage of the river (Prakash et al. 2017).

Table 6. Areal Aspects of Jamuna Watershed

Drainage Density (Dd) (km/km^2)	Stream Frequency (Fs) (segments/ km^2)	Drainage Texture (Dt) (segments/km)	Length of Overland flow (Lg)	Constant of Channel Maintenance (C)	Form Factor (Rf)	Elongation ratio (Er)	Circularity ratio (Rc)
2.64	3.88	40.36	1.32	0.38	0.44	0.71	0.36

Table 7. Areal Aspects of the Sub-Watersheds of the Study Area

Sub-Watersheds	Drainage Density(Dd) (km/km^2)	Stream Frequency (Fs) (segments/km^2)	Drainage Texture (Dt) (segments/km)	Length of Overland flow (Lg)	Constant of Channel Maintenance (C)
Bar Dikharu	3.44	5.07	13.93	1.72	0.29
Dimoru	1.04	1.05	4.42	0.52	0.96
Dillai	3.28	5.05	17.87	1.64	0.30
Diphu	3.29	5.51	20.14	1.64	0.30
Harina	2.16	2.69	5.00	1.08	0.46
Mayong Disa	3.40	5.59	13.79	1.70	0.29
Horgati	2.44	3.85	11.46	1.22	0.40
Buriganga	3.66	6.64	12.60	1.83	0.27
Langhit	3.81	6.51	21.86	1.90	0.26
Jamuna (Upper course)	3.51	5.17	11.67	1.75	0.28

Form Factor (Rf)

Horton (1932) stated form factor as the ratio of the area of the basin and square of the basin length**.** The value of form factor would always be higher than 0.78 for a perfectly circular Basin. Smaller the value of form factor, more elongated will be the basin. The value of form factor of the Jamuna watershed is 0.436 (Table 6), and it ranges between 0.20 – 0.50 for all the sub-watersheds (Table 8). The lower valueof form factor indicates that the Jamuna watershed is an elongated one. A maximum value of Rf (0.50) is recorded for Dillai sub-watershed which indicates the sub-circular shape of the basin (Table 8).

Elongation Ratio (Re)

According to Schumm (1956), the elongation ratio is defined as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin. It is found that a circular basin is efficient enough to discharge the runoff than an elongated one (Singh and Singh 1997). The value of 'Re' varies from 0.6 to 1.0 over a wide variety of climatic and geologic types. Basins with very low relief have values close to 1.0, whereas basins with high relief and steep slope have values ranges between 0.6 and 0.8 (Strahler 1964). These values can be grouped into three categories, namely (a) circular (>0.9), (b) oval (0.9-0.8), and (c) less elongated (<0.8). The Re values of all the sub-watersheds range from 0.28-0.45 (Table 8), which indicates less elongated basin with high relief and steep slope.

Table 8. Shape Parameters of the Sub-Watersheds

Sub-Watersheds	Form Factor (Rf)	Elongation Ratio (Er)	Circularity Ratio (Rc)
Bar Dikharu	0.26	0.32	0.30
Dimoru	0.20	0.28	0.41
Dillai	0.50	0.45	0.56
Diphu	0.35	0.37	0.47
Harina	0.29	0.34	0.34
Mayong Disa	0.38	0.39	0.44
Horgati	0.32	0.36	0.31
Buriganga	0.30	0.35	0.37
Langhit	0.37	0.38	0.32
Jamuna (Upper course)	0.29	0.34	0.37

Circularity Ratio (Rc)

The circulatory ratio is the ratio of the area of a basin to the area of a circle having the same circumference as the perimeter of the basin (Miller, 1953). The circularity tor ratio is mainly concerned with the length and frequency of streams, geological structures, land use/land cover, climate, relief and slope of the basin. Miller (1953) described Rc as a significant ratio that indicates the dendritic stage of a watershed. Low, medium and high values of Rc indicate the young, mature, and old stages of the life cycle of the tributary watershed (John Wilson et al. 2012). The value of circularity ratio varies from 0 (in line) to 1 (in a circle). The Circulatory ratio for all sub-watersheds is in the range of 0.30 to 0.56 (Table 8), which reveals the elongated shape of the basin.

Relief Aspects

Relief is an essential parameter for drainage basin analysis. It reflects the elevation difference between the highest and lowest point of a region. Relief aspects deal with the structural elevation of a basin. The relief measurements like total relief and relief ratio are tabulated in Table 9 and 10.

Basin Relief (R)

Basin relief is an essential factor in understanding the denudational characteristics of the basin, and it is defined as the elevation difference between the lowest and the highest point of a basin. It plays a significant role in landforms development, drainage development, surface and subsurface water flow, permeability, and erosional properties of the terrain (Magesh and Chandrasekar, 2012). Total relief of the Jamuna watershed is 1,305 m (Table 9), and it varies from 140 to 1,200 for the sub-watersheds (Table 10).The high relief value is observed in the northeastern part of the study area which includes the denudational hills Doboka, Borail and Mikir hill range and indicates the gravity of water flow, low infiltration, and high runoff conditions

Table 9. Relief Aspects of Jamuna Watershed

Watershed	Maximum Elevation (H) in meter	Minimum Elevation (h) in meter	Basin Relief (R) in meter	Relief Ratio (Rr)
Jamuna	1,360	50	1310	0.013

Table 10. Relief Parameters of the Sub-Watersheds of the Study Area

Sub-Watershed	Maximum Elevation (H) in meter	Minimum Elevation (h) in meter	Basin Relief (R) in meter	Relief Ratio (Rr)
Bar Dikharu	800	80	720	0.021
Dimoru	340	60	280	0.005
Dillai	700	160	540	0.023
Diphu	300	160	140	0.004
Harina	540	80	460	0.022
Mayong Disa	480	140	340	0.016
Horgati	1,280	80	1,200	0.036
Buriganga	820	80	740	0.037
Langhit	1,340	160	1,180	0.034
Jamuna (Upper course)	1,340	160	1,180	0.048

Relief Ratio (Rr)

Relief ratio is defined as the ratio between the total relief of a basin, i.e. elevation difference of lowest and highest points of a basin, and the longest dimension of the basin parallel to the principal drainage line (Schumn 1956). Relief ratio is an indicator of the intensity of erosion processes operating on the slopes and overall steepness of a drainage basin. Relief ratio increases typically with decreasing drainage area and size of a given drainage basin (Gottschalk, 1964). The Relief Ratio of the sixth-ordered sub-watersheds varies between the values of 0.004 to 0.048 (Table 10). Basin consisting of alluvium (Dimoru sub-watershed) shows the low relief ratio, whereas basins of hilly areas show high relief ratio. Diphu basin of denudational hill areas has a low relief ratio because of high erodability of the rock type. The high values of relief ratio in the eastern part can be explained by the presence of highly resistant rocks of Mikir hill region underlying the basin. The high values of Rr indicate steep slope and high relief and vice-versa.

Conclusion

Morphometric analysis of a drainage basin is the prerequisite to know the hydrological characteristics of a basin. GIS techniques and Remote Sensing data have been proven to be an effective tool in studying the hydrological behavior of a basin. In the present paper, morphometric characteristics of Jamuna watershed have been studied with the help of GIS tool. It is inferred that the Jamuna river falls under eight-order basin. The basin is mainly dominated by first-order streams. The stream network shows dendritic and sub-dendritic pattern which indicates homogeneous lithology. Detailed morphometric analysis has been carried out in the ten six-order sub-watersheds of Jamuna basin. Bifurcation ratio ranges from 3.08-4.65 for the sub-watersheds indicating the geologic structure of the area does not distort the drainage pattern. Low drainage density of 1.04 is recorded in the Dimoru sub-watershed leads to coarse drainage texture indicating permeable sub-soil, whereas considerably high drainage density is recorded in the sub-watersheds situated in the north-eastern part of the study area which indicates fine drainage texture, high runoff and high erosion potential. The stream frequency values of all the sub-watersheds exhibit a positive correlation with drainage density values indicating that there is an increase in stream population with increase in drainage density. The values of form factor of all the sub-watersheds indicate that they are more or less elongated to sub-circular in shape. The high relief value is recorded in the northeastern part of the study area, which includes the denudational hills of Doboka, Borail and Mikir hill ranges and indicates the gravity of water flow, low infiltration and high runoff conditions. The database obtains through analysis of morphometric parameters would be suggested for its proper utilization in the integrated watershed programme that aimed at development and management of water resources of the Jamuna River basin in future.

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QUANTITATIVE ANALYSIS OF LAND USE CHANGE USING REMOTE SENSING AND GIS TECHNIQUES IN GUNTUR URBAN MANDAL, ANDHRA PRADESH STATE

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Abstract

The surface of the earth is undergoing rapid land use / land cover (LULC) changes due to various human activities and natural phenomena. In the current day's context of developmental planning, information on land use/ land cover and the changes over a period of time is vital for all the planning activities. The aim of this study is to gain a quantitative understanding of land use and land cover changes in Guntur urban mandal (which is a part of the Capital Region of Andhra Pradesh) over the period from 2006 to 2016. The results show that the built-up land of 4,412.2 ha and industrial area of 328.2 ha has increased to 6,071.8 ha and 500.2 ha respectively over 10 years, while the other categories of land decreased. The findings will provide insight to the planners and policy makers for the management of urban land and the problems related to urbanization of the city regions.

Keywords: Land use Change, Remote Sensing, GIS, Mandal, Land Management

Introduction

Land is definitely one of the most important natural resources since life and developmental activities are based on it. Land use refers to the type of utilization to which man has put the land. It also refers to evaluation of the land with respect to various natural characteristics. Land use and land cover data are essential for planners, decision makers for land resources management (Babu, et al., 2014). Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current level (Anderson et al., 1976). Geographic Information Systems (GIS) and Remote Sensing (RS) techniques provide effective tools for analysing the land use dynamics of the region as well as for monitoring, mapping and management of natural resources.

Landuse change is a dynamic process-taking place on the biophysical surfaces that have taken place over a period of time and space, and is of enormous importance in natural resource studies. Landuse/ Land cover changes are important elements for monitoring, evaluating, protecting and planning for Earth resources. Land use/ Land cover changes are the major issues and challenges for the eco-friendly and sustainable development for the economic growth of any area.

For identification of land use/ land cover changes, at least two time period data sets are required. The changes in landuse/ land cover due to natural and human activities can be observed using current and archived remotely sensed data (Luong, 1993). With the availability of satellite data at very high spatial, spectral and temporal resolutions, it is now possible to prepare up-to-date and accurate landuse/ land cover map in less time, at lower cost and with better accuracy (Kachhwaha, 1985). The present work has been undertaken to prepare the multi-date land use/ land cover maps of urban mandal of Guntur from Remote Sensing data and to monitor the changes in various land use/ land cover classes using GIS techniques. The present study aims at mapping of landuse/ land cover for the years 2005-06, 2011-2012 and 2015-16 and at quantifying the changes in land use.

Cheruto et al., (2016) demonstrated the assessment of landuseand land cover change using GIS and Remote Sensing Techniques of Makueni County, Kenya. Appala Raju et al., (2013) demonstrated the potential of remote sensing technology for mapping the land use/land cover status of an area and the study illustrates how to classify landuseand land cover from satellite imagery. Harikrishna et al., (2013) systematically studied Land use/Land cover categories i.e. built up land, agricultural land, aquaculture, forest, waste land and water bodies around Kolleru Lake. Harikrishna et al., (2011) have analyzed Landuse/ Land cover classes in Greater Visakha Municipal Corporation (GVMC). Shah and Archana (2006) have analyzed techniques of supervised classification in Land Cover/LanduseMapping of Rishikesh, Uttarakhand. Land use/Land cover classes of Pilibhit District in Uttar Pradesh are studied by Nay Nayak and Behera (2008). Alaguraja and Durairaju (2010) have analyzed Land use/ Land Cover categories of Madurai district in Tamil Nadu using satellite data.

Study Area

The study area comprises Guntur urban mandal with an area of 189.61 sq. km. It lies between 16°14' - 16°16' North latitude and 80°19' - 80°30' East longitude. Guntur City is the district headquarters. The mandal is well connected with transportation by means of rail and road. Guntur an export hub for agriculture products and is also known as a textile hub. The location map of the study area is shown Figure 1.The objective of the study is to generate land use / land cover maps of three time periods and to assess the landuse/ land cover change in the landscape from 2005-06 to 2015-16 using temporal remote sensing satellite data.

Data and Methodology

In order to study the changes of landusepattern and spatial extent of urban expansion, Survey of India (SOI) toposheet on 1:50,000 scale along with multi temporal three season (Kharif, Rabi and Zaid) satellite data of IRS P6 LISS-III possessing a resolution of 23.5m is used for the year 2005-06. IRS R2 LISS-III is used for 2011-12 and 2015-16 at 1:50000 scale. Arc GIS software has been used for mapping and analysis.

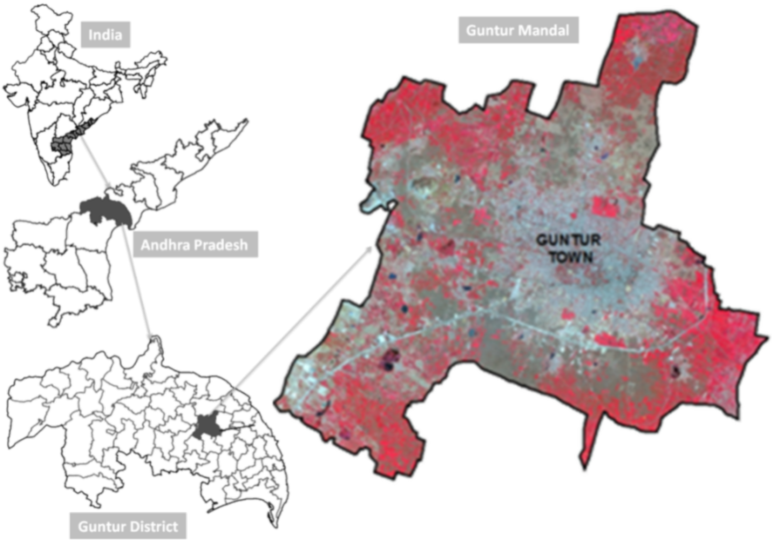

Fig. 1. Location of the Study Area

The overall methodology adopted for the preparation of land use/ land cover map with change analysis is shown in Figure 2. The satellite images are geometrically registered to the SOI topographic sheet (1:50,000) with LCC projection and WGS84 datum. The scenes are clipped to the study area before classification process. Landuse/ Land cover classification is carried out using on-screen visual interpretation techniques in GIS environment. The classified images having different landuse/ land cover categories pertaining to three periods have been compared to derive information on changes. Field research is undertaken to assess the changes in landuse/ land cover of the study area.

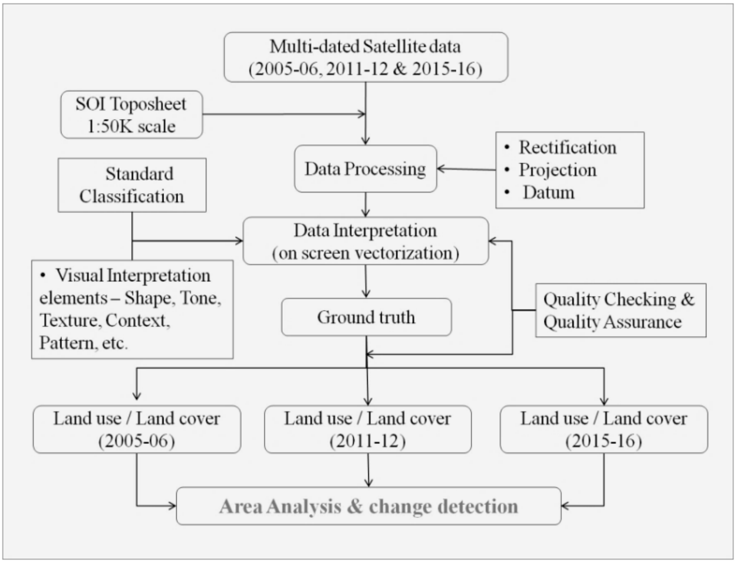

Fig. 2. Schematic of Methodology

Results and Discussion

In the present study, multi temporal satellite imagery of different time periods are used for mapping and computed the landuse changes during the period. These images provide the information about the landuse pattern of the study area (Figure 3).

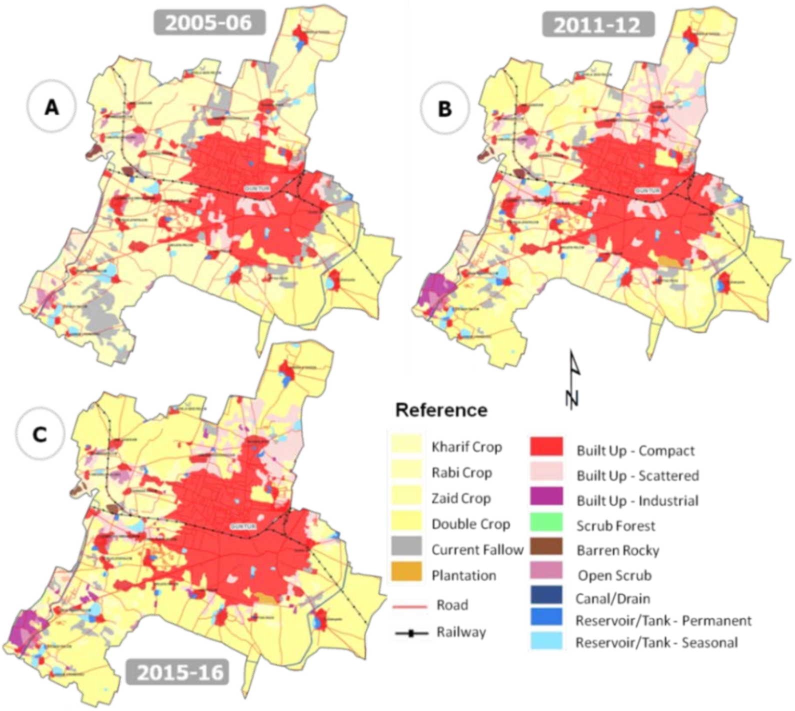

Fig. 3. Land use/ Land cover of Guntur Urban Mandal during (A) 2005-06, (B) 2011-12 and (C) 2015-16

The study area is classified with 13 classes, namely built up, industrial, kharif crop, rabi crop, zaid crop, double crop, plantation, fallow land, scrub forest, barren rocky, open scrub, canal/drain and reservoir/tanks using on-screen interpretation techniques in GIS environment. Information on the existing landuse/ land cover pattern, its spatial distribution and changes in the landuse pattern is a pre-requisite for planning, utilisation and formulation of policies and programmes for making any developmental plan. This information not only provides a better understanding of land utilization aspects but also plays a vital role in developmental planning.

Table-1 shows the spatial extent of the landuse/ land cover in hectares and in percentages during the study period. It is observed that agriculture land (kharif, rabi, zaid, double crop, fallow and plantations) constituted the largest landuse category which is 13448.4 ha in 2005-06 and is observed to have reduced to 11627.8 ha in 2015-16 due to expansion of built-up land. The built up and Industrial categories had occupied an area of 4412.2 ha and 328.2 ha in 2005-06 and increased to 6071.8 ha and 500.2 ha in 2015-06 respectively, witnessing a drastic rise in built up area. The agricultural land category experienced significant loss between 2005-2006 and 2015-2016 which is about 1,820.6 ha. There is no major change in other categories. It is observed that there is a decrease in kharif crop and current fallow area by 37.2% and 5.8% respectively, which is due to increase in the rate of double crop (34.3%). This indicates that there is rapid urban growth in and around Guntur town, which includes residential and official buildings, shopping malls and plazas, infrastructural facilities such as schools, hospitals, recreational parks, gardens etc. Increase in double-cropped area is attributed to the best agricultural practices.

Table 1. Statistical Distribution of Land use /Land cover during 2005-2006, 2011-2012 and 2015-2016 (Units in Hectares)

Landuse/ Land Cover Classes	2005-06		2011-12		2015-16		Rate of change % (±)		
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%	2006 - 2012	2012 - 2016	2006 - 2016
Built Up	4412.2	23.3	5934.3	31.3	6071.8	32.0	8.0	0.7	8.8
Industrial Area	328.2	1.7	387.2	2.0	500.2	2.6	0.3	0.6	0.9
Kharif Crop	9161.9	48.3	4315.6	22.8	2103.3	11.1	-25.6	-11.7	-37.2
Rabi Crop	227.3	1.2	1527.0	8.1	4.0	0.0	6.9	-8.0	-1.2
Zaid Crop	0.0	0.0	3.3	0.0	26.5	0.1	0.0	0.1	0.1
Double Crop	2621.9	13.8	5285.0	27.9	9116.3	48.1	14.0	20.2	34.3
Current Fallow	1437.3	7.6	689.7	3.6	335.8	1.8	-3.9	-1.9	-5.8
Plantation	0.0	0.0	49.6	0.3	41.9	0.2	0.3	0.0	0.2
Scrub Forest	13.3	0.1	13.3	0.1	13.3	0.1	0.0	0.0	0.0
Barren Rocky	53.8	0.3	46.4	0.2	46.4	0.2	0.0	0.0	0.0
Open scrub	193.9	1.0	193.9	1.0	185.9	1.0	0.0	0.0	0.0
Canal/Drain	91.9	0.5	91.9	0.5	91.9	0.5	0.0	0.0	0.0
Reservoir/Tanks	419.4	2.2	423.9	2.2	423.9	2.2	0.0	0.0	0.0
Total	**18961.2**	**100**	**18961.2**	**100**	**18961.2**	**100**	**0.0**	**0.0**	**0.0**

Conclusions

The study has revealed that remotely sensed data (imagery) are important and extremely useful in mapping and monitoring the dynamics of landuse/ land cover. GIS analysis has shown the capabilities of GIS in solving spatial problems and to provide information that aid decision making. The analysis shows that urban expansion has been rapid in and around the Guntur town, at the expense of agricultural land. The information generated for the landuse pattern will aid in understanding the spatial distribution and extent which will help in further planning and taking timely and appropriate decisions for sustainable development. This study is one of such efforts aimed at providing information that would aid in developing sustainable landuse policies in growing urban mandal of Guntur.

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MORPHO-DYNAMIC ASSESSMENT OF RAIDAK RIVER-II CONFLUENCE WITH HELP OF GEOSPATIAL TECHNIQUES

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Abstract

The confluence of Raidak-II into Sankosh river is dynamic in nature due fluvial process of erosion and deposition at different rate. This dynamic is mainly influenced by volume of water, size and quantity of erosional materials contained in river Raidak II in different season especially in monsoon. At the confluence point, there are numbers of bar, islands of various size have been formed every year and also transformed their shape, size and location in every year. The point of confluence of Raidak II into Sankhosh river is not static and in different direction due to these hydro-dynamics. In order to understand the morpho-dynamic at confluence of Raidak II, a period of 40 years (1978-2016) has been taken for analysis. The different temporal morphological features at confluence points and migration of confluence point have been computed from LANDSAT MSS, TM, ETM+ in three different periods-1978-1990, 1990-2001 and 2001-2016 and Google Earth Image in three different years – 2007, 2012 and 2016. Primary data were collected during field visit in 2016 in different seasons (pre-monsoon, monsoon and post-monsoon).

Keywords: Morpho-Dynamics, LANDSAT, Raidak II, Temporal Shifting, Morphological Features, Sand Bar.

Introduction

Raidak is the most important right side tributaries of Sankosh. Sankosh river is also one of the most important right side tributaries of Brahmaputra river. The confluence points of this river are very dynamic and never static. The changes of the confluence point also effect surroundings cultivable areas and settlements. River confluence is one of the most important characteristics of hydro morpho-dynamics of river. The confluence is the point where river joins into main River in different angle. The migration of confluence point is influenced by deposition, erosion and size of sediment deposited. It is also affected by the availability of water in different reaches and the pattern of sediment dispersal around the confluence point (Roy and Sinha, 2007). River confluences have received very little attention from geomorphologists although some very interesting work have been carried out in terms of flow separation and hydraulic geometry (Best and Reid, 1984; Best, 1986, 1987, 1988) and facies models (Bristow et al., 1993).

In India, the Ganges plains, the dynamics of the each individual channels has been received a very wide attention, most notably the migration of the Kosi river (Geddes, 1960; Gole and Chitale, 1966; Arogyaswamy,1971; Wells and Dorr,1987; Agarwal and Bhoj, 1992), decadal-scale hyper avulsive Baghmati system (Sinha, 1996; Jain and Sinha, 2003, 2004), understanding of the confluence dynamic of Ganga-Ramganga valley(Roy and Sinha,2005,2007) and a few other studies in the western Ganga plains (Richards et al., 1993).

Study Area

The river Sankosh which originated in Bhutan is the one of most important eastern Himalayan river which eventually falls in the river system of Bay of Bengal. This river is also a right side tributary Brahmaputra river . It serves as the boundary between the two states West Bengal and Assam. When the river debouches into Duar region of India bifurcated into two main channels. Sankosh has large channel and prominent one as perennial. Sankosh river finally falls into Brahmaputra in Bangladesh and name becomes Gangadhar. The length of Sankosh in West Bengal is 24 km. The total catchment area of this river sub-basin is 10, 146 sq. km.

The Raidak river originates in Mt. Akungphu at an altitude of 6,400 m. in Bhutan. The river Raidak then bifurcates into two channels namely Raidak-I and Raidak-II at Bhutanghat, close to Indo-Bangladesh border. Raidak-I joins into stream system of Torsa and Kaljani, while Raidak-II joins into Sankosh at Bainaguri, Boxirhat, Coochbehar. Sankosh river joins into Brahmaputra in Bangladesh and name becomes Gangadhar (Singha, 2017). The length of Raidak-II is around 50 km in West Bengal. The total catchment area of Raidak-II river sub-basin is 4, 852 sq. km. (Flood Report, 2014). The present study area extended 89˚46' E to 89˚49' E longitude and 26˚20' N to 26˚23' N latitude (Figure 1). The confluence point of the Raidak-II and Sankosh is located at Bainaguri, Boxirhat, Coochbehar district. The confluence junction mainly covered some part of Assam and some part of West Bengal.

Data Used and Methodology

This study mainly used primary and secondary data too to understand hydro morpho-dynamics of confluence point. To study pattern and rate migration / shifting of confluence point for a period of 1978 to 2016, satellite imagery (LANDSAT IMAGE, MSS, TM, ETM) from USGS and Google Earth imageries too had been used. Satellite Imageries which had been used in this study are listed in the Table 1.

Table 1. Satellite Images

Agency	Year	Date of acquisition	Scale	Band combination
LANDSAT-2 MSS	1978	22.02.1978	60M	2,3,4
LANDSAT-5 TM	1990	14.11.1990	28.5M	1,2,3
LANDSAT-7 ETM+	2001	20.11.2001	28.5M	1,2,3
LANDSAT-8 ETM	2016	20.10.2016	28.5M	5,6,7

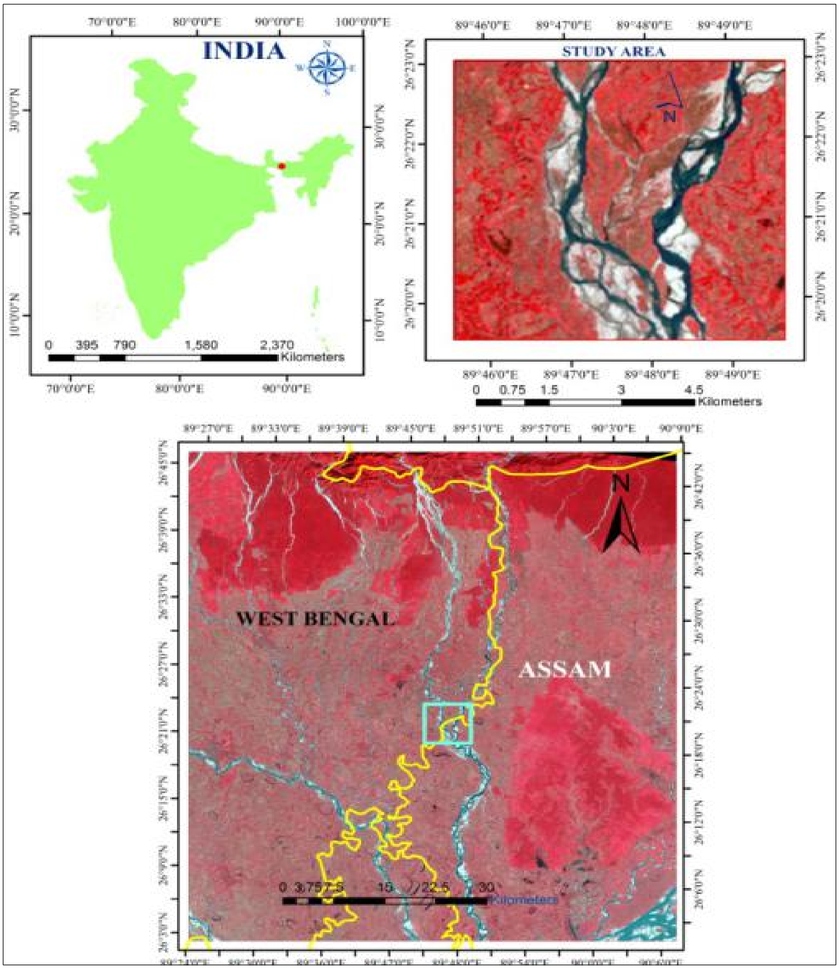


Fig. 1. Location of the Study Area

All the satellite images have been digitized in ArcGIS software version 10.2 and prepared final thematic map. In order to understand hydro-morpho-dynamics of confluence point formation of bar and island for the period of 1978-1990, 1990-2001 and 2001-2016, thematic map had been prepared by digitizing from LANDSAT imageries. Overlapping of digitized thematic map in different period to find out the shifting, growth and rate change. In same manner rate of channel bankline and confluence point shifting had been measured after overlapping of thematic map since 1978 till 2016 with the interval of 10 years. The LANDSAT TM data of pre-monsoon 1978 and after-monsoon 1990, 2001, and 2016 were used to study the bankline changes and confluence point of Raidak-II. The LANDSAT TM of 1978 and 1990 with the band combination 2, 3, 4 and 1, 2, 3 gave good geomorphic features. Similarly, the LANDSAT ETM+ data of 2001 and 2016 with the band combination 1, 2, 3 and 5, 6, 7 provided distinct geomorphic features (Figure 2).

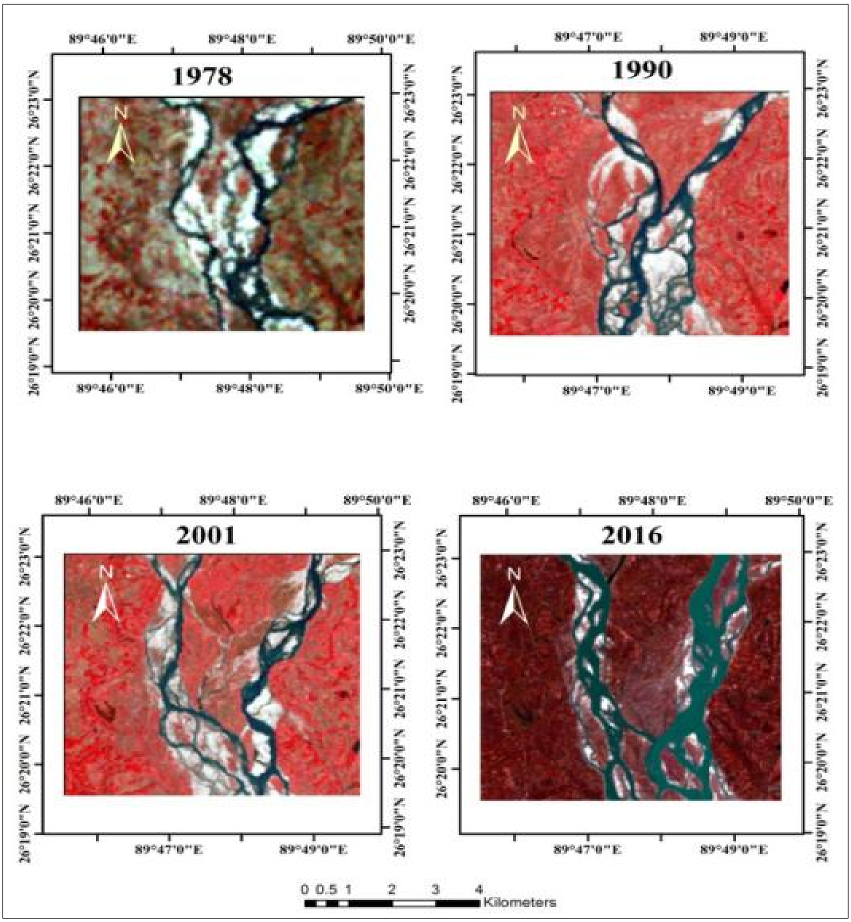


Fig. 2. Morphology in Different Years

The visual interpretation of the bankline and confluence point was done based on the ton, texture and color. The bankline of 1978, 1990, 2001 and 2016 were generated in the GIS platform using ARC-GIS version10.2. The rate of bank line and confluence point shift were obtained with the help of thematic mapping of the bankline and confluence point changes on 1:300,000 scale. To study the shifting of bankline, the 1 km stretches of the rivers was divided into six sections at average 200 meter interval. The nature of bankline changes were studies within changes on right and left bank line.

The both banklines of Raidak-II for the year 1978 was taken as based map. The bankline of year 1990 was over laid on base map of 1978 to assess the shifting rate and direction. The shift on bankline was measured with respect to change in bankline of 1978. Since, the river Raidak-II and Sankosh are flowing north to south and the right and left bank are on the west to east of the flow direction. Therefore any shift in bankline is measured with respect to the west and east shift of the bankline. The bankline shift in 1990, 2001 and 2016 were measured in similar manner.

Discussion

Morphological Change of Confluence

Different changes have been identified at the confluence of the Raidak-II into Sankosh river. These changes are morphological changes, bankline shifting that induced confluence point migration. Morphologically the confluence of Raidak-II river is braided; the channel is characterised by different sizes of bar and island and finally join into Sankosh river. At this conflunce point the rive deposited fine erosional materials on the river bed and form different sizes bars and island. These sand islands are used by agricultural practice and settlement. The Channel Bed on Cross-Section at Bainaguri, Conflunce Point is shown below.

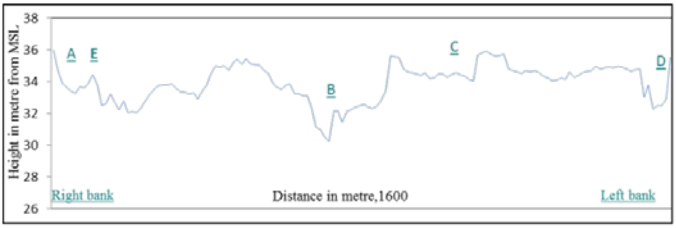
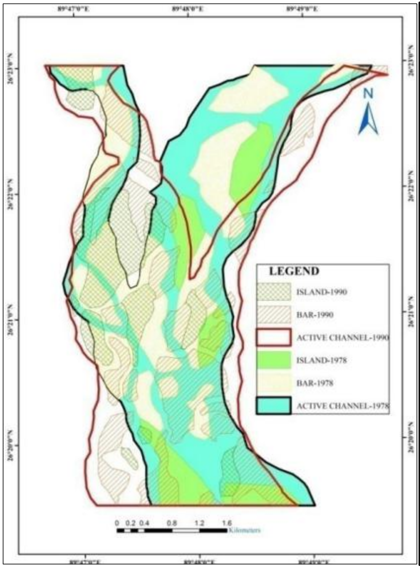


Chart 1. Bar and Island Change (1978 - 1990, 1990-2001 and 2001-2016)

At confluence the bars and island change their size, shape and location every year due to high flow in monsoon season and erosive nature of catchment areas. Here mainly discuss the bar and island change in the period of 1978-1990, 1990-2001 and 2001-2016 (Plate 1).

In the period of 1978-1990, change their shape and size of the both river (Figure 3 and 4). In the period of 90-2001, the bars and islands had also changed their shape, size and location (Figure 5)

Plate 1.



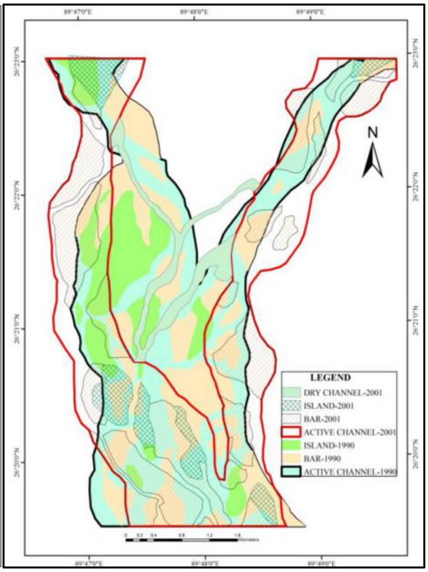


Fig. 3. Morphological Changes 1978-1990

Fig. 4. Morphological Changes (Different Location) 1978-1990

Migration Rate and Direction of Confluence Point (1978-2016)

The confluence point of the Raidak-II river is highly dynamic. Deposition, erosion and bifurcation are common phenomena which occur every year at the confluence point. The confluence point change of different years of the Raidak-II river is shown by maps (Figure 5) and rate and direction are shown in Table 2.

Table 2. Confluence Point in Different Years

Year	Rate (in km)	Direction
1978-1990	0.877	East
1978-2001	2.845	South-East
1978-2016	1.826	South-East

Bankline Migration Rate and Direction at Confluence (1978-2016)

Bankline migration perhaps is a very common hydro-morphologic phenomena in an alluvial channel. In general sense, channel bankline migration is simply the laterally movement of a bankline across its flood plain across a time frame. At the confluence the bankline of Sankosh and Raidak-II river is very dynamic. At this point the bankline will mainly shift in the right and left direction with different rates. The present study mainly discuss about the rate and direction of bankline shifting in three period, 1978 to1990, 1990 to 2001 and 2001 to 2016. In order find nature of shifting, six cross section have been drawn along the both river and only one section is drawn on final output channel. (Figure 6). Since river is moving from north to south, left bank is on east and right bank is on west of river.

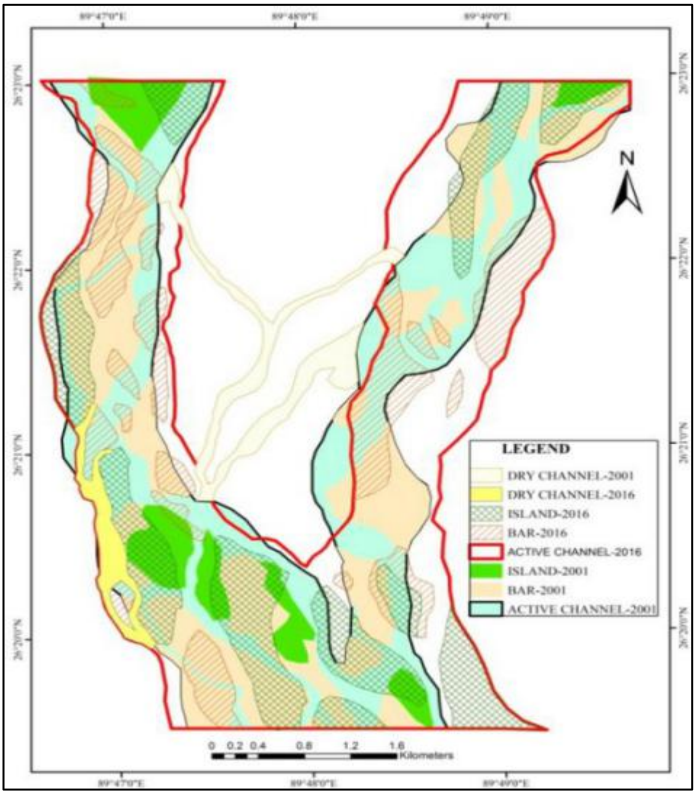


Fig. 5. Morphological Change 1990 -2001

(a) Bankline Shifting Rate and Direction in 1978-1990

In this period the bankline shifting and direction is different at different selected point. Here the bankline of 1978 is base line and calculated the rate and direction of bankline migration of 1990 on the basis of bankline 1978. Maximum shifting rate is found at 1, 2 and 3 section of the river channel.

(b) Bankline Shifting 1990-2001

In this period the bankline shift in different scale. The right bankline of Sankosh river channel is mainly shifting in right direction and bankline of Raidak river II is mainly shifting in right direction. Maximum shifting found at sections 1, 2, 3, 4 and 5 (Figure 6).

(c) Bankline Shifting 2001-2016

In this period bankline shifting rate is measured on the basis of bankline 2001. The maximum bankline shifting rate is occurred in the upper part of the both channel at section point 1, 2, 3 and 4 (Figure 6). Mainly bankline of Sankosh river shift in left direction.

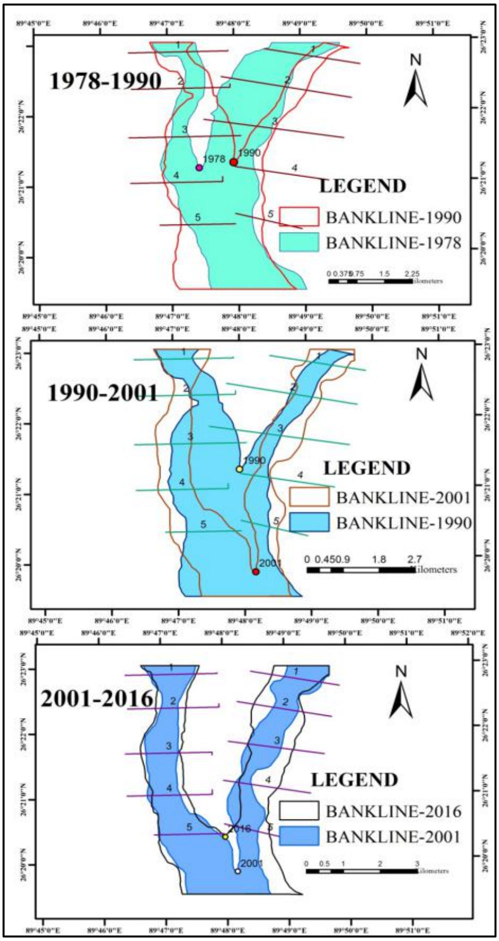


Fig. 6. Bank line shifting 1978 - 2016

Table 3. The Rate of Bank line Shifting both Left and Right Banks at Confluence

Section	Right bank				Left bank			
	Raidak-II		Sankosh		Raidak-II		Sankosh	
	Rate (in metre)	Direction	Rate (in metre)	Direction	Rate (in metre)	Direction	Rate (in metre)	Direction
1978 - 1990								
1	66.96	R	1073	L	261.05	L	340.51	L
2	48.126	L	1363	L	197.94	L	474.71	L
3	163.88	R	1084	L	570.82	L	77.665	L
4								
5								
6 (Final Output Channel)	872.60	R			385.97	R		
1990 - 2001								
1	31.607	R	152.32	R	390.1	L	374.1	L
2	416.1	R	99.78	L	670.99	R	220.15	L
3	358.5	R	107.24	L	985.1	R	545	L
4								
5								
6 (Final Output Channel)	502.84	L					56.34	R
2001 - 2016								
1	80.83	L	341.47	R	65.66	L	72.44	R
2	142.54	R	531.6	R	211.18	L	139.09	L
3	137.95	R	4.35	R	42.75	L	328.77	L
4	122.29	L	91.56	L	175.45	L	701.7	L
5	17.61	L	14.94	L	79.4	L	302.72	L
6 (Final Output Channel)	154.68	R			505.3	L		

The Rate of Bank line Shifting both Left and Right Banks at Confluence is explained in Table 3.

Conclusion

Raidak-II is located in the eastern part of Alipurduar and Coochbehar district. It is the lower course of Raidak river (Wangchhu in Bhutan). In the north, it is bordered by Bhutan Himalaya and the Sankosh in the south and east. At confluence point in the rainy season most of the bars and island except few of which are used for settlement are under water. Most of them have been transformed in rainy season.

River channel bankline mainly shift in the right and left direction at confluence point. The confluence of the Raidak and Sankosh river is dynamic. The observation of confluence point river in year 1978-1990 was turned east with distance of 0.877 km, in 1978-2001 was on south-east with 2.845 km whereas 1978-2016 was on south-east direction with 1.826 km. The confluence point is change the location every year.

Acknowledgements

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Archives - 1

NEWS AND NOTES

from The Madras (Indian) Geographical Journal
(Volume XIV, 1939, pp. 91-93)

This issue of the Journal, which commences the 14th volume, opens with the Presidential Address of Mr. N. Subrahmanyam, delivered at the Geography and Geodesy Section of the Indian Science Congress at its 26th Session held at Lahore in January 1939. It presents a synthetic view of India on a geographical basis.

* * * *

An account of his impressions of the Indian Science Congress Session at Lahore with special reference to the Geography Section is published on another page front the pen of a talented visitor.

* * * *

The first meeting of the Association for the year was held on January 2, 1939 at the Meston Training College, when Mr. K. •G. Grubb of the Mildew Settlement, London, a delegate to the World Missionary Conference at Tambaram, delivered an interesting and useful lecture on "*Regional Contrasts in Brazil*," with Miss E. D. Birdseye in the chair.

* * * *

The 13th Annual Meeting of the Association was held at the Meston Training College on February 17, 1939. The 13th Annual Report for the year 1938 (appended to this number) was passed; and the results of the election of office-bearers and members of council were announced (Vide wrapper sheet). Miss E. D. Birdseye is the President of the year.

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An ordinary meeting was then held with Mr. M. Subramania Ayyar in the chair, when Mr. N. Subrahmanyam gave a talk on *''Some Impressions of the Punjab,"* a summary of which is given on another page.

* * * *

A meeting of the Coimbatore Branch of the Association was: held at the Students' Literary Association, Coimbatore on 7th February 1939, when Mr. S. N. Chandrasekhara Iyer (of the Agricultural College) delivered a lecture on *"The Major Crops of Coimbatore District*," with Mr. M.S. Natesa Iyer (of the Government College) in the chair.

* * * *

Another meeting of the Coimbatore Branch was held at the Municipal High School Hall on 25th February 1939, when Sri A. V, Kutti Krishna Menon, M.A., B.L., L.T., gave a lantern lecture on *"Impressions of Japanese Tour",* with Sri Rao Bahabur C. M. Ramachandra Chettiyar in the chair.

* * * *

A Summer School of Geography has been organised under the auspices of the Association to be conducted at the Geography Department of the Teachers College, Saidapet from 17th April to 20th May 1939. Lodging and boarding for those that require it will be provided in the Teachers' College Hostel; and special arrangements are made to accommodate lady teachers. The course will be an intensive one; and will be longer than usual by two weeks.

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The Ninth Geographical Conference of the Association will be held at the Kellett High School on the 8th, 9th and 10th May 1939, along with the Provincial Educational Conference, when papers on various aspects of the Geography of Madras and its Environs will be read. *Prof. Rao Saheb C.S. Srinivasachari* of the Annamalai University will preside.

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Two Refresher Courses in Geography have been organised by the Deputy Inspectors of Schools, North and South Ranges of Madras City, for the benefit of teachers of Aided Elementary Schools in the two ranges at different centres ; and the classes are conducted by Mr. N. Subrahmanyam.

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The Academic Council of the University of Mysore has accepted the proposal to include Geography in the Intermediate Course. It is understood that it will be actually given effect to in 1940.

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It is pleasing to note that degree courses have been recently started in Geography in the University of Calcutta, thereby coming into line with other Northern Indian Universities in this respect. Madras continues to have the degree course in the University Calendar only!

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While the disaster of the Dehra Dun Express near Hazaribagh Road in Bihar on the 12th January 1939 is officially believed to be due to sabotage-removal of rails by some unknown persons the Special Correspondent of the *Labourt Times*, extracts from whose article appear, elsewhere, strikes an original note, by tracing the causes of the disaster to the unsettled condition of earth after the terrible recent earthquake.

*　　*　　*　　*

We are glad to welcome the revival of the defunct Geographical Association of Ceylon, under the name of the *Ceylon, with Geographical Society* Mr. D.N. Wadia, the Government Mineralogist, as President •

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The Annual Conference of the British Geographical Association was held at the London School of Economics in the first week of January 1939 with Sir Thomas Holland as President. A summary of his Address on *"the Geography of Minerals"* and of the symposium on India is published on another page.

Archives - 2

NEWS AND NOTES

from The Madras (Indian) Geographical Journal

(Volume XIV, 1939 pp. 206-209)

A Summer School of Geography was held at the Teachers' College, Saidapet under the auspices of the Association from 17th April to 20th May 1939. It is interesting to note that some of the teachers attending the course came from such distant places as Bombay, Poona, Janjira, Hyderabad and Kottayam. A report of the course is published elsewhere.

* * * *

The Ninth Geographical Conference of the Association was held at Madras on the 8th, 9th and 10th May 1939 at the Leith Hall, Triplicane under the Presidency of Prof. Rao Saheb C.S. Srinivasacharya. His Presidential address on *"the Historical Geography of Madras"* along with some of the papers read at the Conference are published in this issue. The remaining papers will be printed in the next (September) number.

* * * *

Under the joint auspices of the Geographical Conference, the Provincial Educational Conference and the Summer School of Geography, several short and two whole-day excursions were conducted the latter on 6th and 7th May. The first of these major excursions was a circular tour in which the main object was to study some of the geological formations round Madras as well as the sources of its water-supply. The second major excursion on 7th May was to Tirukkalikundram and Mahabalipuram.

* * * *

The Tenth Geographical Conference will be held at Tinnevelly (Tirunelveli) in May 1940, when papers on various aspects of the Geography of that district will be read and discussed. This will complete the study of a contiguous region and fill a gap.

* * * *

The Coimbatore branch of the Association has been continuing to show steady work. Under the auspices of this branch a public lecture was delivered on 3-6-39 at the Y.M.C.A. Hall by Mr. N. Subrahmanyam on *"Geography in Everyday Life"* with Mr. U. Kannappa, District Educational Officer, Coimbatore in the chair.

* * * *

With the reorganised L.T. Course, the syllabus in Geography has also been completely revised, being made at the same time a bit more elaborate and specific. To meet the present situation, in which students are taught the pedagogy of geography without a preliminary training or qualification in subject-matter, special regions are to be prescribed each year, a knowledge of which will be required in answering the questions on padagogy.

* * * *

In the absence of the co-operation of the colleges, which have refrained from providing for the teaching of Geography for which the University has passed regulations, the Diploma is the only other qualification in subject-matter that is available for the prospective teacher of Geography. It is to be regretted that the new regula- tions have failed to prescribe this or even Intermediate Geography as a preliminary qualification for admission to the L.T. course in Geography. So, the anomaly of putting the cart before the horse, or the cart alone without the horse, will continue.

* * * *

In the S.S.L.C. course, A-Group Geography is getting to be more and more popular; and the Examiners' Reports state year after year that there is a steady improvement in the answers of the candidates. But the teacher of Geography can get no credit for it, nor discredit when his work is slack, as the S.S.L.C. authorities have refused to show the History and Geography marks separately, before adding them.

* * * *

At the same time, practically no scope has been given to the high school pupils to specialise in Geography; and only a dozen out of over 400 schools teach C Group Geography. More schools and more teachers of Geography are keen on providing for its teaching; but so long as it is a blind alley, leading to no college studies, they cannot have it. Meantime mutual impoverishment continues merrily-Colleges not supplying to schools teachers who have taken their degree in Geography, and schools not supplying to colleges pupils who have *specialised in Geography* in their S.S.L.C. course. The pessimist puts the question "Can the situation improve in a decade or two?"

* * * *

Intermediate Geography offers a good grounding for economic and geological studies in the degree course ; but due to the intransigence of the colleges, that foundation has not been provided any- where and cannot be availed of.

* * * *

The syllabus in Geography for forms 1 to 3 has recently been revised and modernised. But the training in Geography of the secondary grade teacher who is to handle it remains as it was several years ago. It is hoped that the Secondary grade training syllabus will soon be brought into line with the L.T. syllabus.

* * * *

The Elementary School has not yet been touched at all in the matter of Geography teaching. While deprecating the introduction of an elaborate and uniform syllabus at that stage, we would strongly urge the need for some guidance being given to the elementary school teacher which would help him to teach some good Geography to the children.

* * * *

While such is the position of Geography and Geography teaching in schools and colleges, the *teacher* of Geography does not seem to have a place or status in several schools; and anybody is thought to be good enough for handling the subject. This view is not surprising as the Educational authorities do not insist upon the possession of the requisite qualification.

* * * *

The 27th session of the Indian Science Congress will be held at Madras from January 2 to 8, 1940. Dr. S.P. Chatterjee of Calcutta University has been elected President, Mr. George Kuriyan the Recorder, and Mr. B.M. Thirunaranan the Local Secretary of the

Geography and Geodesy section for this session. It is hoped that several good papers will be contributed to this section, which was confirmed as a separate one only last year.

* * * *

We are glad to record that the Lecturers in Geography at Lahore have organised a University Branch of the Punjab Geographical Association with Miss C.L.M. Geary as President and Prof. E. T. Dean as secretary. The following are among the papers read in their monthly meetings:-

Poona and its Surroundings (Miss C. L. M. Geary) ; Pre- sent Political Situation in Central Europe (Mr. A. N. Kapur) ; Social Customs of some of the Tribes of South Africa (Mr. Farhat Ullah Khan); and the Damian beyond the braided Indus (Prof. E.T. Dean).

* * * *

The British Association for the Advancement of Science will hold its next annual session at Dundee August 30-September 6, 1939. The President of the E. Section (Geography) is Mr. A. Steevens, Head of the Department of Geography at Glasgow, and its Recorder Mr. J.N.L. Baker of the School of Geography, Oxford.

* * * *

The World Federation of Education at Associations will be meeting in Rio de Janeiro in August 6-11, 1939. The agenda of the Geography section of this Conference includes :-

(a) Methods of establishing closer contacts between geography teachers in different countries.
(b) Sources of Geographical pictures, etc.
(c) Means of keeping teachers' knowledge of Geography up-to-date.

* * * *

We welcome with pleasure the *Geo-Press Service*, which illustrates rapidly allimportant political, economic and social events, natural phenomena and the leading explorations, with clear and comprehensive maps accompanied by adequate comments; and is edited by a staff of expert geographers. In the present rapidly shifting times when far reaching events are of daily occurrence, the Geo-Press Service, Geneva fills a gap.

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Archives - 3

NEWS AND NOTES

from The Madras (Indian) Geographical Journal

(Volume XIV, 1939, pp. 307-310)

Three meetings of the Association were held during the quarter in which three lectures were arranged for teachers of Geography. On 29-7-'39, Miss. E.D. Birdseye gave a talk on *"Asking Questions in Geography"*; on 19-8-'39, Mr. N. Subrahmanyam lectured on *"Map Work in Teaching Geography"*; and on 9-9-'39, Mrs. P.S. Sundara Raj spoke on *"The Use of Pictures in Teaching Geography."*

* * * *

The new Elementary School Syllabus in Geography recently issued by the Department of Education has been found to be unsatisfactory; and protests have been raised against its introduction in several quarters. We have no doubt that the Director of Public Instruction, to whose notice the matter has been brought, will take early steps to get it suitably revised .

* * * *

There appears to be a general feeling that the S.S.L.C. Geography is in urgent need of overhauling; and we could point to some of its objectionable features, such as unequal mating with History, with no means of knowing the candidate's performance in the Public Examination, with only an hour's paper to meet which difficulty short tests have been introduced, study of pure regional geography only to the neglect of General Principles (Part IV of the original syllabus being omitted); and now comes the latest reform in the shape of the portion for the public examination being confined to Eurasia only to the neglect of the other continents (which form a 'B-Group' within the subject) .In short the 1929 scheme and syllabus have by successive tinkerings become in 1939 very lopsided indeed. Probably it is not opportune to ask for or attempt any change now, as the Reorganisation of Secondary Education is now on the anvil and everything will go into the melting pot.

* * * *

It is pleasing to note that at long last the Madras University *Diploma Course in Geography* has come to be popular, as measured by the strength of the class this year. It is hoped that it will continue to be so at least until such time that Colleges provide for teaching Geography in the Degree Course. The Geography Departments of Training Colleges have now a better chance of getting students qualified in the subject, and schools a better chance of having fully qualified teachers of Geography.

* * * *

As few Andhra students have so far taken advantage of the training afforded by the University Diploma Course in Madras, it is desirable that the *Andhra University* institutes its own Diploma Course so that Andhra graduates seeking admission to the Geography Department of the Training College, Rajahmundry, may get the requisite preliminary qualification in subject-matter before undergoing the teachers' training.

* * * *

We are glad to note that the *University of Mysore* is taking further steps to implement its former resolution to introduce Geography by bringing into their academic bodies draft schemes for Intermediate, B.A., and B.Sc., Courses with the intention of starting it at the Intermediate stage in the Academic year 1940-41 and carrying it right along.

* * * *

Arrangements for holding the *27th Session of the Indian Science Congress* at Madras in January 1940 are proceeding apace; and the Executive Committee and the various sub-committees of the Reception Committee are busy working out the preliminaries. Among the longer excursions to be organised in connection with the Congress are those to Mahabalipuram, Gingee, Mettur Dam and Madura, besides short local ones.

* * * *

The proposal for an *All-India Geographical Society*, mooted first at the Calcutta Session of the Science Congress in 1938 has not so far materialised itself; and there has been little response from the several provinces and states, the chief reason being probably the absence of strong Geography Departments in most of the Indian Universities. It is hoped that in 'the coming session of the Congress at Madras, some progress may be made towards the realisation of the proposal.

* * * *

Closely connected with the previous question is the urgent need for an *All-India Geographical Journal*, which can well be the organ of such an All-India organisation. Geographical research is yet in its infancy in this country; and it is only through societies and magazines that a proper fillip can be given to it.

* * * *

The *XVth All-India Educational Conference* will be held at Lucknow (and not at Patna as originally decided), on December 27-30, 1939. *Dr. Sir S. Radhakrishnan* will presioe over the Conference. An All-India Educational Exhibition will be held along with the Conference in connection with which excursions will also be arranged.

* * * *

The Report of the *Patna College Geographical Society* for 1937-39 shows a record of useful activities carried on under the direction of its energetic President, Prof. Z. Ahsan. Among the extraordinary meetings of the year is an interesting debate reported in it on *"Flood Control in Bihar",* presided over by Mr. J.B. Sen, Parliamentary Secretary to the Government of Bihar.

* * * *

While some parts of the country like Bihar and Bengal have problems connected with flood control, Madras in common with certain other drier parts of India have problems of their own, suffering from the vagaries of the monsoon. The water-supply of Madras and certain other towns is threatened; while famine conditions prevail in the country-side .

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The principal map production office of the Survey of India, the *Photo-Litho Office*, whose machines pull out annually more than 3,000,000 impressions valued at over Rs . 3,00,000, celebrates its jubilee this month (September). Of the original contributions of this office, mention may be made of the direct zinc printing process, now known throughout the world as the *"Vandyke Process",* which was evolved at this office, and is named after the late Mr. F.R. Vandyke, Manager of its Lithographic Branch, who was responsible for the discovery.

* * * *

A grim war has broken out in Europe, whose magnitude, developments and repercussions are too early now to gauge. The map of the Continent is being re-drawn, though no one can foresee at present the shape that it will finally assume. Various and far-reaching will be the effects of this war in most countries of the world .

* * * *

Says *The Times of India*, in a recent issue:- "From India's point of view, there is one great difference between this war and the last. In 1914 the industrialization of the country was in its infancy and the cutting off of European supplies of manufactured articles meant complete dislocation of our economic life.

* * * *

"To-day, however, conditions are different. Indian industries have made vast strides in the past two decades. To mention only a few staples; India is now virtually self -sufficient in such important commodities as cement, sugar, soap, matches and shoes. She has also considerably expanded her production of other essential articles: iron and steel, cotton textiles, paper, chemicals, rubber products (tyres, etc.), the simpler types of electrical equipment (bulbs, switches and fans), and so on.

* * * *

"The result is Indian economy has not been gravely dislocated by the war. On the contrary, if she can manage to buy the necessary machinery and plant from the United States, there is every chance of a number of new secondary industries being established in the near future **** Here is a big opportunity for Indian enterprise".

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Archives - 4

NEWS AND NOTES

from The Madras (Indian) Geographical Journal

(Volume XIV, 1939 pp. 440-442)

Three meetings of the Association were held in the last quarter of the year (October- December); and in these the series of talks to teachers of geography, carried on in the previous quarter, were continued and completed. On 14-10-'39 *Mr. B. Clutterbuck* spoke on *'the Use of Diagrams in Teaching Geography*'. On 28-10-39 *Mr. George Kuriyan* delivered a lecture, illustrated with slides, on '*the Far Eastern Problem*.' On 25-11-39 Miss J. M. Gerrard completed the series with a talk to teachers on '*the Lesson Plan*.'

* * * *

An excursion by bus was organised to Vellore on 16th and 17th December 1939 and conducted by the Secretary, visiting *en route* the Victory Memorial Blind School at Poonamallee, the shalebeds at Sriperumbudur and Conjeeveram. On the afternoon of the first day the historic fort at Vellore was visited and the Vellore hill (1,670 feet) climbed. The following day the party climbed Kailasgarh (2,741 feet) , 5 miles from Vellore, and returned to Madras the same night .

* * * *

The Tenth Geographical Conference of the Association will be held at Ambasamudram in the Tinnevelly District in May 1940, when papers on various aspects of the Geography of the District will be read and discussed. Further details regarding the Conference will be announced in due course.

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Mr. P.G. Dowie of the Geological Department, Presidency College had contributed a paper to the Ninth Geographical Conference at Madras on *'The Physical Aspects and Geology of the Neighbourhood of Madras*,' which has been included in this issue. In this paper he has brought together a good deal of material found scattered in the Memoirs of the Geological Survey of India and presented them in an interesting and exhaustive manner from his intimate personal knowledge of the region.

* * * *

Prof . M.B. Pithawalla of Karachi has revised in this issue in some details his plan for a division of India into Physiographic Regions presented to the Lahore session of the Indian Science Con- gress and published in the previous issue of the journal.

* * * *

We welcome with pleasure *Mr. Nafis Ahmed*, M.Sc., Lecturer in Geography, Muslim University, Aligarh, as a contributor to our journal. His paper on *'Muslim Contributions to Geography*' published in this issue, will be found interesting. It is understood that Mr. Ahmed has been appointed Profesor of Geography in the Islamiah College, Calcutta, and that he will be leaving Aligarh shortly.

* * * *

The 27th Session of the Indian Science Congress will be held in the Medical College, Madras from the 2nd to 8th January 1940 under the presidency of Prof. B. Sahni, F.R.S. The Geography and Geodesy Section of the Congress will be presided over by Dr. Shibaprasad Chatterjee of Calcutta University, whose address will deal with '*the Piace of Geography in National Planning.'*

* * * *

The main item of business in the special meeting of the General Committee of the Congress is the re-grouping of the Sections; and among the proposals is one to transfer Geodesy to Mathematics section, to be called the section of Mathematics, Astronomy, Statisics and Geodesy, and another to amalgamate Geography and Geology sections into one as it was before the Jubilee Session at Calcutta in 1938.

* * * *

The British Association met in Dundee on August 30, 1939; and in section E (Geography) about one third of the papers had been read when on September 1st the Session was interrupted upon receipt of the news of the German invasion of Poland.

* * * *

"The Presidential Address to Section E, delivered on September 1, by Mr. A. Steevens, contained a lucid examination of the most conspicuous geographical concept whose enunciation is associated with British Geographical thought, the concept connected with the phrase *Natural Geographical Region*, especially in so far as it is exemplified in North America, Russia and Europe. It appears to Mr. Steevens that the unity of the natural geographical region is dependent in large measure upon organisation, in the shape particularly of communications,............ In Western Europe the increased efficiency of communication and recently the peculiarly intimate cohesion organised by the radio, have so far expanded the area throughout which a perfect neighbourliness may be found that it is possible nowadays to define the European nation-state as 'a community occupying a natural geographical region as its immediate environment, because it is a natural growth limited by its Geographical circumstances.'

With the break-up of the session, progress with plans for a British National Atlas proposed by Prof. E.G.R. Taylor at the Cambridge Session last year, had now to be delayed indefinitely.

Few of the social functions and none of the longer excursions had taken place when the session abruptly closed."

- Scottish Geographical Magazine, Sept. 1939

* * * *

The invasion of Finland, the latest instance of unprovoked aggression by a mighty power on a small state and the heroic resistance of the latter against odds should ultimately lead through untold suffering to a new world order in which freedom and safety can be vouchsafed for all peoples of the world, big or small, in Europe or elsewhere, whether through the League or through a new federal union.

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THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai - 600 025

UG & PG Results of 8th Talent Test - 2018

THE IGS FOUNDER PROF. N. SUBRAHMANYAM AWARD

With the Cash Prize of Rs. 10,000/-

(First Prize: Rs. 5,000/-, Second Prize: Rs. 3,000/- & Third Prize: Rs.2,000)

UG Results of 8th Talent Test - 2018				
Register Number	**Name**	**Institute**	**Rank**	**Photo**
150829	Ramesharavind P.	Department. of Geography, Government Arts College (Autonomous), Karur - 639 005	**1**	
15BGE115	Harikrishnan T.	Department of Geography, Government Arts College (Autonomous), Coimbatore - 641 018	**2**	
1522Q0021	Gayathri C.	Department of Geography, Bharathiar University Arts and Science College, Gudalur - 643 212	**3**	

PROF. A. RAMESH AWARD

With the Cash Prize of Rs. 15,000/-

(First Prize: Rs. 7,000/-, Second Prize: Rs. 5,000/- & Third Prize: Rs.3,000)

PG Results of 8th Talent Test - 2018				
Register Number	**Name**	**Institute**	**Rank**	**Photo**
33216409	Sudeshaa Saha	Department of Geography, University of Madras, Chennai– 600 005	**1**	
162GE004	Helan Jenifer S.	Department of Geography, Nirmala College for Women (Autonomous), Coimbatore - 641 018	**2**	
16MAG213	Benedict Rosario C.	Department of Geography, Government Arts College (Autonomous), Coimbatore – 641 018	**3**	

Please Note:

1) The Winners are requested to send their passport size photograph, postal address & contact phone number by email (kkumargeo@gmail.com / geobalas@gmail.com)
2) The Winners are requested to make arrangements to attend the award ceremony function being arranged in the *National Seminar* on Geospatial Technology for Land Use Analysis organised at Department of Geography, Bharathidasan University, Tiruchirappalli on 02 March, 2018 at 2:00 p.m.
3) For any queries kindly contact the Coordinator Dr. K. Kumaraswamy (9442157347) / Co-coordinators Dr. G. Bhaskaran (9444414688) or Mr. K. Balasubramani (9944060319).

Name of the Universities and Colleges Participated in the 8th IGS Talent Test Examination Conducted on 02/ 03/ 2018

1) Department of Geography, University of Madras, Chepauk, Chennai – 600 005.
2) Department of Geography, Madurai Kamaraj University, Madurai - 625 021.
3) Department of Geography, Bharathidasan University, Tiruchirappalli - 620 024.
4) Department of Environmental Remote Sensing and Cartography, Madurai Kamaraj University, Madurai - 625 021.
5) Department of Geography, Presidency College (Autonomous), Chennai – 600 005.
6) Department of Geography, Queen Mary's College (Autonomous), Chennai - 600 004.
7) Department of Geography, Bharathi Women's College (Autonomous), 85, Prakasam Salai, Chennai - 600 108.
8) Department of Geography, Tourism and Travel Management, Madras Christian College (Autonomous), Tambaram, Chennai - 600 059.
9) Department of Geography, Government Arts College (Autonomous), Salem – 636 007.
10) Department of Geography, Arignar Anna Government Arts College, Namakkal – 637 002.
11) Department of Geography, Government Arts College (Autonomous), Coimbatore - 641 018.
12) Department of Geography, Nirmala College for Women (Autonomous), Coimbatore – 641 018.
13) Department of Geography, Bharathiar University Arts & Science College, Amaikulam, Puliam Parai (P.O.), Gudalur - 643 212.
14) Department of Geography, Government Arts College (Autonomous), Karur – 639 005.
15) Department of Geography, Periyar E.V.R. College (Autonomous), Tiruchirappalli – 620 023.
16) Department of Geography, Government Arts College, Thiruverumbur, Tiruchirappalli – 620 022.
17) Department of Geography, Kundavai Nachiar Government Arts College for Women (Autonomous), Thanjavur - 613 007.
18) Department of Geography, A.V.V.M. Sri Pushpam College (Autonomous), Poondi, Thanjavur - 613 503.
19) Department of Geography, Government Arts College (Autonomous), Kumbakonam - 612 002.
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GEO-SPATIAL TECHNIQUES TO UNDERSTAND FLOOD HAZARD AND ITS IMPACT ASSESSMENT IN LOKRAI MOUZA, DARRANG DISTRICT, ASSAM

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Abstract

Floods are the most common natural hazards that can affect people, infrastructure and natural environment to a great extent. According to an investigation made by World Meteorological Organization (WMO) on the disasters caused by major types of natural hazards all over the world, floods occupy third place after cyclones and earthquakes ferocity by ranking (Pandharinath, et al., 2004). Floods cause large-scale damages to our socio-economic life as well as to the natural environment. Likewise, flood is a perennial problem and all kinds of common flood damages prevail in the study area of Lokrai Mouza, Darrang district of Assam. The study covers a wide range of database generated from both primary and secondary sources.The present study involves the use of survey of India topographical sheet (1967-68), satellite image (IRS-P6 LISS III) and other secondary data were used for the preparation of land use/land cover map and different kinds of analysis. The result shows that the agricultural practises as well as the socio-economic life of many villages in the study area are in highly vulnerable position due to havoc of flood. The study aims to find the frequency of flood, assess the LULC change, cause and impact of flood on public health and socio-economic life. It is expected that the findings of the study will help in proper planning and management for minimizing the damage of the flood in the study area.

Keywords: Flood, Hazard, Geospatial, Vulnerable, Management

Introduction

Floods are considered the most significant natural disaster affecting from the perception of their frequency, financial cost and most importantly the impact on the population and the disruption to socio-economic activities. The term 'flood' generally means the river floods which is an unusually high stage of water in a river. Flood is a perennial problem for the state of Assam and it is not an exception in case of Darrang district too. Floods cause large-scale damages to the socio-economic life of the people as well as to the ecology and environment of the Darrang District to a certain extent. The study area i.e., Lokrai Mouza of Darrang district of Assam is a low lying are mostly dominated human habitation and paddy cultivation. The River Nanoi and its tributaries, which emerge from Eastern Himalaya, create flood havoc in study area annually specially during monsoon period. These rivers are over loaded due to heavy and continuous rain spells lasting for several days together. As a result, the river could not able to carry the excessive water and thus the nearby areas get inundated mainly because of breaching of embankments and overflow of the rivers. In this context, Remote Sensing is very reliable and expeditious techniques for assessment and mapping of flooded areas. The identification and mapping of flood prone areas are valuable for risk reduction. The present study introduces the frequency of flood, assess the LULC pattern, cause and impact of flood on public health and socio-economic life. It is expected that the findings of the study will help in proper planning and management for minimizing the damage of the flood in the study area. The broad objectives of this study are to assess the LULC pattern, to understand the flow characteristics and to examine the flooding scenario and its cause and effect relationship of the Nanoi river.

Study Area

The study area i.e., Lokrai Mouza lies in the western most part of the Darrang District in Assam. It extends from $26^{o}\,21'$ N to $26^{o}\,24'$ N latitudes and $91^{o}50'$ E to $91^{o}52'30''$ E longitudes (Figure 1). The study area covers a total area of 13.6 km^2. There are five villages under the study area of Lokrai Mouza, Darrang District viz., Dhekipara, Goroimara, Basachuba, Solpam, Punia and Bodiasicha. Physiographically, the area belongs to a single unit with the rest part of the north bank plain of the Brahmaputra. It is almost a alluvial plain dotted with a few lowly elevated hills scattered in the south western corner along the bank of the Brahmaputra, extending from Bhehenichapari in the south to Salmara in the north. The Climate plays an important role in agricultural setting and arrangement of crop season in study area. There is heavy rainfall in summer and continuous drought in winter. The winter monsoon is mostly dry, but the summer monsoon is hot and humid. The summer monsoon rainfall determines the water supply round the year and it effects in the agricultural production of the district as well as in the study area. Accordingly, two crops – *kharif* and *rabi* are closely related to the summer and the winter monsoon seasons respectively.

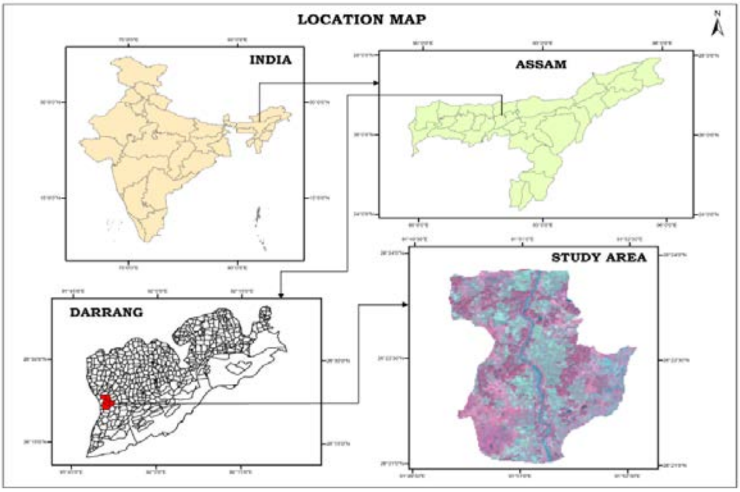

Fig. 1. Location of the Study Area

Methodology

The present study is mainly based on primary data in conjunction with secondary data. The spatial and non-spatial data have been widely used in remote sensing and GIS technology. The base map of the study area have been prepared using Survey of India topographical sheet at 1:50,000 scale. Satellite imagery of IRS-P6 LISS III, 2015 have been used for the preparation of other thematic maps like LULC map, flood inundation map etc. River stage discharge data have been used for flood frequency pattern in the study area. A buffer map using buffer tool in GIS environment have been used to delineate zones of influence and characterization of the flood hazard. The questionnaire has been designed as per the objectives set for the study and simple random sampling technique has been followed during data collection. Data regarding impact of flood on public health and socio-economic life have been collected from the Revenue and Disaster Management Department, Darrang, Govt. of Assam and the nearby villagers.

Results and Discussion

Land use and Land cover Scenario

Knowledge of land use and land cover is important for most of the planning and management activities (Lillesand and Keifer, 1994). Knowledge of changes in land cover is becoming far more important from both ecological and economical point of view (Lucas et al, 1990). The increasing human population in the tropics combined with changing socio-economic condition, changing policies and the local impacts of globalization, promote rapid changes in land use and land cover. LULC mapping through digital as well as visual interpretation technique using remote sensing technology gives us a clear view of the landscape. Keeping in view of this, the land use/ land cover polygons as seen in the satellite data of the study area has been delineated on screen using NRSA standard classification system and a preliminary interpretation map has been prepared. All together six land use classes have been identified viz: Agriculture, River, Mixed built-up land, Siltation area, Vegetation and Wetland. For the identification, IRS P6 LISS III data have been used for the year 2015. It has been reported from the field study that previously the study area has been mostly occupied by agricultural land such as paddy fields, crop plantation etc. But the flood occurred of 2014 has changed the land use pattern of the study area significantly. The statistics shows that most of the area belongs to agricultural land use category i.e., 51 % of the total area followed by vegetation cover occupying 19 %, Mix built up land accounting for 13 %, wetland having 12 % and the category like river and siltation area also occupies a smaller areal coverage. (Figure 2 and Figure 3; Table 1) One of the important findings of this study is though the agricultural category occupies a larger areal extension, but the productivity has gone down to a pathetic condition after the flood in 2014. It is mainly due to the siltation in the agricultural fields, which badly affects the productivity.

Table 1. Land use Category of Study Area - Lokrai Mouza, 2015

Land Use Category	Area in 2015 (in Ha.)	Area in %
Agriculture	1,76,01,767	51%
River	6,31,578	2%
Mixed built-up land	45,12,526	13%
Siltation	10,81,870	3%
Vegetation	65,12,527	19%
Wetland	39,62,779	12%

Source: Computed from IRS-P6 LISS III satellite data of 2015

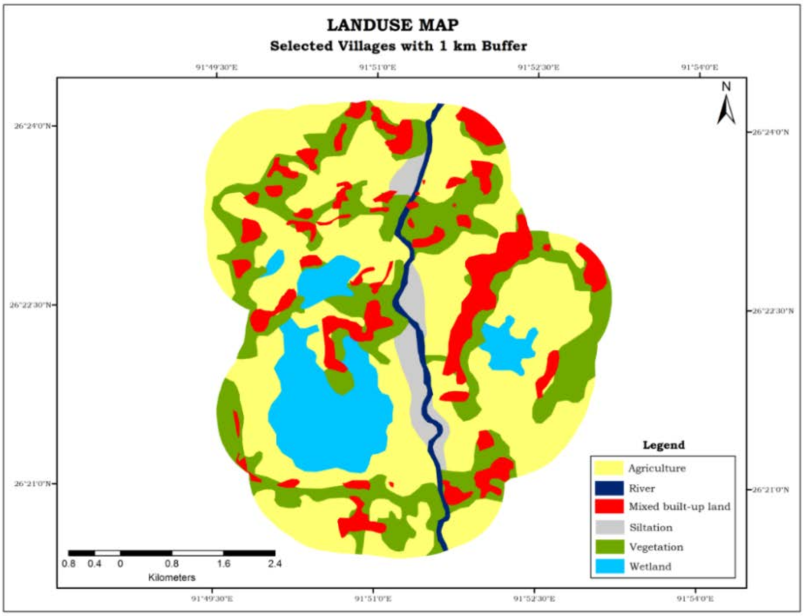

Fig. 2. LULC of the Study Area, 2015

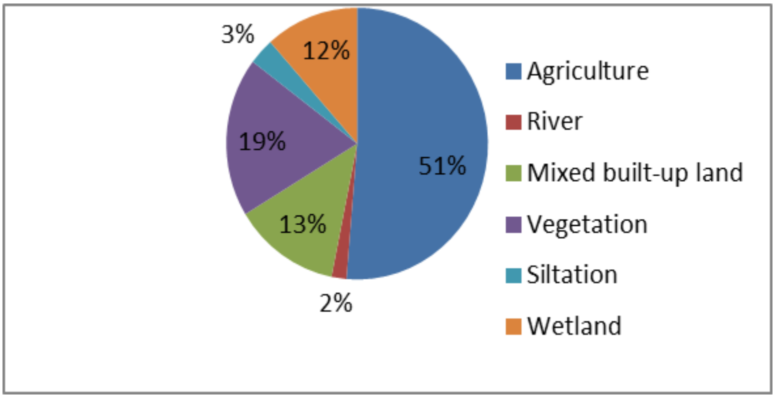

Fig. 3. Land use category of Study Area (Lokrai Mouza, 2015)

Intensity and Flow Characteristics of Flood

The Flood Scene in Study Area of Lokrai Mouza, Darrang District

Assam floods are triggered by heavy rainfall at the end of June in neighbouring Bhutan and Arunachal hills through Brahmaputra River and its tributaries. Flood waters have caused havoc in the study area in the year 2014 between 23rd to 30th September. The embankment of Nanoi River was breached at Punia and Duaripara thereby submerging the villages like Gopalpur, Lokrai, Basachuba, Duaripara, Punia, Goroimara, Solpam, Badiasicha, Toragaonares etc. It is not only in the 2014, but also the floods of 2010 and 2012 have brought a remarkable change in the whole district in general and in the study area. The impact of flood during those years can be well understand by the mean monthly stage discharge hydrographs of the particular years.

Flood Scene of2010

The district faced unprecedented and sudden flood in the 1st week of August 2010 caused due to heavy rains in the catchments of the river Nanoi. The damages were mainly caused by the overflow of Nanoi Rivers and beaching in embankments. There was severe erosion on the left bank embankment near Punia and Goroimara village. A vast area under the catchments of Nanoi Rivers was under water in that flood. The average discharge and Water Level (WL) in the river Nanoi at National Highway (NH) crossing were recorded as 17.98 m^3 and 50.91 m respectively during that flood (Figure 4)

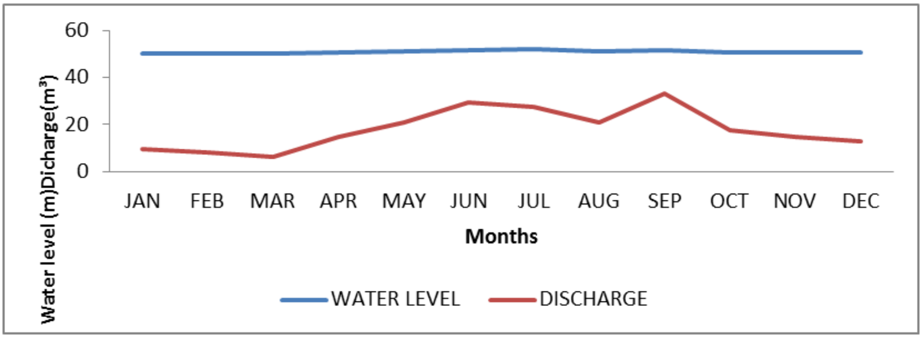

Fig. 4. Stage and Discharge Hydrograph of Nanoi River, N. T. Road Crossing Site (2010)

Flood Scene of 2012

In the year 2012, two waves of floods badly affected the district in the month of August and September. The flood wave came in September caused extensive damage to the standing crops. This delayed flood caused severe damage to the standing crops accounting about 80% of the total flood loss in the district.There occurred breaches in embankments of Nanoi and Bornoi rivers at many places causing damages of protected areas. The river Nanoi eroded parts of Punia, South Dhekipara, Basachuba, Solpam, Dumunichowki, Badiasicha villages severely, which caused extensive damages to house and other properties. Fertile agriculture fields were converted into barren land in many places due to sand deposition. Road communication was snapped all over the district including the study area for which it became impossible to send food-stuff to the remote areas. . The average discharge and Water Level (WL) in the river Nanoi at National Highway (NH.) crossing were recorded as 14.19 m^3 and 50.93 m respectively (Figure 5).

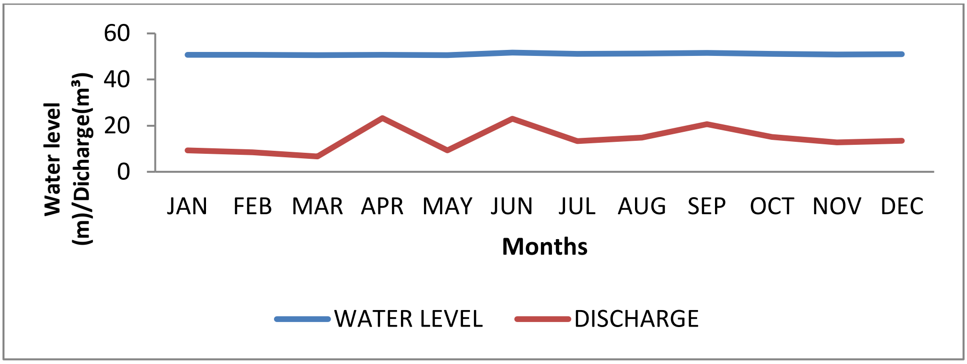

Fig. 5. Stage and Discharge Hydrograph of Nanoi River, N. T. Road Crossing Site (2012)

Flood Scene of 2014

The District faced unprecedented and sudden flood in the last week of September 2014 caused due to heavy rains in the catchments of the river Nanoi. The damages were mainly caused by the overflow of Nanoi Rivers and beaching in embankments. There was severe erosion on the right bank embankment near South Dhekipara and Solpam village. A vast area under the catchments of Nanoi Rivers was under water. Fertile agriculture fields were converted into fallow land in many places due to sand deposition.The average discharge and Water Level (WL) in the river Nanoi at National Highway (NH.) crossing were recorded as 13.85 m^3 and 51.13 m respectively (Fig. 6).In addition to that the flood inundation map shows that all the villages have been sub-mergered under the water during the period of flood (Figure 7)

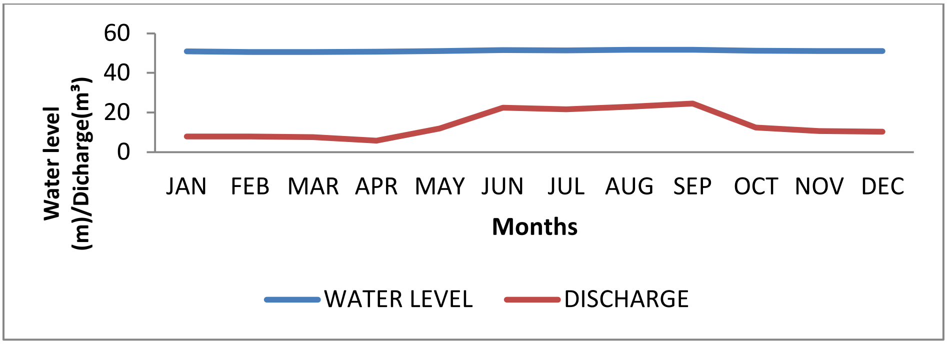

Fig. 6. Stage and Discharge hydrograph of Nanoi River, N. T. Road Crossing Site (2014)

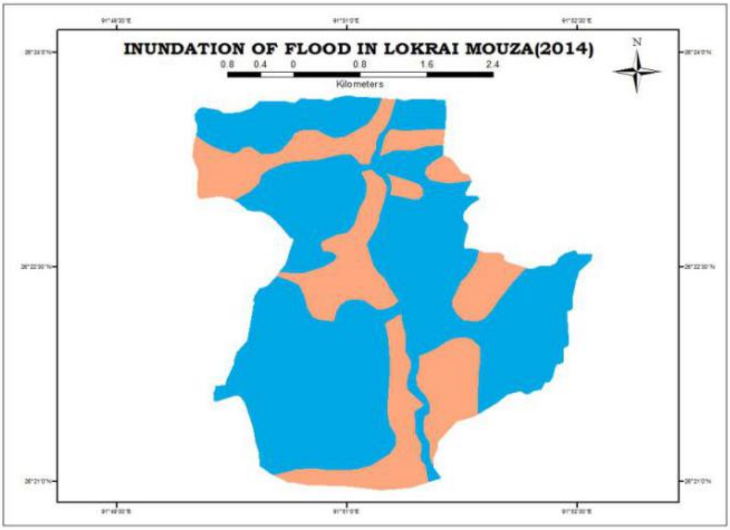

Fig. 7. Flood Inundation in Lokrai Mouza, September 2014

Flood Hazard Zonation

The buffer analysis was used to characterize flood vulnerability for the study area. It is totally based on the field visit and the perception of respondents during the field study. As the study area mostly belongs to low lying alluvial plain, that is why, the immediate nearby area of the river gets highly prone severe flood. On that basis, buffer zones have been created based on their proximity to River Nanoi using ArcGIS software at specified distances of 500m, 1,000m and 1,500m for the identification of areas that are highly prone, moderately prone and less prone to flood hazards (Figure 8)

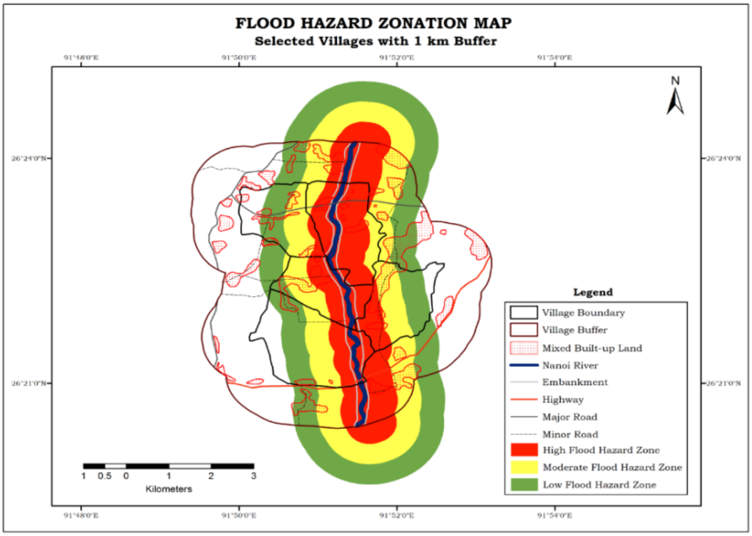

Fig. 8. Flood Hazard Zonation Map of the Study Area

Causes of Floods in Study Area

It has been observed from study that the basic causes of the occurrence of floods in the study area are the same as that of the entire valley, where floods are the combined results of natural as well as anthropogenic factors. During the months of monsoon (June to September) there occurs excessive rainfall over the study area as well as over the neighbouring hill slopes of the Bhutan Himalaya and these rivers carry huge amount of sediments to the valley region and deposited on the river-beds and in their flood plains. The anthropogenic factors mainly include deforestation in the upstream, encroachment of floodplains for various kinds of human activities, unscientific and improper construction of embankments and other industrial activities etc. All these factors seem to have significant impacts on the fluvial regime of the rivers Nanoi and their tributaries which in turn affects the study area.

Impact and Assessment of Flood on Study Area

It is well examined from the above analysis that flood being one of the most serious problems, cause huge loss of property and other kinds of belongings of people in the study area. All five villages like Dhekipara, Basachuba, Solpam, Punia and Bodiasicha etc have been inundated by the flood frequently from the excessive water from Nonoi River and its tributaries and the study area have been highly affected. (Table 2).

It is found that the extensive damage of land, crops and property occurs in the study area. From the field observation and analysis of secondary information it is found that floods, bank erosion and sediment deposition have adversely affected the agricultural land in the study area. Though 80 % of people of Lokrai Mouza are engaged in agricultural activities, but unfortunately the tillers of the land in the district as well as in the study area suffer from heavy losses of their standing crops during the heavy flood periods. Again, the lands owned by the peasants near the river banks which are more to most vulnerable to erosion are affected by floods very frequently. Because of such flood events crops and croplands are seriously damaged every year. Apart from this the transport and communication has been also adversely affected by the occurrence of flood. Most of the metal and village roads have been broken as they have been submerged under water continuously for more than ten days. It is also observed that many health diseases have been occurred after the flood event.

Table-2: Flood Affected Areas and Damages of the Study Area in 2014

Sl. No	**Damage Category**	**Total Quantity** (Sq. Km)
1.	Area Affected	13.63
2.	Villages Affected	05
3.	Crop Area Affected (In Ha)	575 Ha.
4.	Population Affected	4,928
5.	Animals Affected	2,450
6.	Human Life Lost	02
7.	House Damages	73

Source: Revenue and Relief Branch, Darrang, Govt. of Assam

Conclusion

The paper elucidates that the flood hazard and its impact can be well understood by using Geospatial technology in conjunction with field visit. It is observed that the River Nanoi and tributaries, which emerge from Eastern Himalaya, create flood havocs in study area during monsoon period, these rivers are over loaded due to heavy and continuous rain spells lasting for several days together. As a result, the study area faced a tremendous affect from the flood resulting in loss and damage of property, cropland and even life too. Therefore, considering the present trend of increasing flood occurrence, this kind of near real time study of flood monitoring, mapping and damage assessment could be useful to the planners and other respective departments of state and central governments.

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APPLYING GEOSPATIAL TECHNIQUES FOR MAPPING COASTAL RESOURCES OF MAHATMA GANDHI MARINE NATIONAL PARK OF ANDAMAN AND NICOBAR ISLANDS

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Abstract

Coastal resources are diverse habitats that make up the coastal ecosystems like mangroves, coral reefs and sandy beaches provides us with invaluable benefits to the environment, human and marine life. Coastal areas are facing threats from both natural and anthropogenic disturbances such as coastal erosion, sea level variations, tourism and many other activities. Remote sensing and GIS techniques are very much useful to provide practical and cost-efficient solutions and information for environmental protection and management. The present study was made to map and to delineate the areal distribution, and percentage change occurred to coastal resources and shoreline in 2006, 2010, 2014 in Mahatma Gandhi marine national Park (MGNP), Wandoor island in Andaman and Nicobar Islands using satellite data sets of LISS -III, Landsat 5 TM and Landsat 8 OLI_TIRS. MGMNP depicts a unique combination of forest and marine ecosystems in the form of tropical evergreen and moist deciduous forests occurring on the islands. The result reveals that there is a continuous decrease in the area of mangrove forest along with constant improvement in the health of corals. A careful assessment of areal distribution and percentage change in area of the coastal resources that occurred in the coastal ecosystems of marine national park were identified, and few suggestions were given for the conservation and management of these rich and productive resources.

Keywords: Landsat Data**,** Remote Sensing, GIS, Coastal Resources, Ecosystem, Andaman and Nicobar Islands

Introduction

Coastal resources refer to the natural resources in the coastal area, including land, forests, coastal waters and wetlands, sand minerals, hydrocarbons and other living coastal organisms (Walters, 1998). Coastal zones are among the world's most diverse and productive environments (Dharanirajan et al., 2010). Coastal areas are endowed with a wide range of coastal ecosystems like mangroves, coral reefs, seagrass, sandy beaches etc. (Ramchandran, 2003). In many areas, the coastal topography formed over the period, which provides significant protection from natural calamities like cyclones and tsunamis. However, these natural barriers could diminish or even be lost if they are not managed properly. Conservation and management of the coastal features require knowledge about the geomorphic condition of existing coastal resources and the associated anthropogenic activities. The critical resources along the coast such as mangroves, seagrass beds and coral reefs are supporting ecosystems and livelihoods in coastal areas.

Remote sensing and GIS techniques have been widely used in mapping and monitoring these coastal ecosystems. It is useful to monitor these ecosystems in a nearreal-time manner, and suitable management measures can be derived (Dharanirajan et al., 2010). Remote sensing and geographical information system (GIS) have been widely used as another option than conventional method for monitoring the shoreline position (Ryuet et al., 2002; Yamano et al., 2006). Detection of coastal land cover change, multi-temporal data of the Landsat TM were found to be more suitable for the identification of deforested areas, mapping the regeneration/ regrowth of forest are helpful in tracing major changes in the land over an area.In this context, the Indian Remote Sensing satellite sensor LISS- III and Landsat 8 having spatial resolutions of 23.5 and 30m respectively could be better for the coastal resource mapping.

In Andaman and Nicobar group of islands, entry to many of the islands are restricted, and the use of tools like remote sensing GIS plays an important role in getting the repetitive datasets of those regions.

Study Area

The Andaman and Nicobar group of islands are scattered in the Bay of Bengal. Andaman and Nicobar archipelago consisting of over 572 islands and islets lie in the lap of Bay of Bengal situated between latitude: $6^0$45'- $13^0$41'N and longitude: $92^0$12'- $93^0$57'E to the eastern side of India's mainland. The islands lie approximately 1200 km from the mainland of India.

The Mahatma Gandhi Marine National Park (MGMNP), Wandoor, located between $11^0$22'06 to 11^0 36'34" N latitude and 92^0 30'00" to 92^0 40'33" E longitude in the Bay of Bengal (Figure 1). It is situated 29 km away from Port Blair by covering a total area of 281.5 sq. Km. It is the first Marine National Park of Andaman & Nicobar Islands which is situatedon the south-west coast of the South-Andaman Island. This park was created on 24^{th} May 1983 under Wildlife Protection Act of 1972 with an aim to protect the marine life in the islands such as corals and nesting sea turtles prevalent in the area (Ravichandran, 2006). This park is surrounded by 14 islands, viz., Alexandra, Belle, Boat, Chester, Grub, Hobday, Jolly Buoy, Malay, Pluto, Redskin, Riflemen, Snob, Tarmugli, and Twins . There are some shallow sheltered creeks in the northwest portion of the park, while in the eastern and southern parts consist of moderately deep ocean sea. It depicts a unique combination of forest and marine ecosystems in the form of dense tropical wet evergreen, moist deciduous and littoral forests occurring on the islands.

There was a study made on the coastal areas and have classified these areas as the areas which are endowed with a wide range of coastal ecosystem like mangroves, coral reefs, sea grasses, lagoons etc. The study has described about the various areas in India, which is rich in mangroves and corals. In Tamil Nadu, satellite data for the year 1897 and

1994 were acquiredand the result shows that there is a loss of 260 ha. area of mangrove forest during the same period. There was a fast clearing of healthy mangrove areas in Mahanadi coast has been clearly demarcated using LISS-III data. Another satellite data derived from LISS-III was used for the study of coral reefs in the Gulf of Mannar. Supervised classification of LISS-III data is used to identify the different species of corals and the result of the study shows that the coral reef over these regions is highly getting degraded. Through this paper, it has been concluded that remote sensing and GIS techniques are providing valuable information in assessing and monitoring the coastal ecosystem (Ramchandran, 2000).

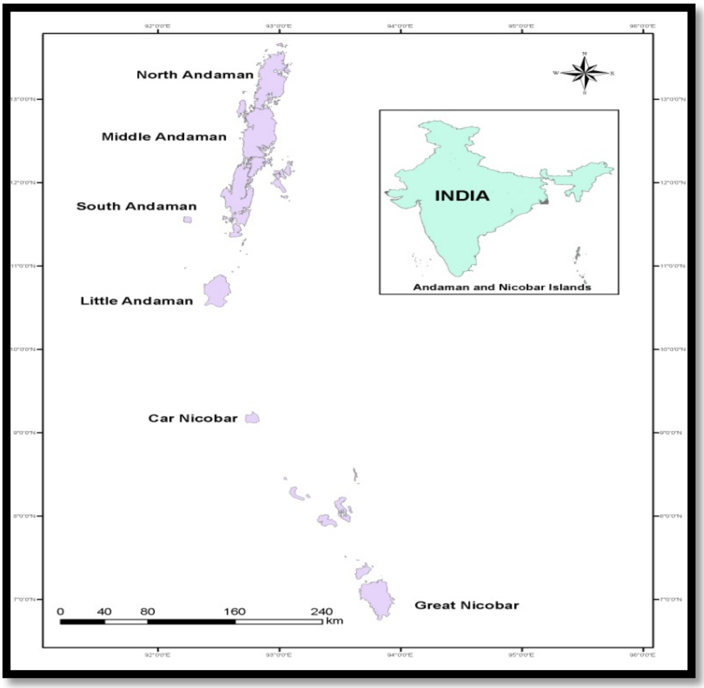


Fig. 1. Location of Mahatma Gandhi Marine National Park (MGMNP), Andaman and Nicobar Islands

A study has been carried out to know the status of GIS and Remote sensing application in coastal resource management in India. India has a long coastline with numerous lagoons, estuaries, mangrove swamps that supports rich living and non-living resources. Tools like RS and GIS are helping in generating data required for micro and macro level planning for coastal management in a sustainable manner. Satellite data used for the study were Landsat and LISS-III for 1989 and 1996. This study reveals that there is a substantial loss in the mangrove area, i.e. Muthupet mangrove forest and Pichavaram mangrove forest over the same period. Results show that the application of remote sensing and GIS are playing an important role in assessing the change of mangroves over a long period. This helps in effective management and conservation of these types of mangroves, coastal wetlands, coral reefs and other protected areas (Jayaraman, 2007).

This paper described different approaches to the remotely sensed data of coral reef are reviewed. LISS-III data was used for identification of different types of coral reefs from the coasts of Gulf of Mannar by using the different methodologies. Visual identification of satellite imagery was useful to delineate the extent of coral reef areas. Different types of classification methods were applied in this study and comparison has been done. K-means which is a simple unsupervised classification of IRS-LISS-III data failed to differentiate between different species of coral reef. MLC (Maximum Likelihood Classification) and PCA (Principal Component Analysis) of IRS-LISS-III data are found to be the most suitable for identifying the different types of coral reefs and other associated features. Result demonstrates that PCA is giving more accuracy that MLC. Apart from the sensor characteristics features, different enhancement techniques also proved to be useful for coral reef mapping (Thanikachalam, 2011). The objectives are to map ecologically and geologically critical coastal areas in, to delineate changes in coastal resources between 2006 - 2014 and to study shoreline changes occurred during the period 2006 - 2010 in MGMNP

Methodology

Image Pre-Processing

Satellite data are geo-registered using standard geometric correction algorithm of ERDAS Imagine 9.2 software using Survey of India toposheet (1:50,000 scale). Enough care was taken to keep the accuracy of the area calculations- digital image analysis technique following the methodology of SAC (2006). Making use of various band combinations, FCC's for LISS-III and Landsat data were generated. Based on visual interpretation, coastal resource maps were prepared using the image interpretation keys shown in (Table 1). The methogology is described in Figure 2

Table 1 Selected Image Interpretation Keys used for Mapping of Coastal Resources.

Sl. No.	Category	Tone	Texture	Association	FCC
1.	Dense Mangroves	Bright Red	Smooth	Low energy costs or quiet depositional areas.	4,2,1 (LISS-III and Landsat 5), 5,6,7 (Landsat 8)
2.	Degraded Mangroves	Light Brown (LISS-II),Blue and Cyan (Landsat)	Moderate	Associated with mangroves	4,2,1 (LISS-III), 4,5,3 and 5,3,2 (Landsat 5 & 8)
3.	Healthy Coral Reefs	Turquoise	Smooth	Coastline	4,2,1 (LISS-III and Landsat 5), 5,6,7 (Landsat 8)
4.	Sand over Reefs	Green	Smooth	Associated with Healthy Corals	4,2,1 (LISS-III), 4,5,3 and 5,6,7 (Landsat 5& 8)
5.	Sand Beaches / Areas	Bright White	Smooth	Shore	4,2,1 (LISS-III), 4,5,3 and 5,6,7 (Landsat 5 & 8)
6.	Vegetation	Red		Land / Islands	4,2,1 (LISS-III), 4,5,3 and 5,6,7 (Landsat 5 & 8)

The MLC algorithm was applied to perform multi-spectral image classification. It is a supervised parametric technique that requires input parameters such as the number of classes and features (spectral bands) present in the data and the Gaussian parameters. The success of maximum likelihood classification is highly dependent on the reparability of spectra for different habitats in the image. Similar spectra may lead to confusion in the supervised classification and misclassification in the output image map (Thanikachalam, 2011). The entire sub-scene was thus classified into different classes. Contextual editing was also performed to maintain accuracy. The shapefileswere created,and the areas covered separately for each class were estimated. The changes occurred throughout the year were analysed in a GIS.

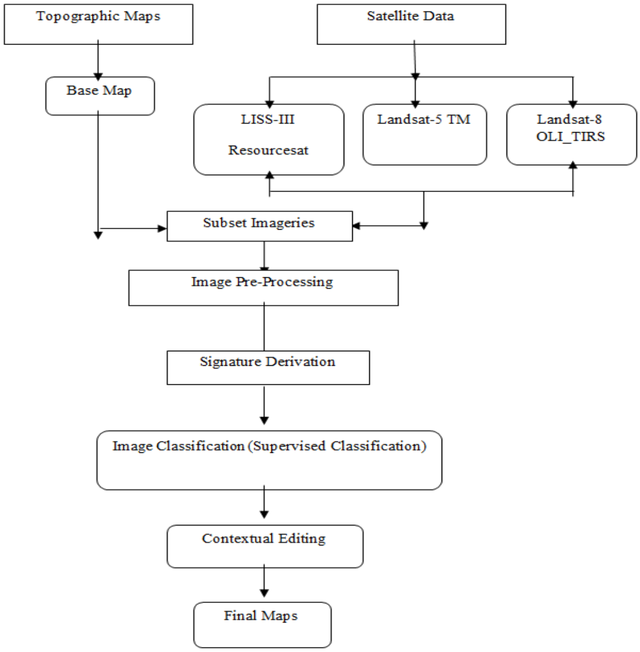


Fig. 2A. Schematic Diagram Representing the Methodology (Coastal Resources)

Results

Mangroves

The remote sensing imageries of the study area aware us about the area of mangrove wetlands which is in many places. They can be identified by their bright red colour with smooth texture, irregular shape and on another side, the sparse areas within the mangroves were visible by their light brown colour with rough to moderate texture.

In the study area, the mangroves are well developed and are mainly observed in the following islands of the marine national park i.e. Tarmugli, Alexandra, Redskin, Hobday and Boat Island. The dense mangroves are spread over an area of 447.6 ha. During the year 2006, 251.5 ha. in 2010 and 219.8 ha. in the year 2014 which is showing a decrease in the dense mangrove. It is estimated that there is a decrease of about 227.8 ha in the overall time period of the study that is from the year 2006 to 2014 (Figure 3, 4 and 5).

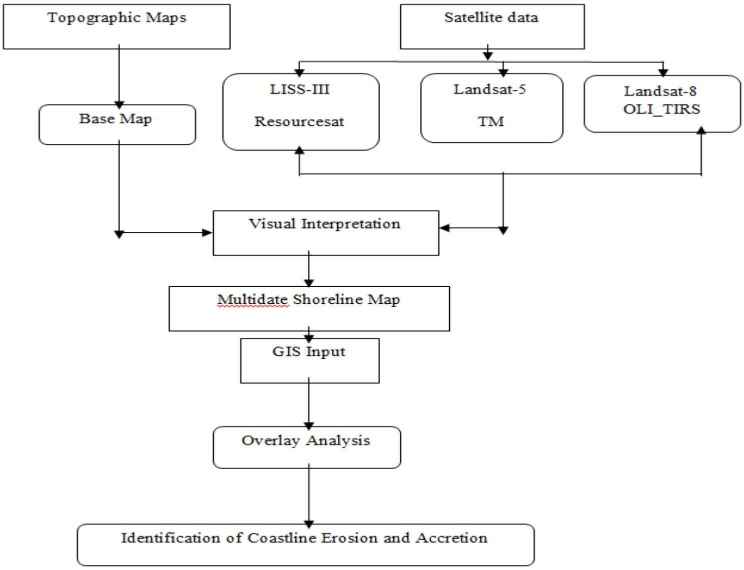


Fig. 2B. Schematic Diagram representing the Methodology (Shoreline Change Mapping)

In the study area, sparse mangroves are mainly noticed in islands like Tarmugli, Redskin and Boat Island. It covers an area of 323 ha. (42%) in the year 2006, during the year 2010, it covered an area of 562 ha. (69%) moreover, in the year 2014, it has covered an area about 314.4 ha. (59%). Through this result, we can analyse that during the year 2006 the area covered by the sparse mangrove was less and in the year 2010 it got increased by 239 ha.

Corals

The reef flat is generally broader on the south-west and narrower on the eastern side. Broader reef flats are present in the islands like Tarmugli, Boat, Jolly Buoy and Snob. The coral reefs are complete with wide and extensive reef flat, coralline shelf and coral heads, which are an indication of continuing coral growth activity and are found in islands like Tarmugli, Boat, Chester, Redskin and Alexandra. These coral reefs are identified by their turquoise colour with irregular, broad to narrow shape and smooth texture.

Based on the present study after the classification of the satellite imageries the total area covered by coral was about 1411.2 ha. In the year 2006, 2149 ha. In 2010 and during the year 2014 it was about 2895.4 ha. It is richer over the west coast as compared to the east coast. Coral reefs in the study area are further classified into healthy corals and sand over the reef. Sand over reefs is irregular in shape, greenish in colour and its smoothness in texture. Healthy coral reefs are more on the western part and narrow over the eastern part. It is spread over an area of 543.3 ha. (38.5%) in 2006, 1467.7 ha. (68.2%) during 2010 and 2502.11 ha. (86.4%) in the year 2014.

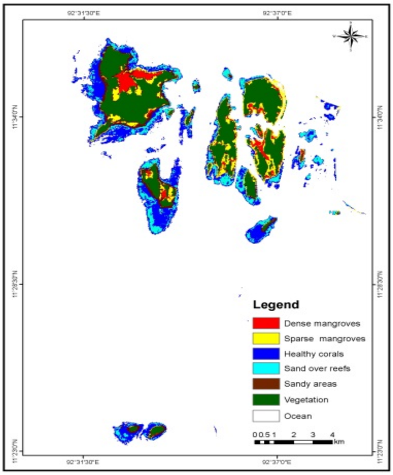
The area covered by sand over reefs was found to be more during the year 2006. It is estimated that during the year 2006 it is covering an area of 867.91 ha. (61.5%) moreover, during the year 2010, it got decreased to 682.02 ha. (31.7%) moreover, in 2014 it again got decreased to 393.43 ha. (13.5%) (Figure 3, 4 and 5).

Sandy Areas

The presence of sand in Andaman is noticed as a very thin strip along the coastal region. Generally, the sandy area appears as the bright white tone in satellite images. In the study area, entire shore, islands and back shore regions are all covered by sand beaches. The total area covered by sand in 2006 was 676 ha and in the year, it got decreased to 451 ha. Again in the year 2014, the sandy area was increased to 743 ha. This is showing that there is a decrease in the sand area, which has been observed over a period of 4 years. The sand areas have decreased between the year 2006 and 2010 and it was estimated as 225 ha (Figure 3, 4 and 5) and Table 2, 3 and Table 4.

Table 2. Areal Distribution of Coastal Resources of MGMNP

Categories		Area in 2006 (ha.)	Area in 2010 (ha.)	Area in 2014 (ha.)
Mangroves	Dense	447.6	251.5	219.8
	Sparse	323	561.9	314.4
Coral Reef	Healthy	543.3	1,467.7	2,502
	Sand Over Reefs	867.9	682	393.4
Sand	Sandy Area	676	451	743
Vegetation	Forest	1,752.4	1,875.3	1,882.7



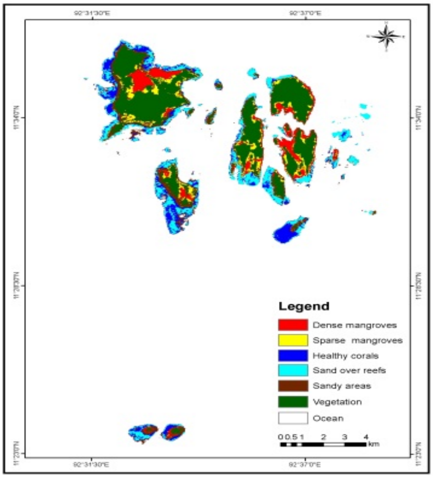


Fig. 3. Coastal Resources of MGMNP (2006)
Fig. 4. Coastal Resources of MGMNP (2010)

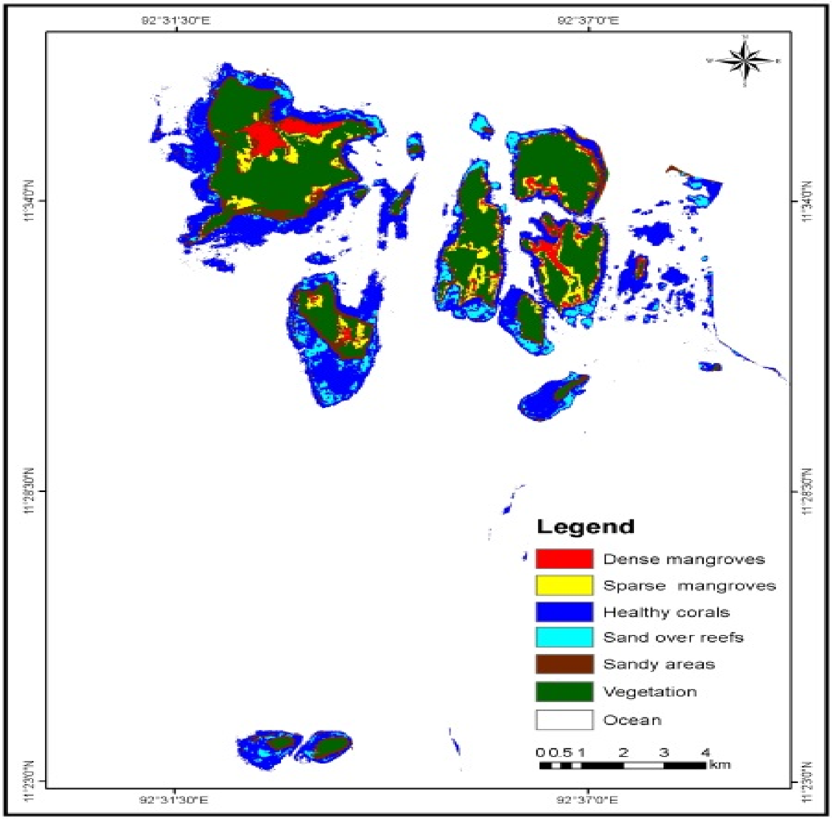


Fig. 5. Coastal Resources of MGMNP (2014)

Table 3: Areal Change of Coastal Resources in MGMNP

Categories		Change in Area (ha.)		
		2006-2010	**2010-2014**	**2006-2014**
Mangroves	Dense	-196.10	-31.70	-227.8
	Sparse	+238.90	-247.5	-8.60
Coral Reef	Healthy	+924.40	+1034.3	+1958.7
	Sand Over Reefs	-185.90	-288.6	-474.5
Sand	Sandy Areas	-225	+292	+67
Vegetation	Vegetation	+122.9	+7.40	+130.3

The changes in the areal distribution of various coastal resources between 2006 and 2014 are graphically shown in Figure 6. The change in the area of each of the 14 islands is graphically shown in Figure 7.

Table 4. Percent Change in Area of Coastal Resources of MGMNP

Categories		Percent Change in Area (ha.)		
		2006-2010	2010-2014	2006-2014
Mangroves	Dense	-43.8	-12.6	-50.8
	Sparse	+73.9	-44	-2.6
Coral Reef	Healthy	+170	+70.4	+360.5
	Sand Over Reefs	-21.4	-42.3	-54.6
Sand	Sandy Area	-33.2	+64.7	+9.9
Vegetation	Vegetation	+7	+0.3	+7.44

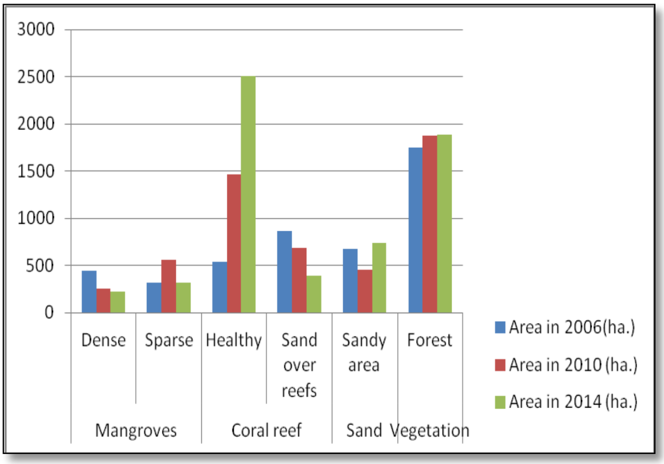


Fig. 6. Areal Distribution of Coastal Resources in MGMNP

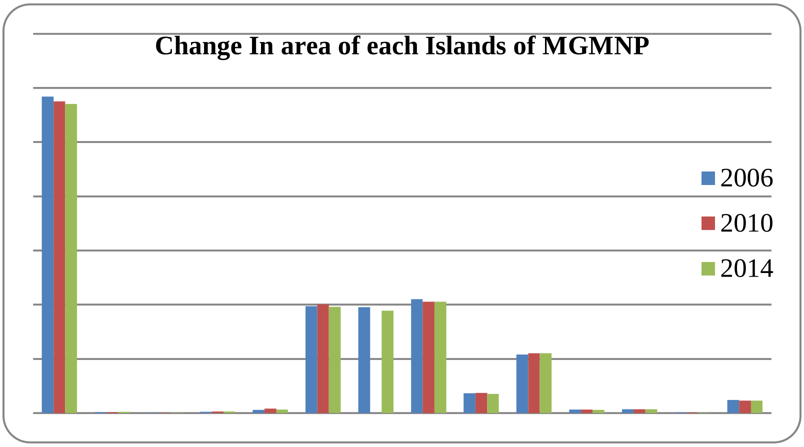


Fig. 7. Change in Area of each Islands of MGMNP

Shoreline Change Mapping

The study is mainly based on visual interpretation of satellite imageries. Satellite data products include LISS-III (2006) and Landsat 5 TM (2010) were used for the study. The base map was generated based on the survey of India topographic maps. The satellite image wasgeo-registered with the base map using more than 15 ground control points in the ERDAS Imagine 9.2 software. The geo-registered image was entered in Arc GIS Environment for shoreline delineation. With the help of digitisation technique, the satellite imagery was digitised as a line feature. Shorelines representing different years of the study area were present by overlay analysis. Finally, the identification of the shoreline changes has been done. The detailed methodology of shoreline change mapping is given in the following schematic diagram (Figure 8).

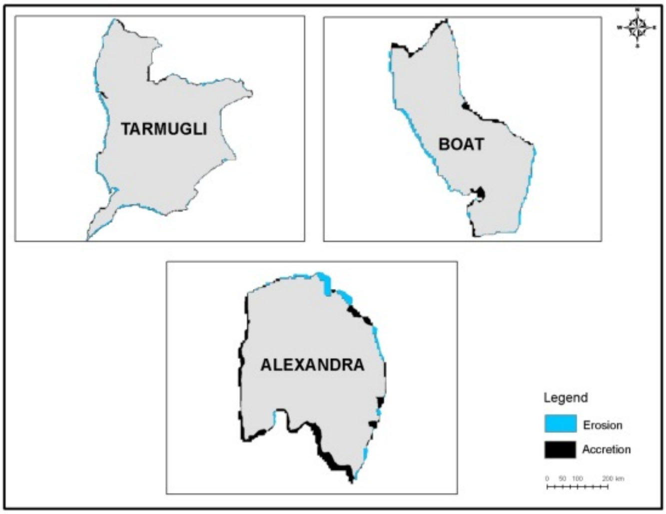


Fig. 8. Schematic Representing the Methodology (Shoreline Change Mapping)

Shoreline Mapping

For satellite images, visual interpretation and shoreline delineation have been conducted. Accretion and erosion are two inverse processes. Accretion means increases the area of agricultural, forest and fishing land, but it does not yield the sediment in the seaport, while the erosion leads to the loss of land, destruction of buildings houses and threatens human life. The analyzing result has shown the erosion/ accretion areas through time in (Fig. 9 and 10). Most of the erosion and accretion in the year 2006- 2010 is higher.

This region was examined with full vegetation cover in two satellite images. Through these satellite images, the two inverse processes have been found in the islands like Tarmugli, Boat, Alexandra, Redskin and Hobday. The area covered by Tarmugli Island in the year 2006 was 1168.4 ha. And it got reduced in the year 2010 to 1150.4 ha. Tarmugli is the largest island in the Mahatma Gandhi Marine National Park. It has been observed that most of the erosional shore in the year 2006 to 2010 is found in the south -

west part of the Tarmugli Island and accretion is found in North and parts of Eastern part of the island.

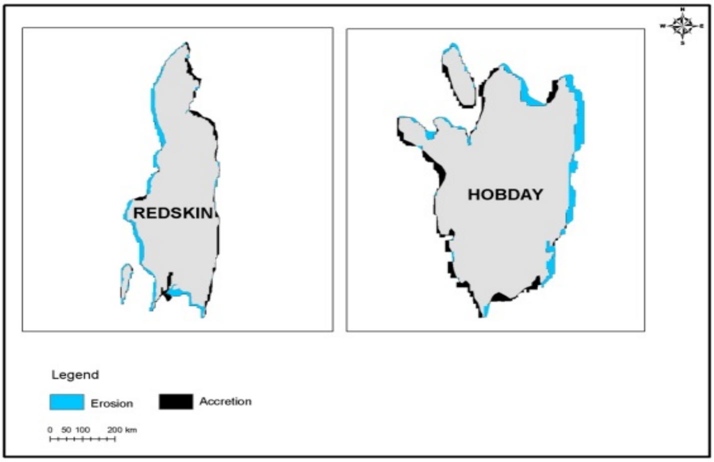


Fig. 9. Shoreline Change of 2006-2010

It has been observed that most of the erosion has happened in this island. There was a huge difference of areal extent in this island in the case of Boat Island, the area covered by this island during 2006 was 216 ha. and in the year 2010 it got increased to 220.4 ha. and it has been observed that from the year 2006 to 2010 there is an accretion of area towards north east part of the island. Eroded areas are found to be very less in this island and are only found in west part of the island. In Alexandra Island, it has been found that there is an increase in the area of island. It has been estimated that during the year 2006 the areal extent of this islands was 394.9 ha. and in the year 2010 it got increased to 401.4 ha. this shows the result for accretion of land and the accretion is more towards south part of this island and erosion has been occurred in the parts of north of this island as shown in the (Fig. 9).

In Redskin Island, the areal extent was 421 ha. In the year 2006 and it got lessen to 410.8 ha. Which is a difference of 10 ha, it has been observed that erosion has occurred more towards the west part of the island and accretion has happened towards the north part of the island. In the case of Hobday island, there is a huge change in areal extent because in the year 2006 it has been estimated that it has covered an area about 391.5 ha. Of land and in the year 2010 it got decreased to 377.87 ha which is showing the loss of 13ha. of land. In this island, through the visual interpretation accretion has happened very less and can only see towards west part of the island. It has been observed that eroded areas are more on this island it is more towards north-east part of the island as shown in (Fig. 10).

Discussions

The present study focused on one of the marine national parks of Andaman and Nicobar Islands. In Andaman, environmental degradation such as cutting trees, destruction of mangroves along with pollution, urbanization and population growth are the major problems. Other problems include siltation, sand mining, tourism, poaching, runoff, coral extraction, bleaching, development of shell craft industry, development of new jetties, poor land use practices, storms and wave actions, sedimentation, sea level rise, erosion and coral disease. Most of the coral reefs in the park are fringing reefs. The critical habitats like mangroves, coral reefs, seagrass beds, beaches contribute to the species diversity of the park. This is the richest among all marine national parks in the country. The other important ecosystems are sandy beaches. The presence of sand in Andaman is noticed as a thin strip all along the coastal region. The sandy beaches are used for sand mining, water extraction, recreation, agriculture and extraction of minerals. Satellite remote sensing has been found to be a very useful and valuable application tool in the forest management including mangroves, not only in monitoring, but also in carrying out the impact of deforestation on global climate.

By analysing the classified images, in the year 2006 many of the sandy patches were identified in islands like Redskin, Tarmugli, Boat, Jolly Buoy and Malay. This may be due to after effects of Tsunami that has happened in year 2004. Many of the coral reef areas were submerged due to deposition of sand over reef flats. In the year 2010, there has been an improvement in the scenario of corals; there is a decrease in the deposition of sand over the coral reefs this may also cause a reduction in beaches. In the year 2014, there was an increase in the health of coral reefs. It is mainly because the government has taken interest to protect this area from the tourist activities.

The spectral reflectance curve from LISS-III and Landsat images has clearly brought out the variation in the spectral signature of different island features. The coastal resources like dense mangroves, sparse mangroves, healthy coral reefs, sand over reefs, sandy areas and vegetation. It has been observed that in LISS-III satellite image healthy coral reef areas are showing higher reflectance value in Band 1, but there is a gradual decrease in Band 2, 3 and 4. Sandy areas are also showing higher spectral reflectance in Band 1, and it is slightly slanting towards the Band 2, 3, and 4. Dense mangrove compared to sparse mangrove areas showing less reflectance value in Band 3.

In Landsat imagery, it is been observed that sandy areas are showing higher spectral reflectance in Band 1 and 5. Healthy coral reefs are also showing high spectral reflectance in Band 1 as compared to sand over reefs. Sand over reefs is showing higher spectral reflectance in Band 6 along with dense and sparse mangroves. Dense mangroves and vegetation having same spectral reflectance in Band 1 it is slight high and then constantly decreasing towards Band 2 and 3 and again showing high spectral reflectance in Band 6.

About 80% of the mangroves are distributed in the Sunderbans of West Bengal and the Andaman and Nicobar Islands with the rest in other states. Among the macro-level environmental factors that determine the area, species, diversity and biomes of the mangrove wetlands. The great Sumatra earthquake on 26 December 2004 was one of the fivemajor earthquakes of magnitude > 9.0 in the recent history of instrument recorded earthquakes. The special feature of the earthquake was the spectacular development of a tsunami and the devastation it caused in Asian and African countries surrounding the Indian Ocean. In the Indian context, this magnitude 9.3 earthquake resulted in the submergence of the built environment and the emergence of new beaches in Andaman and Nicobar Islands (Javed and Murty, 2005). After that, there is no extensive study has been carried forwarded to study these beaches.

Conclusion

The MGMNP can be called as the lungs of Bay of Bengal region especially in the Andaman and Nicobar Islands. It is having the total vegetation cover of 5,510ha. Has not having any anthropogenic destruction. It must be protected well from tourist activities. Conservation of the natural and cultural resources and their ecological relationship are the primary objectives of management of Mahatma Gandhi Marine National Park. This can only be achieved through strict protection to avoid any disturbances to the critical habitats like mangroves, coral reefs, seagrass beds, sandy beaches etc.Conservation and management of the coastal features require knowledge about the geomorphic domains existing in the coastline and their usage. The areas bounding tidal pools can be considered for the afforestation of mangroves as the present study reveals that remote sensing and GIS plays a crucial role in delineating the coastal resources. The results that are derived from the study will be beneficial for the coastal ecosystem management.

Acknowledgments

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REMOTE SENSING AND GISSTUDY ON CHANGE DETECTION IN LAND USE LAND COVER IN KONDARAPET MANDAL, KARIMNAGAR DISTRICT, TELANGANA

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Abstract

Land use and land cover is an important component in understanding the interaction of the human activities with the environment. Mapping landuse/land cover (LULC) changes at regional scales is essential for a wide range of applications, including landslides, erosion, land planningetc. LULC alteration (based specially on human activities), negatively affect the patterns of climate, the patterns of natural hazards and socio-economic dynamics in global and local scale. In this study, LULC changes are investigated by using of remote sensing and geographical Information Systems (GIS) in Kondarapet Mandal, Karimnagar District. For the purpose IRS-IC-LISS III data has been acquired for the year 2011-12 and 2015-16. The area lies geographically between the 78^0 42' 23", 78^0 45' 22" East and 18^0 29' 35", 18^0 29' 51" North. The main objective of this paper is to identify the temporal change in landuse and Land cover in the area. Therefore, available data on LULC changes can provide critical input to decision-making of environmental management and planning the future.

Keywords: IRS Data, Land use, Land cover Change, Socio-Economic, GIS, Decision Making.

Introduction

Land use / Land cover (LULC) changes play a major role in the study of global change. Landuse/land cover and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disaster-flooding. These environmental problems are often related to LULC changes. Therefore, available data on LULC changes can provide critical input to decision-making of environmental management and planning the future. Land resources are being exploited faster than they are renewed, as a result ecosystem are degraded, life support processes are threatened and biodiversity, being the key factor in maintaining biosphere resilience is decreasing at an alarming rate. Landuse Land cover is an important component in understanding the interaction of the human activities with the environment. soil, water, flora and fauna are the important land resources, which together influence in the survival of human beings by supporting food production and providing a congenial living environment. The Government of India has accorded highest priority to the holistic and sustainable development of rain-fed areas through integrated watershed development approach. Watershed management programme are mainly targeted for optimal utilization of land and water resources with minimum hazards to natural resources and environment. The remote sensing technology has immense potential to meet the challenges of land resource mapping, evaluation and management. This technology facilitated scientific methods to evaluate the watershed between two different years (before and after watershed program implementation) for land use land cover changes. These changes are assessed by interpretation and mapping of landuse land cover classes using high resolution satellite imagery (LISS III) in GIS environment. The objectives are to identify the temporal changes in landuse/ land cover and to assess the spatial distribution of landuse/ land cover

Methodology

To achieve the objectives of the study, IRS-IC-LISS III data acquired for the year 2011-12 and 2015-16 were used for landuse classification. To identify land resource inventory of land use/land cover classes, temporal change in landuse/ land cover for the study area, the density and spatial distribution of landuse / land cover using remote sensing data and, the integrated use of GIS and remotesensing were used for study area.

Study Area

The study area (Figure 1) comprises, Nizamabad Watershed of Kondaraopet Mandal, Karimnagar district, which spreads over an area of 1335 ha. It covers in SOI Toposheet Nos. 56 J/10, 56 J/11, 56 J/14 and 56 J/15. These area lies geographically between the 78°42'23", 78°45'22"E longitudes and 18°29'35" ,18°29'51"N latitudes.

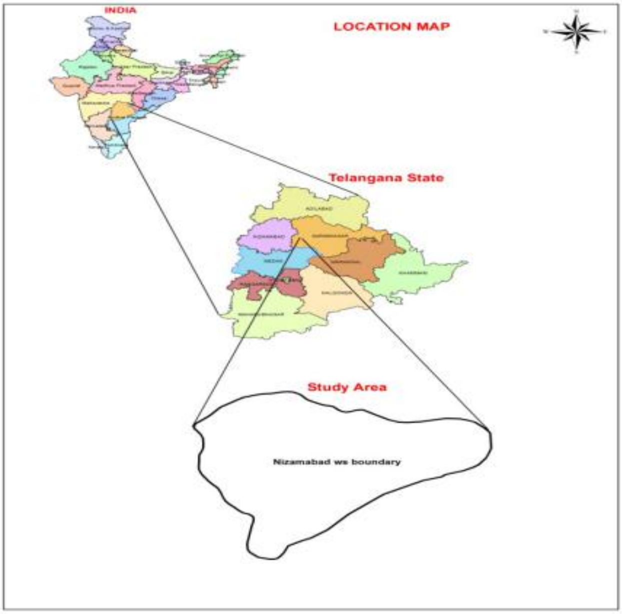

Fig. 1 Location of the Study Area

Anuradha. et al. (2017), study has been undertaken Nalgonda district to analyse the impact of changes in rainfall and temperature on the agricultural productivity at the mandal / district level in this district of Telangana. The analysis included statistical evaluation of rainfall, temperature and other meteorological parameters for a period of ten years. Atasoy. et al. (2006) paper, on determining land use changes with digital photogrammetric techniques investigates the determining land use changes in the Eastern Black Sea region of Turkey. Digital photogrammetric techniques with high accuracy have been used to monitor land use/cover changes by comparing old and new aerial images. It concludes that human land use activities have been basic factors in shaping land cover change during the 50-year period.Dwivedi, et al (2005), studied land-use/ land-cover change analysis in part of Ethiopia using Landsat Thematic Mapper data. Hemanandhini et al. (2016), work on urban sprawl prediction and change detection analysis in and around Thiruvannamalai Town using Remote Sensing and GIS, highlights the time to time changes of urban growth. Mas (1999), monitored land-cover changes by change detection techniques. Raghavswamy et al. (1996), paper deals with the evaluation of ERS-1 Synthetic Aperture Radar (SAR) data in conjunction with Indian Remote Sensing data (IRS) LISS-II optical data in synergistic combinations with microwave data for land use/land cover mapping and assessment. Here part of East Godavari District of Andhra Pradesh, India covering Coringa reserved forest and Kakinada town and its surroundings covering 1900 sq.kms of area has been considered for the study.

Ramachandra et al (2007), paper explores various land cover and land use techniques that could be used for bio resources monitoring considering the spatial data of Kolar district, Karnataka state, India. Ratnaparkhi. et al. (2013), paper discusses on the land cover of Parbhani city by classification of image. The city has been developing rapidly over the last decade and for any successful planning, require giving reliable information about land use/land cover distribution. This study illustrates that integration of remotely sensed data and GIS techniques are effective to provide such information. Subramani. et al, work emphasis on theoretical and practical issues in contemporary urban studies and remote sensing; the spectral, spatial and temporal requirements of remotely sensed data in relation to various urban phenomena; methods and techniques for analysing and integrating remotely sensed data and image processing with geographic information systems to address urban problems; and examples of applications in which applying remote sensing to tackle urban problems is deemed useful and important. Venkatesh et al. (2018), paper focus on how GIS and remote sensing are land related technologies and are therefore very useful in the formulation and implementation of the land related component of the sustainable development strategy. The different stages in the formulation and implementation of a sustainable regional development strategy can be generalized, and evaluation of planning options. Vani et.al paper focuses on the environmentally and hydrological degradation of water bodies in urban area, which has bad impact on basic urban needs like domestic water supply, recreational activities & irrigation water. Secondary data method was used for analysis. Zhao .et al (2004), in his paper highlights that knowledge-based visual change detection and classification-result overlay methods are more appropriate than the multi-temporal composite and classification, and image ratio. The latter two methods are useful and efficient when remote sensing data acquired in the suitable season are available, and distinct spectral characteristics of different land use types exist. The results show that the area of cultivated land in this region decreased by 5321.8 ha over the period 1987 to 1998, i.e. 483.8 ha every year, mainly concentrated in the central paddy field region and northeast dry land region.

Analysis

The study was carried out specifically for the years, 2011-12 and 2015-16: Base maps including road, railway, settlement, village location and watershed boundary extracted from the topographic sheets and converted into GIS database. The modifications in the LULC map updated with Remote Sensing imagery. GIS enabled, to identify the gross area, areas of changes and spatial distribution between 2011-12 and 2015-16. The same has been shown in the following Figures 2, 3, 4, 5 and Figure 6 and Tables 1, 2 and Table 3.

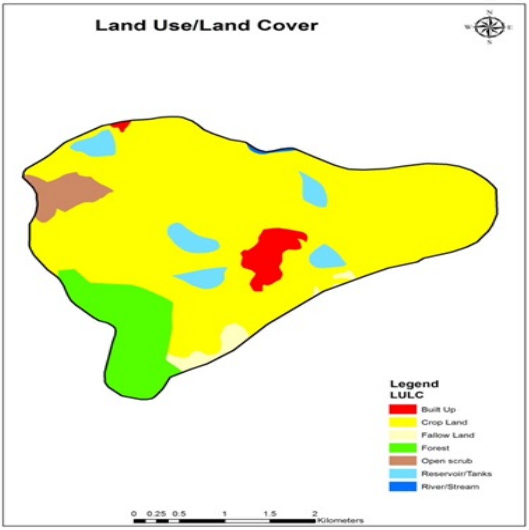

Fig. 2. Landuse/ Land cover of the Study Area (2011-12)

Table 1. Land use/ Land cover of the Study Area (2011 -12)

Land use /Land cover (2011-12)	Area (in Hectares)
River / Stream	3
Forest	144
Builtup	28
Reservoir / Tanks	65
Fallow Land	161
Open Scrub	15
Crop Land	920
Total	1,335

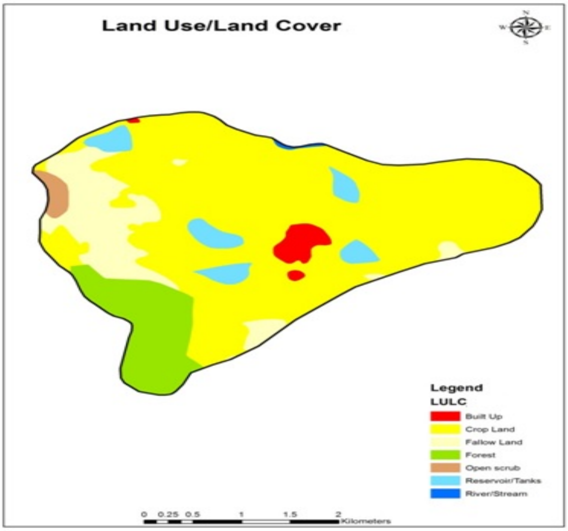

Fig. 3. Land use/ Land cover of the Study Area (2011-12)

Table 2. Land use/Land cover of the Study Area (2015-16)

Land use /Land cover (2015-16)	Area (in Hectares)
River / Stream	3
Forest	144
Built -Up	41
Reservoir / Tanks	65
Fallow Land	25
Open Scrub	41
Crop Land	1,016
Total	**1,335**

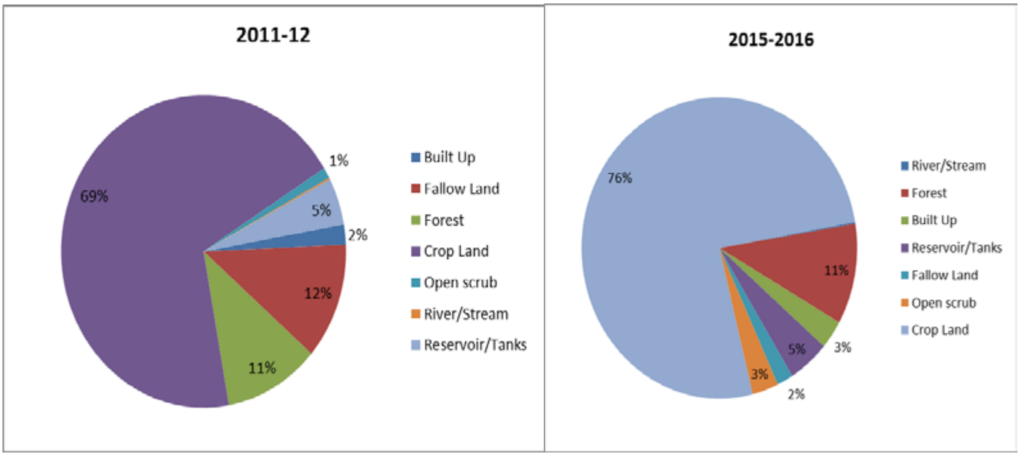

Fig. 4. Pie Diagram of Land use/ Land cover (2011-12)
Fig. 5. Pie Diagram of Land use/ Land cover (2015-16)

Table 3.Area Statistics of Land use/ Land cover of years 2011-2012 and 2015-2016

LandUse /Land Cover	2011-12 ha	2015-16 ha	Comparison Change	Percent	Remarks
River / Stream	3	3	0	0.22	No Change
Forest	144	144	0	10.79	No Change
Built - Up	28	41	13	0.97	Positive
Reservoir / Tanks	65	65	0	4.87	No Change
Fallow Land	161	25	136	10.18	Negative
Open Scrub	15	41	26	1.95	Positive
Crop Land	920	1,016	96	7.91	Positive

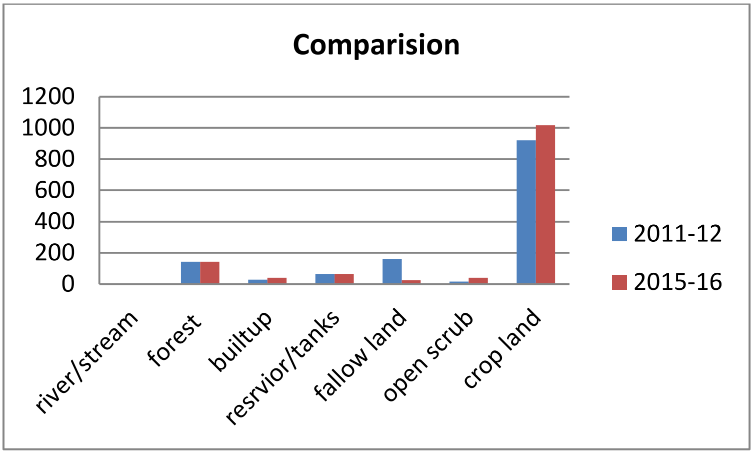

Fig. 6. Comparison 2011 - 2012 and 2015 - 2016

Results and Discussion

- The major common land use categories such as agricultural land, wastelands, settlements, forest and water bodies identified and mapped from the topographic sheets.
- The land use of the year 2011-12 was mapped, classified and calculated accurately from the toposheets, it was compared with those prepared from the satellite images (IRS 1C LISS III).
- The IRS 1C LISS III data used as the source for the landuse/land cover mapping.
- The registration and digitization of the watershed was done using Arc GIS 10.2 Software to create land use coverage.
- Six land use categories i.e. agricultural land, wastelands, settlements; forest &water bodies are identified.

Conclusion

- The results have shown that in the total study area of 1335 ha, water bodies and forest areas remained unchanged.

- The net 10.83 % has undergone changes in increase in cropland, built-up and open scrub. (Table 3)
- Correspondingly a net 10.18 % decrease in fallow land is observed. (Table 3)
- Consideration of the existing socio-economic scenario is necessary before implementing any sort of land use practices in the study area in future.
- It is expected that the findings of the investigation will undoubtedly be of use to planners and local bodies to implement suitable land use plans in the watershed, thereby achieving eco-preservation and enabling the restoration tanks under various watershed programme.

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BASIC UNDERSTANDING OF GNSS/IRNSS AND IMU/INS NAVIGATIONAL SYSTEM

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Abstract

Availability of accurate, spatial data is to display special pieces of information or an unlimited amount of essential mapping information (layers) applied to the knowledge base of any given professional field. On the ground, location, position, tracking, navigation and other spatial information can be obtained using GNSS. The study suggests the possibilities in using Inertial Measurement Unit (IMU) toguide independently in absence of positioning of communication loss (IRNSS, GPS) on ground in order to stay well informed with the geographic information and other spatial information of its location onPDA.Acquiring GNSS data using receivers such as GPS and GLONASS; GPS & IRNSS and integrating it with IMU and INS would be necessary for better navigational guidance.

***Keywords*:** GPS, GNSS, IMU,INS, IRNSS, PDA

Introduction

The GIS enables to provide the required geographic feature and itslocation details. Geo-locational details are important for maps it up-dation, precise information content etc.To locate on the map, need GNSS. Due to rough terrainthere can be a possibility inlow visibility of GPS satellites at higher elevation angles or inlower elevation angles due to shadowing of signals from natural or man-made obstructions (hills, ravines, tunnels, high rise buildings). In order to overcome such snags, a hybrid Multi- Navigational Satellite System of GNSS integrated with Inertial Measurement Unit (IMU) can overcome in situations like partial or complete absence of navigational satellite signals.

Global Navigation Satellite System (GNSS)

GNSS receivers provide geo-spatial positioning, location, timing with global coverage. It includes viz: GPS (American), GLONASS (Russian), Galileo (European), and BeiDou (China) and other regional satellite systems. Use of Multi-Navigational Satellite Systems like GNSS will reduce observation time and make measurements more precise. The positional dilution of precision will be minimized dramatically with increased availability of satellites particularly in the area of shadowing. Possibility of signal availability can be fulfilled by integrated Global Positioning System (GPS) and Indian Regional Navigation

Satellite System (IRNSS) receivers. Adoption of dual frequency solutionspromisebetter performance. The adoption of muti-constellation receivers is lower primarily because of cost and less complexity of open signals on multiple frequencies.GNSS can support a constellation up to 33 satellites; 31 satellites in orbit; 6 placed in Medium Earth orbit (MEO) at an orbital height of 20,180 km.

NAVSTAR - Global Positioning System(GPS)

The Global Positioning System (GPS), originally Navstar GPS, is a Satellite-based radio Navigation System (SATNAV) owned by the US government. GPS satellite constellation consists of 24 satellites positioned in six earth-centered orbital planes with four operation satellites and a spare satellite slot in each orbital plane. It is a global navigation satellite system that provides geo-location and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. Obstacles such as mountains and buildings block the relatively weak GPS signals.

The GPS does not require the user to transmit any data, and it operates independently. The GPS also provides critical positioning capabilities to non-civilian, civil, and commercial users in all countries with a GPS receiver.The receiver gets a signal from each GPS satellite. The satellites transmit the exact time the signals are sent. By subtracting the time, the signal is transmitted from the time received, the GPS can tell how far it is from each satellite. The GPS receiver also knows the position of the satellites, now the signals are sent. So, given the travel time of the GPS signals from three satellites and their position, the GPS receiver can determine the position in three dimensions - east, north and altitude.

To calculate the time the GPS signals took to arrive, the receiver needs to know the time very accurately. The GPS satellites have atomic clocks that keep very precise time - theoretically accurate to about 14 nanoseconds.Most receivers lose accuracy in the interpretation of the signals and are only accurate to 100 nanoseconds.Although, the GPS receiver needs 4 satellites to work out position in 3-dimensions, however receiver able to get signals from 3 satellites, position is determined, with less accuracy. In the mountains, the 2D fix could be hundreds of metres off. In plains 3D fix provide positional accuracy up to 5 metres.

New GPS receiver devices using the L5 frequency expected to begin release in 2018 are expected to have a much higher accuracy and pinpoint a device to within 30 centimetres. The L1 carrier is modulated by both the Coarse-Acquisition (C/A) and Precise (P) codes, while the L2 carrier is only modulated by the P code. Both the C/A and Pcodes impart the precise time-of-day to the user. The L3 signal at a frequency of 1.38105 GHz is used to transmit data from the satellites to ground stations. The L4 band at 1.379913 GHz is being studied for additional ionospheric correction. The L5 frequency band at 1.17645 GHz was added in the process of GPS modernization.

Global Navigation Satellite System (GLONASS)

GLONASS or Global Navigation Satellite System is also a space-based satellite navigation system operating in the radio navigation-satellite service. It provides an alternative to GPS and is the second navigational system in operation with global coverage and of comparable precision with total 27satellites and24 satellites in orbit placed in MEO at an orbital height of 19,130 km.According to Russian System of Differential Correction and Monitoring data, of 2010, precision of GLONASS navigation definitions for latitude and longitude are 4.46–7.38 metre. In comparison, the higher time precision of GPS navigation definitions is 2.00–8.76 metre Therefore, the civilian use alone is less accurate than GPS. On high latitudes (north or south), GLONASS' accuracy is better than that of GPS due to the orbital position of the satellites.Improvements are expected to bring accuracy of GLONASS to 0.6 m or better by 2020.

GALILEO

Galileo is the global navigation satellite system that is being created by the European Union (EU) through the European Space Agency (ESA) with global coverage and of comparable precision with total 30 satellites and 14 operational satellites placed in MEO at an orbital height of 23,222 km. The intended public accuracy is one meter and for encrypted users is one centimetre. Galileo is intended to provide horizontal and vertical position measurements within one metre precision, and better positioning services at higher latitudes.

Indian RegionalNavigationSatelliteSystem(IRNSS)

The Indian Regional Navigation Satellite System (IRNSS) with an operational name of NavIC (NAVigation with Indian Constellation) is an autonomous regional satellite navigation system, that would provide accurate real-time positioning and timing services in India. It will cover India and anarea extending 1,500 km around it(primary service area) with plans for further extension. The system at present consist of a constellation of seven satellites. Three satellites are located in the geostationary orbit and the remaining four are located in geosynchronous orbits with the required inclination and equatorial crossings.

The first satellite was launched in July 2013 and the last satellite was launched in April 2018. The system is intended to provide an absolute position accuracy of better than 10 meters throughout Indian landmass and better than 20m in the primary service area of Indian Ocean. The Standard Position Services (SPS), will be an open service for all users without encryption and Restricted Service (RS), for authorized users with encryption are the basic services offered by IRNSS. The intended accuracy for encrypted users is expected to be 0.1 meter and un-encrypted accuracy is expected to be around 5m. IRNSS potential use would be for navigation and Location Based Services (LBS). It is expected to be operational for messaging services in 2018 (Hindu, 2018). Unlike GPS, which is dependent only on L-band, NavIC has dual frequency (S and L bands). Terrestrial, Aerial and Marine Navigation are some of the applications of IRNSS.

Figure 1 specifies interface between space and user segment. Each IRNSS data provides signals in L5 and S bands. A step towards Satellite based Navigation Services in India are IRNSS &GAGAN.The GPS Aided Geo Augmented Navigation (GAGAN) is a Satellite Based Augmentation System (SBAS) of Indian Space Research Organization (ISRO) and Airports Authority of India (AAI)-ISRO.

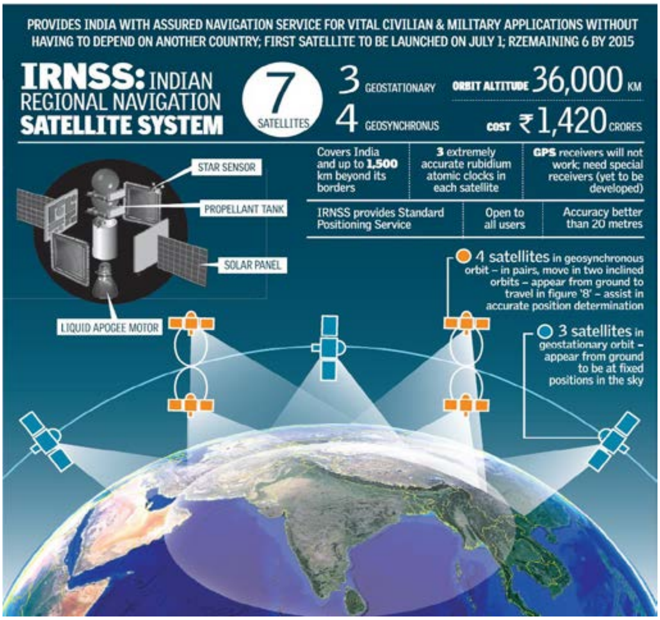

Fig. 1. IRNSS Schematic

Some Applications of IRNSS are:

- Terrestrial, Aerial and Marine Navigation
- Disaster Management
- Vehicle Tracking and Fleet Management
- Integration with Mobile Phones
- Precise Timing
- Mapping and Geodetic Data Capture
- Terrestrial Navigation aid for Hikers andTravelers
- Visual and Voice Navigation for Drivers
- GIS Mapping
- Location Based Services (LBS)

IRNSS Frequency Bands

The IRNSS SPS service is transmitted on L5 (1164.45 – 1188.45 MHz) and S (2483.5-2500 MHz) bands. The frequency in L5 band has been selected in the allocated spectrum of Radio Navigation Satellite Services Figure 2.

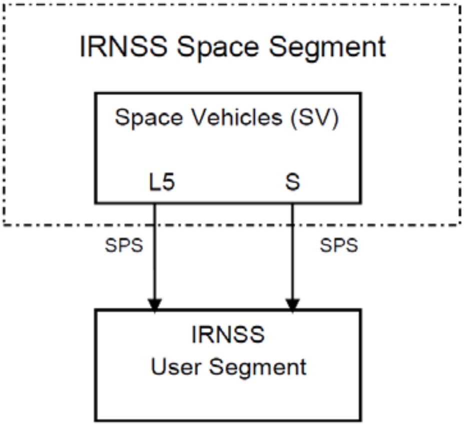

Fig. 2. IRNSS Space Segment Interface with User Segment

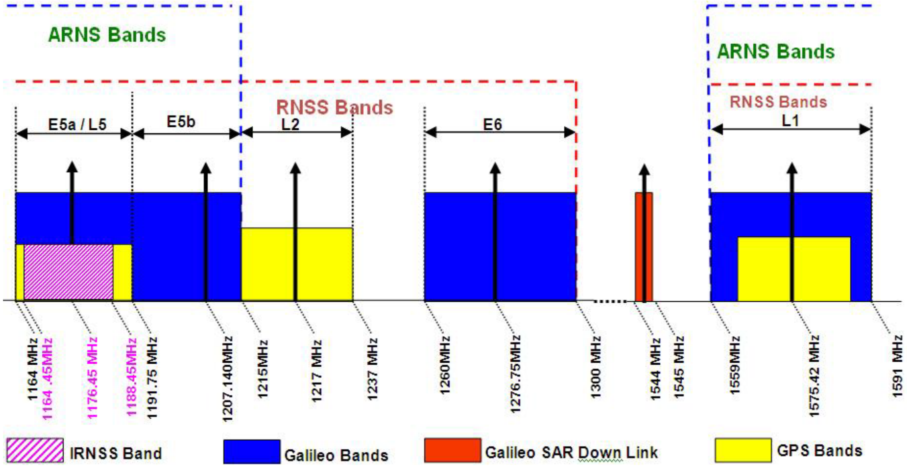

Fig. 3. IRNSS Spectrum for Radio Navigation Satellite Services in L-Band

The IRNSS carrier frequencies and the bandwidths of transmission for the SPS service is shown in Table 1.

Table 1. IRNSS Carrier Frequencies and Bandwidths

Signal	Carrier Frequency	Bandwidth
SPS – L5	1176.45 MHz	24 MHz (1164.45 -1188.45 MHz)
SPS – S	2492.028 MHz	16.5MHz (2483.50 – 2500.00MHz)

Inertial Measurement Unit(IMU)

Inertial Measurement Unit (IMU) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the magnetic field surrounding the body, using a combination of accelerometer, gyroscopes, and sometimes magnetometers.

A wireless IMU is known as a W-IMU. The fusion of satellite and inertial measurements can provide a continuous navigation solution during GPS signal outages (Jekeli 2001). High Sensitivity GPS (HSGPS) receivers currently are able to track low power signals, albeit are more susceptible to larger multi-path and increased noise errors in the process (Ray 2007). The current limitation of single IMU is the position drift of the user during a GPS signal blockage or outage (Godha et al 2006). Therefore, twin IMU can be utilized as they yield more accurate results,improve reliability, and continued navigation (Jared Bancroft et al 2008).

Limitations of IMU

A major disadvantage of using IMUs for navigation is that they typically suffer from accumulated error. Because the guidance system is continually integrating acceleration with respect to time to calculate velocity and position, any measurement errors, however small, are accumulated over time. This leads to drift. Due to integration a constant error in acceleration results in a linear error in velocity and a quadratic error growth in position. A constant error in attitude rate (gyro) results in a quadratic error in velocity and a cubic error growth in position. Positional tracking systems like GPS can be used to continually correct drift errors (an application of the Kalman filter).Gyroscope and accelerometer sensors behaviour is often represented via a model based on the following errors, assuming they have the proper measurement range and bandwidth.

Multi-GNSS & IMU/INS Integration

In absence of partial ortotal GPS signal, Multi-GNSS will make measurements more precise i.e. obtaining measurements from other GNSS such as GPS, IRNSS and/or GLONASS. The fusion of satellite data and inertial measurements data can provide a continuous navigation solution. The estimated calculation of location can be made out using kalman filter, an algorithm that uses a series of measurements observed over time and produces estimates of unknown variables that tend to be more accurate than those based on a single measurement alone.

Inertial Navigation System (INS)

An inertial navigation system (INS) is a navigation aid that uses a computer, motion sensors (accelerometer) and rotation sensors (gyroscopes) to calculate position, orientation, and velocity of a moving object advances in navigational aids that give accurate information on position, in particular satellite navigation has made simple dead reckoning by humans obsolete for most purposes. However, inertial navigation systems, which provide very accurate directional information, use dead reckoning and are very widely applied. INSs contain Inertial Measurement Units (IMUs) which have angular and linear accelerometer (for changes in position); some IMUs include a gyroscopic element (for maintaining an absolute angular reference).Angular accelerometer measure how the vehicle is rotating in space. Generally, there is at least one sensor for each of the three axes: pitch (nose up and down), yaw (nose left and right) and roll (clockwise or counter-clockwise from the cockpit).Linear accelerometer measure non-gravitational accelerations of the vehicle. Since it can move in three axes (up & down, left & right, forward & back), there is a linear accelerometer for each axis.

Conclusion

With the rapid development ofGNSS, obtaining better satellite availability and geometry when used together in a full-constellation would enhance the benefit. IMU can provide navigational aid to the unit for a certain period of time. The user can easily locate himself on the map/ground even if the satellite signal is unavailable. This hybrid device may have a wide range of additional applications such as geographical exploration, cartography and geodesy, surveying, vehicle location systems, search and rescue operations (Mandal et al, 2016). Acquiring GNSS data using receivers such as GPS and GLONASS; GPS & IRNSS and integrating it with IMU, and INS would be necessary for better navigational guidance.

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ANALYSIS OF GEOSPATIAL INFORMATION AND WEB ENABLING TO SUPPORT RURAL GOVERNANCE

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Abstract

There is a need to employ more and more technological tools to handle depleting natural resources in a more judicious way to sustain sustainable productivity and to harness demographic dividend. Geospatial technology, ICT tools and Mobile technologies, visualisations using Web GIS portals has potential to integrate domains of information generation. It offers scope for content dissemination to rural habitats and farmers to absorb, understand and act upon. Remote sensing and web enabled rural application projects such as MGNREGA, PMKVY, IWMP have resulted in instances of success and acceptance for monitoring, evaluation and governance. Bhuvan web-portal based services have demonstrated potential to achieve further upscaling using integration of spatial and ancillary information available across governments, academia and voluntary bodies

Keywords: Geospatial, High Resolution Remote Sensing, ICT, Web Portal Bhuvan, Rural Governance,

Introduction

Technological Advances have rendered vast quantity of geographic information available to increasingly larger number of stakeholders hitherto un-addressed. Format, diversity and con-temporariness of the content made available, seems to have enabled sizeable fraction of rural level players sufficiently. Readiness of governance system to incorporate the digital content, harnessing strengths of ICT paradigm, seems to be stemming the tide of non-transparency and low accountability. Attempts at national level remote sensing application domain, in developing reliable web enabled information for field such as rural development and watershed management have resulted in to acknowledged instances of success. Bhuvan based web services to disseminate remote sensing and geographic information content for projects such as Mahatma Gandhi NREGA, Watershed Development Component of PMKSY (erstwhile IWMP), Rashtriya Krishi Vikas Yojana has been accepted as standard solution by central ministries for monitoring and evaluation. Current discourse is an attempt to trace the endeavours especially in the context of advent of high-resolution remote sensing coupled with leapfrogging android technologies.

Needs in Rural Governance

Governance of rural development initiatives, in context of Panchayat Raj institutions has its own characteristic features such as trade off in terms of institutional autonomy, history of lack of transparency as well as low levels of awareness in rural masses about programme. Incremental nature of improvement and amelioration of rural agrarian based economic performances, compounded by warped demographic trends necessitate constant look out for hopeful precedents especially through technological methods. Multiplicity of investment in welfare measures by Central and State Governments alike in rural hinterlands to address the burgeoning problems connected to rural distress alone needs serious harmonization to avoid duplication and realize result-oriented performances. Emphasis on cooperative federalism in establishing working mechanisms by Central Government, to achieve successful outcomes in rural governance have incorporated essence of digital technologies increasingly. Setting of realizable goals in terms of implementation and outcome, monitoring the progress in a widely varying socio-political ambience, catering to the need of mid-course adjustments of the project are demanding components in achieving comprehensive rural development programme, which need best of the technological interventions. While administration needs to focus on the routine measures of the regular operations, governance imbues the principles of innovation in service deliverance drawing from the success stories of collaboration, cooperation as well as coherence of state and citizens. Technological paradigms based on latest trends in computation, communication as well as internet offer unprecedented labyrinth of information network, offer much desired pathways in this context.

Villages need better economy, driven especially by a stable ecosystem not disturbing the natural resources irreparably. Degradation of soil and water resources evident in majority of the dry land agro-ecosystems and that of northern part of Karnataka is alarming. It may drive productivity levels to feeble levels in near future if not cared for. People and their domesticated fauna have consumed primary productivity of the land without much attention to its recuperation. Natural vegetation on critical land cover contexts of uplands, stream buffers, hillocks as well as sacred groves has either been grazed or harvested with resultant endangerment of biodiversity and water as well as soil. Since they are common resources, damage to the system is hardly observed, realized and acted upon by communities. Rare success stories of conservation of soil, water and vegetation are driven by committed individuals or well-funded organizations and may fade in to oblivion due to non-institutionalized wisdom. Loss of efficiency by up to 25 per cent within a decade for a globally awarded good practices context, as for instance in Mahbubnagar, Telangana, in watershed conservation driven rural development initiative may be an eye opener

Water Management as Key to Rural Economy

Cycles of drought and deluge have started hitting even developed economies hard, as exemplified by recent spate of disasters such as forest fire, flood, cyclones in USA, which is estimated to have equaled a loss to the tune of at least 1.5 trillion dollars.

Realizing the essence of setting up of entire rural development paradigm, especially that of MGNREGA as Mission Water Conservation has been an exemplary and welcome realignment. In a distinguished move DoRD, DoLR and Ministry of Water resources rechristened current rural employment paradigm in to a natural resource management-oriented approach in lieu of earlier relief-based approach. Mission Water Conservation essentially is aiming to adopt principle of ridge to valley wise treatments on watershed principles. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) is a flagship programme at Central level to develop decentralized micro irrigation network across farm scape of India using the conservation dividend emanating from watershed conservation as well as irrigation projects.

PMKSY aims to achieve high degree of effective water availability and use for Indian farms especially in water scarce regions. The ingenious way in which development initiatives focusing on rural development are hemmed is noteworthy and brings in innovative angle of deliverance of each component tied to farm level productivity precisely. Integrated Watershed Management Programme (IWMP), Mission Water Conservation (MGNREGA), Har Khet Ko Pani (HKKP, Water for Every Farm) and Per Drop More Crop (PDMC) are four major pillars of PMKSY which in turn are linked by principle of water to be delivered preferably for dry land farming. All four programme are being monitored by ISRO using integrated web GIS based solutions including smart phone apps. Monitoring IWMP and Geo-MGNREGA has substantial relevance for the current perspective since it involves sizeable investment in plantations of both horticulture and forestry crops as well as additional agriculture achieved due to them.

Addressing Major Schemes Under Rural Development

Monitoring of IWMP projects across the country was initiated as exercise limited to 10 states and 50 districts for special projects under PMO focus. After about 15 months of the initiation of the project, Department of Land Resource decided to allot all IWMP implemented project monitoring to NRSC. Monitoring involves observing 8200 projects (covering about 81000 micro-watershed) every year for five years beginning from 2013-14 period which is about 3.5 – 4 years after the first allocation of IWMP. By virtue of its innovative convergence of high-resolution data, vector database from state level nodal agencies for watershed management as well as precise geotags of activities completed on the ground, this project was recognised at highest level of Government as a flagship remote sensing application project addressing operational requirement. The challenge of applying high resolution remote sensing datasets to detect changes brought in due to watershed interventions as well as non-treatment reasons across varied agro-climatic contexts makes it unique. Especially the scope of integrating land cover alterations effected due to other projects as inducing changes in surface and subsurface hydrology is far reaching.

Srishti hosts range of IWMP related GIS database categories in addition to the annual high-resolution images of 2.5 m color pixels. Functionaries at state level (called SLNA, State Level Nodal Agencies) and below (called WCDC/PIA, Watershed cell cum

Data Centre or Project Implementing Agency) can upload various types of information on watershed projects and related biophysical aspects, for a wider access, display and updating across chain of organization. Drishti available as download from Bhuvan website uses global positioning system signals of smart phone and tags the photograph captured. Ancillary information on each element monitored can be updated using a standard format. This tool can compensate for the gaps in space-based imaging and help to bring in seamless information on watershed activities to decision maker's desk (Figure 1).

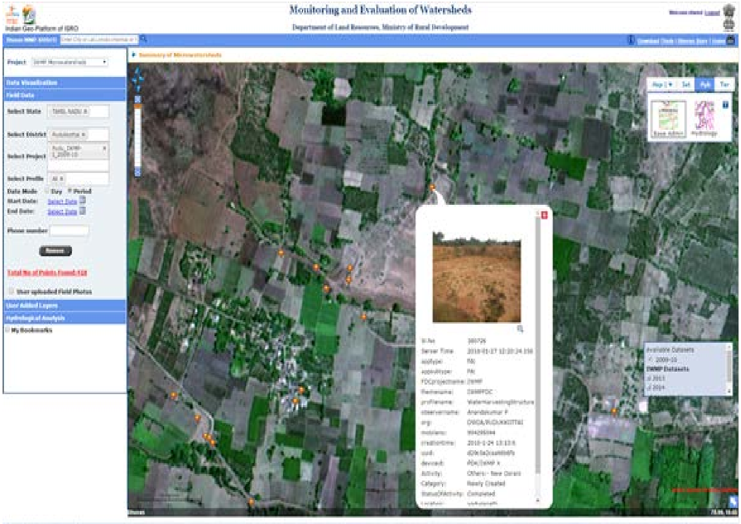


Fig. 1. Bhuvan Interface Depicting Geotag Details of an Asset Created Under IWMP Programme

Till date 9.6 Lakh geo tag points have been uploaded using Drishti App. In total, 6700 satellite images of different time series have been hosted on Srishti portal. Satellite images have been acquired for 2013-2014 onwards every year.

i) Identifying Additional Agriculture

Identifying additional cultivation brought in due to IWMP treatment is not a straight forward case of monitoring. Due to non-availability of high temporal high-resolution data it has been difficult to demonstrate on satellite imaging. Monitoring the same using very multispectral high spatial and temporal data from Dove Constellation of Satellites from Planet Labs for month of Jan-2014, Nov, Dec, Jan (Rapid Eye), Feb, Apr, May of 2017 has been made possible now at least on pilot basis (Figure 2). The constellation offers potentially every day color high resolution sensing of any part of Earth. 88 of Dove satellites used launching services of PSLV and the event marked an innovation by India in space technology. Rapid eye is another constellation formation by European Space Agency.

Study showed that a clear case of additional agriculture was observed evidently (Figure 3) on Planet Scope images of high temporal frequency at high resolution (C–H) due watershed development activity. Farm pond (FP) is evident since Nov 2016 (C) till May

2017, which showed an extent of 0.025 ha in the high-resolution multispectral image. Crop extent increased till May (E-H) which indicated that water conservation has possibly impacted farming positively. Prior to treatment (A & B) no intense cropping observed. Bhuvan image (J) is shown as reference Natural Color Composite (wherein blue band is synthesized using standard algorithm from existing green band) image for the site.

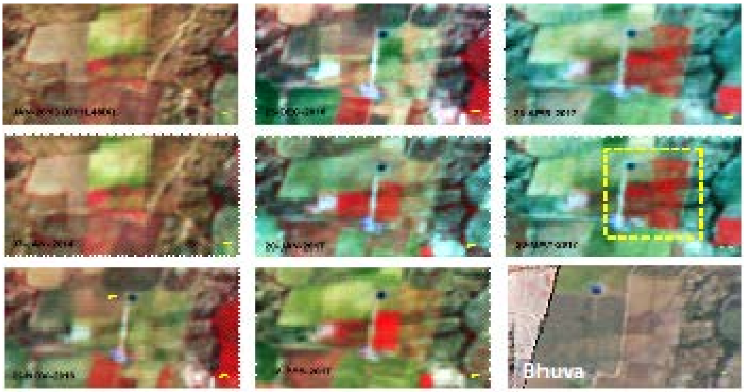


Fig. 2. Time series (Monthly) data from Planet Lab Dove constellation satellites *showing emergence of additional agriculture in IWMP Watershed landscape for IWMP:46-2011-2012; Chittoor district, Andhra Pradesh. Farm pond note seen till 2014 - January. G and H clearly demonstrate water availability during lean season. J indicates the signals as on Bhuvan interface.*

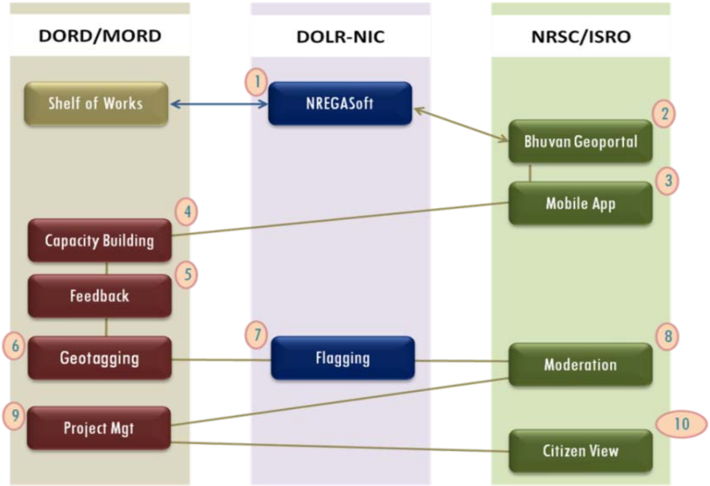


Fig. 3. Framework of GeoMGNREGA Implementation

ii) Monitoring Rural Employment Initiative

Geospatial application for Mahatma Gandhi National Rural Employment Guarantee Act as implemented by Department of Rrual Development, MoRD, GOI has been an exemplary instance of bringing paradigmatic shift to operational domain governing rural development. Process has integrated database available at National Informatic Centre, DoRD in NREGASoft with Bhuvan GeoMGNREGA web application so as to serve to field level officers through Smart Phone App for inventory of completed assets in two distinct phases of implementation. First phase geotagged all the assets completed since 2006-07 till 2016-17 with second phase taking up three stage geotagging of works being implemented with financial allocation component linked to geotagged reporting. Apart from this, GeoMGNREGA on Bhuvan also serves spatial content to another app called JANMANREGA, which is a citizen feedback app on the completed assets reported after verification. Third party verification is another vital component of quality control of database created which again is supported through Bhuvan by an app and web service. Capacity Building of massive team of resource personnel at Panchayat level, Block level, District level has been accomplished through Training of Trainers, who are usually State level nominees by NRSC in association with NIRD&PR set up. Learning of the entire programme of capacity building points to the fact that Geospatial technology has been adopted very fast and field level personnel have incorporated it as new dimension in their field operations for bring transparent reporting. Moderation step which is critical to ascertain the quality of the reported geotag is a mandatory for reporting geo-tagged assets to interface. Performances of states in terms of accomplishing the implementation is in fact measured through geotagging rates and have accordingly been recognized at national level. Needless to say, a simple geospatial application has evolved in to pivotal cog in the entire system of rural development implementation.

Need for Automated Image Analysis

Rural development domain is characterized with the need to monitor activities and implementation at micro level. Current experience shows governance needs that are linked to higher scale entities, which matter for agrarian economy especially at field scale. Advent of high-resolution datasets on open source platforms such as Google Earth, Bhuvan has brought in a context, wherein users expect identification of objects on a large area by experts, so as to incorporate such information in assessment and planning of works done in rural areas. High-resolution natural color composites from Indian Remote Sensing, coupling information from 2.5 meter or 1 mts black and white as well as colored images of 5 metre pixels bring in image surfaces relevant to governance context. However, most of the information retrieval is restricted to visual analysis, especially for operational purposes. Given the advent of machine learning, deep learning and template matching algorithms, the potential for automated to semi-automated retrieval of content using high resolution images is vast.

Object Based Image Analysis (OBIA) is a recent approach incorporating innovations related to robotic vision and derives its principles of analysis using context of topologic features. High resolution image analysis needs to be addressed beyond per pixel approach, since each object is likely to consist of several spectral regions, which may extend similarly in all the objects around it (Neeraja, 2016). For instance, a tree can consist of high proportion of NIR and R reflectance, which is certainly a repeating phenomenon across the image, in turn not amenable to analysis for a per pixel signature set. Hence need would be pick out the edges of a tree crown image, either manually or by an algorithm, followed by setting specific rules of shape, spectral average or texture as well as association with other objects to provide a hierarchically clear identity for the entity. Such an approach would be possible by using OBIA based algorithms, available now in major COTS, while it was available only in e-Cognition software to begin with. Still, open source OBIA may have some limitation in comprehensive realization of the product, possibly due to developments being incorporated at full strength. Attempt to automate OBIA based digital change detection was conducted using IRS image pairs for watershed work assessment (Figure 4).

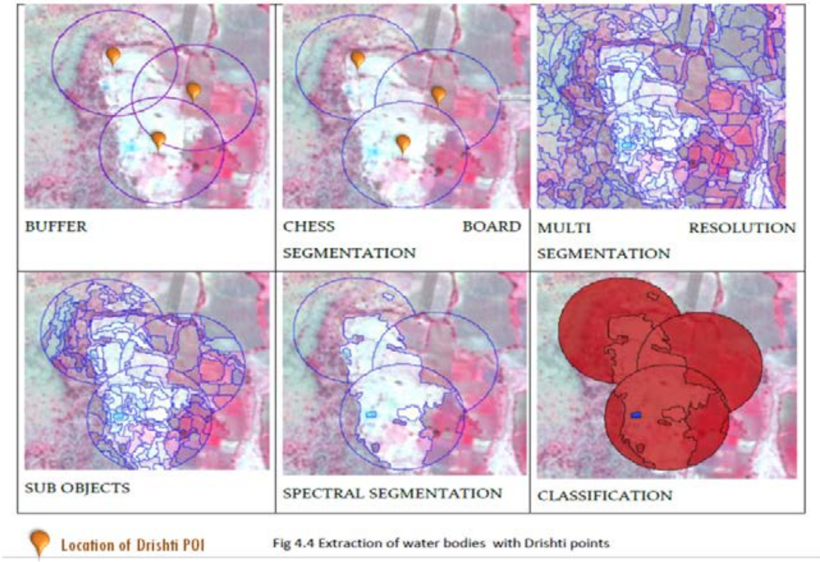


Fig. 4. Segmentation based Object Detection in High Resolution Images for Watershed Treatment

Proximity to reported location of a watershed development activity through a smart phone app was analyzed based on OBIA in COTS (e-Cognition) environment. Point of Interest (POI) is used for developing proximity followed by constrained segmentation using multi-resolution mode at scale amenable to object to be discerned. A bi-temporal image-based change was used to assess detection of new water body around geotag. Images used consisted of both CARTOSAT PAN as well as LISS-IV multi-spectral images. Water body changes were observed between PAN images due to distinct tonal transitions that are possible between water and non-water. A chessboard segmentation (to select out the zones of interest, buffers) is applied followed by multi-resolution segmentation at scale 10 to create objects, in turn followed by spectral segmentation to realize homogeneous entities corresponding to farm ponds. Chessboard segmentation is done at image extent level so as to derive only the buffered entities as zones of operation. Sub objects were processed by classifier using ruleset with regard to change spectral reflectance from earlier time period to current period. Detection was realized as shown in distinction of the object created. Detection strength will increase as the resolution of the image increases, while at 2.5 metre color resolution, this was a significant result.

Regional level changes plantations were assessed using multi-spectral IRS LISS IV and Cartosat 1 PAN combination for a eight year difference from 2005 to 2013 as part of assessing dynamics of trees outside forests in districts of Yamunanagar and Sahranpur on either side of river Yamuna in Haryana and UP respectively. Study used OBIA based image analysis for bringing out the change in the plantation pattern across the given time period. Segmentation was applied using PAN resolution on which multi-spectral as well as PAN texture-based indices (Figure 5) were implemented to discern the various levels of changes. Rule sets were built to assign segments for various spectral and textural transitions.

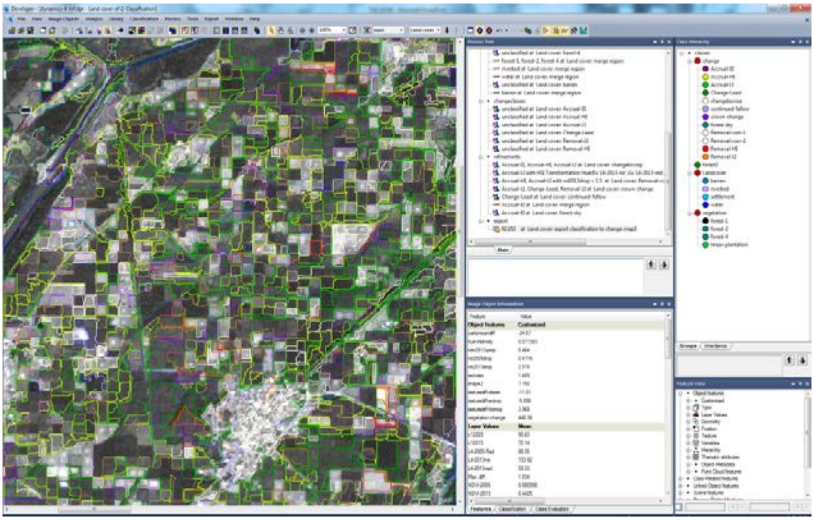


Fig. 5. OBIA Approach for Delineation of Agroforestry Plantations Rendered through CARTOSAT PAN segments. Characteristic shapes of Plantations are Delineated Clearly as Segments

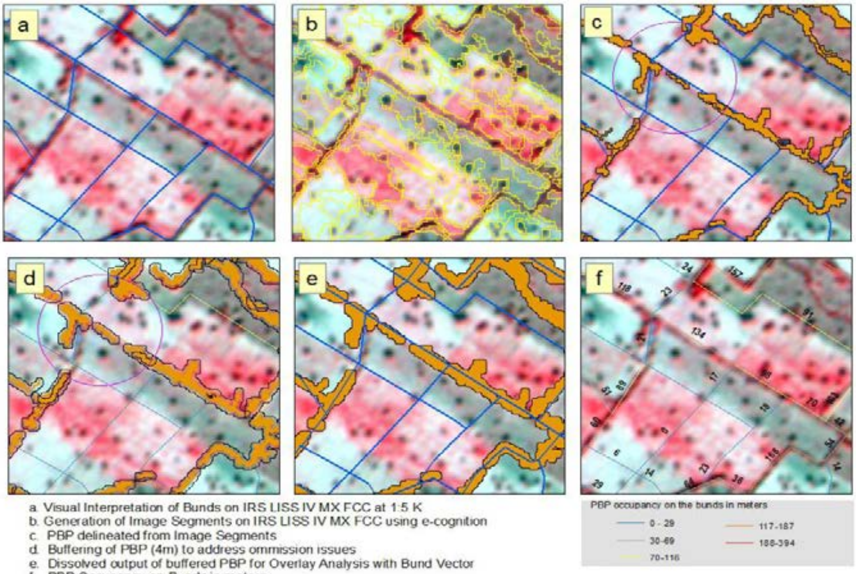
The textural features were captured by GLCM Contrast and Heterogeneity while NDVI related change vectors were used as thresholds to determine the changes in density in combination. Without segmentation it may be very difficult to localize the spectral or textural behavior. First cut determination of shapes using shape index and differentiating then against linear patches was found suitable. Categories such as planting, felling, increase and decrease in density as well as persistent plantations with and without crown density were classified. Dark green tone represented newly established plantations, while red patches show felled plantations, with deep blue areas indicating persistent plantations (Figure 6). In all plantations increased from a 493 sq km in 2005 to about 910 sq km in 2013, which indicated the trend in farming orientation from herbaceous crop to woody crop as dominant crop.

Fig. 6. Classified Segments of Agroforestry Plantations Delineating Various Stages of Growth and Harvest

The prevailing socio-economic state coupled with lack of labor seemed to drive such massive trend, which also gets influenced by the industrial markets, seeking composite wood manufacturing on large scale. In a rural context, tree planting plays major role as supportive biomass investment by farmers especially with sustenance level of production. This is especially more relevant in arid to hype rarid environments due to multipurpose benefits such as fodder, shade, fruits, small timber and wind sheltering effects they offer. In view of high manifestation of tree planting on bunds, in a watershed area in Rajasthan, study was conducted to ascertain the effectiveness of segmentation-based image analysis on pan sharpened multi-spectral image sets. High-resolution image analysis was conducted using OBIA for understanding its effectiveness in delineating the bund tree planting, which is an essential part of rural ecosystem management. Entire watershed project area covering 6400 ha was processed using e-Cognition multi-resolution algorithm involving multi-spectral and PAN bands, followed by interactive delineation of all bunds to assess the occupation by trees, called PBP or peripheral bund plantations (Figure 7). PBP segmented from high-resolution Carto + LISS IV image was enhanced by a proximity of 4 m to address omission issues as against the bund. Bund occupancy was presented as total length in meters. Strength of segmentation was evident as depicted in insert b, which detected even individual canopies as well. Ten classes of bund occupancy (in %) by trees i.e. PBP where was categorized to understand the variability in the spread. Completely covered category i.e. 100% occupancy was found to be highest with 3390 units. followed by 1463 number of bunds with no tree cover at all. 501 units consisted crown occupancy of < 25 %, while 1295 units were with occupancy in 90-99% range. Thus 4685 bund units were covered with more than 90% PBP occupancy (i.e. 46% of total bunds). Study illustrates potential of assessing tree wealth using the strength of automated segmentation approach, which can set good method as semi-automation process (Gupta *et al.,* 2018).

Criticality of Smart Phone Applications

Smart phones are evolving fast in terms of processing, imaging and storage capacity. Strength of android technology is accommodating the tools as well as aiding communication, with a open source trait, has established itself as leading and desired technology of today. Smart phone apps, which are able to convey wide variety of information from and towards user community from serving establishments have turned central, to geo-information domain as well. Probably, android technology brings more meaning to high-resolution imaging. Such a precision content labeling might not have been possible on a image surface by image analysis alone, by limited set of personnel in such a time frame. Ability of android apps to photograph report and receive prescriptions, if any, presented on a high-resolution earth observation image, has brought in new meaning for business and governance.



a. Visual Interpretation of Bunds on IRS LISS IV MX FCC at 1:5 K
b. Generation of Image Segments on IRS LISS IV MX FCC using e-cognition
c. PBP delineated from Image Segments
d. Buffering of PBP (4m) to address ommission issues
e. Dissolved output of buffered PBP for Overlay Analysis with Bund Vector
f. PBP Occupancy on Bunds in meters

Fig. 7. Delineation of field Peripheral Bund Plantation using OBIA on High Resolution PAN sharpened IRS imagery in Rajasthan

Smartphone applications need to be designed and implemented after thorough consideration of the user needs as well as the limitations rendered by quantity and quality of the database being served or being built from community interaction. While apps in general cater to various requirements of the products and services, those specific to geospatial related governance, serve formats or format specific contents to be handled on field to generate information on the works done or structures created. Such data creation applications must cater to the wide-ranging capabilities of line departments as well as connect to open source GIS service built on open source. Teams working across state wide monitoring systems may face specific issues of handling the app due to aspects connected to instrument, app design, understanding about the handling, connectivity due to signal shadows or signal drop as well as memory of the instrument. Experience gained in support provided to apps catering to national programme such as MGNREGA, IWMP etc. reveals that unless an issue connected with app is resolved entire process is slowed down, as the tool is the interface of the community to a geospatial set up. Team supporting app has to attend to the diverse queries initiated to its logical end to make it a successful utility supporting monitoring and evaluation of the programme. With such continuous role executed smart phone apps have certainly strengthened the technology of geoinformatics quite critically.

Web Based Technologies and Related Complexity

Natural corollary of amazing advances in processing images acquired from various platforms, coupled with easily affordable smart phone tools, is the need to either disseminate or draw the content from various levels of stakeholders across a GIS, advent of web enabled tools in terms of rendering geographic information as well as interaction with clients through server - client architecture has witnessed immense innovations and growth. Open source GIS software availability has taken geoinformatics to every web client wishing to apply it, as compared to the erstwhile days of commercial suite related constraints. Global efforts in engineering a comprehensive GIS suite capable of analytical and visualization processes by open source community are continuous and extant, which in turn offers core advantage of seamless integration of innovations due to ever growing strength of developers associated. However, since open source architectures may aim often at distributed users, but not at enterprise scale, a cautious and pragmatic approach is required while expanding certain operations. Optimisation of computing resources has to be managed externally, while establishing a national level service architecture.

Internet based serving of geographic information is endowed with specialties of reaching global clientele with innovative database products along with necessity to set up a round the clock performance support system. Limit for an average web visitor in terms of waiting for the web service to communicate a meaningful information, known to be just about 60 seconds, web managers need to invest best of their resources to meet such standards. Prolonged delays in such services have potential to wean away several new as well as long standing users, which may otherwise have great potential to add value to entire geo-information service chain due to vigorous use of data and provision of much wanted performance feed backs.

A typical web GIS development cycle consists of understanding the operational requirements of a GIS project till its use by clients and maintenance essential to keep it sailing through. Though surveying and acquisition processes are perceived to be non-technical steps by many managers, it consumes enough time and concentration, while demanding best comprehension of the various team members alike, Conceptual design and database realization are involved processes with iterative steps involved often.

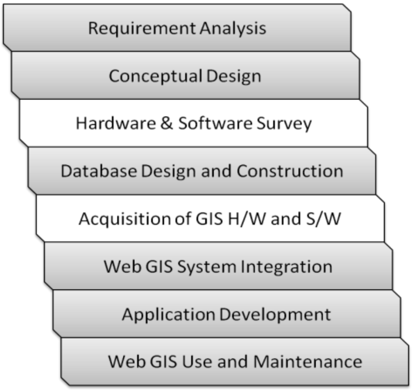


Fig. 8. Web GIS Development Cycle 2002, (Alisheikh et.al)

A design executed to meet unrealistic targets can only result in poor utility and large-scale error corrections. Integrating components of hardware and software efficiently to develop the system and to place application on it after its proper development needs thorough participation of thematic personnel, who in fact play a major role in translating user community needs to a realizable web GIS entity or tool (Figure 8). Realisation in terms of open source may be often tedious in the initial stages but may have potential for wider utility even by the last mile stakeholders, who especially in developing countries have low affordability of commercial technology often.

Conclusion

Developing nations need to employ more and more technological tools to handle their depleting natural resources in a more judicious way, in compliance to international standards of Sustainable Development Goals (GSD's) as well as Climate resilience. Indian context of growing urban economy needs to be coupled with water secure farm economy to sustain better hinterlands of sustainable productivity as well as performing demographic dividend. Geospatial technology has unprecedented potential to integrate widely varying technological domains of information generation, dissemination and rendition for rural settings to absorb, understand and act upon. As the hand-held mobile telephony reaches newer levels of content generation and consumption, precise, apt and relevant developmental information needs to be served to individual and guilds for better participation and policy implementation, which will ease the delays in communication of a higher and scientific order.

Breaking the barriers of language as well as scientific lexicons through virtual illustrations, realized using geospatial illustrations of appropriate scale, can go a long way in capturing the imagination of farmers and other rural habitants in an accelerated manner. Geospatially indexed natural resource management prescriptions, scenarios, impact reports as well as educative components help to build an informed rural society, in a fashion characterized by high ease of access.

Governance circles may need to take a note of the accomplishments increasingly, available in this field, so as to develop efficient delivery mechanisms. Indian Remote Sensing Systems coupled with advances in ICT tools have demonstrated such information networks, through Bhuvan portal in a significant way and scope exists to upscale them further involving integration of variety of geospatial and ancillary information available across governments, academia, voluntary bodies as well as international level information systems.

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APPLICATION OF TOTAL STATION (TS) IN SURVEYING AND MAPPING OF GANDHI NAGAR SLUM, UPPAL MUNICIPALITY, HYDERABAD, TELANGANA

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Abstract

Surveying and mapping are important for assessment, planning and development. Accurate physical survey and investigation helps to know the existing situation on ground.Total Station is one of the principal surveying instruments. Slums are discreet and compact entities which spread across in towns and cities landscape. It is possible to carry a detailed large-scale mapping of slum areas using Total Station (TS) on a scale of 1: 500. The study discusses the approach adopted as part of the pilot study undertaken using Total Station in surveying and mapping of Gandhi Nagar Slum, Uppal Municipality, Hyderabad city. The study was jointly carried by IISM / SOI and NRSC / ISRO, Hyderabad in November 2012 under,'SFCP' scheme of MoHUPA, Govt.of India, New Delhi. The study enabled preparation of GIS ready digital basemap, capture of details onto High Resolution Satellite Imagery (HRSI) and integration of household and utility data. GPS was also used to generate GCP's for the Total Station (TS) traverse survey.

Keywords: Surveying, Total Station, Hyderabad City, High Resolution Satellite Imagery.

Introduction

Surveying and mapping are important for assessment, planning and development. Accurate physical survey and investigation helps to know the existing situation on ground; revision of project costs, reduce completion and execution time, and bring improvement in quality of development. It holds good in any infrastructure projects like water supply, sewerage, solid waste, road, canal, cadastral surveying etc. Slums are discreet and compact entities which spread across in towns and cities landscape. A large scale surveyed and a GIS ready digital map of slum areas help in redevelopment and improvement. A *'Slum is defined as a unit area with 100 population living in 20-25 households'* (MoHUPA, 2010). The Census (2001) has defined it as a, *'unit area with 300 population living in 50-60 households'.*

Ministry of Housing and Urban Poverty Alleviation (MoHUPA), Government of India, New Delhi launched the National Mission Scheme called the,'Slum Free City Planning' (SFCP), under Rajiv Awas Yojana (RAY) in March 2010 (2011). GIS mapping involved survey of all geo-locations and the extent of all *boundaries of notified and non-notified slums in a city, preparation of city base map using High Resolution Satellite Imagery (HRIS)* and transfer of slum boundary onto the base map. Total Station is one of the principal surveying instrument. The scheme prioritized slums for detailed large scale mapping of slum areas using Total Station (TS) on a scale of 1: 500. The results presented here is part of the pilot study undertaken using Total Station (TS) in surveying and mapping of Gandhi Nagar Slum, Uppal Municipality, Hyderabad, Telangana (2012). The study was jointly carried by IISM / SOI and NRSC / ISRO, Hyderabad. GHMC, Hyderabad extended all necessary support and socio-economic database of the slum. A large scale GIS ready digital map for slum area was made ready. Further, Integration of spatial, socio-economic and attribute data was carried using ArcGIS 9.2. The survey, mapping output and report was completed in nine days in November, 2012 (IISM/SOI, 2012).

Fig. 1. View of Gandhi Nagar Slum, Uppal, Hyderabad

Study Area

The Gandhi Nagar Slum is located in Uppal Municipality, Hyderabad. The geographical area covers 2.91 hectares (Figure 1).

Methodology

The methodology consists of following steps (IISM/SOI, 2012)

Ground Control Point (GCP) Collection Using GPS.

The accuracy of a survey depends on the correctness of its framework. Thus, first it is essential to cover the whole area with a number of carefully determined points, which will form a framework. This would prevent any errors and allow to base the ensuing survey of the physical detail in the area and to generate an accurate map.

Global Positioning System (GPS)

The GPS is based on the satellite system developed for surveying, navigational and location applications. Surveying (geodetic, cadastral, telecommunication, planning with GPS has become popular due to the advantage of precise positioning (in three dimension), accuracy (meter to millimeter), speed, freely and continuously available (except cost of user receiver) and accessible in all weather conditions.. The configuration of satellites are so planned so as to ensure that at least four satellites are available to the user at any instant of time on earth, on ground, in the air or in the sea. The satellites send the signals continuously in two frequencies i.e. L_1& $L_{2..}$ The GPS receives the signals and converts into digital form. Results are obtained to a global datum (WGS 84).GPS consist of space (satellites), control (orbit, time) and user segment (receiver)

Working Principle of GPS

The working principle is based on the measurement of pseudo ranges between the used and the four satellites in orbit. Starting from the known satellite co-ordinate reference frame the three-dimension co-ordinates of the user receiver can be determined. From the geometrical point of view three range observation measurements are sufficient. A fourth observation becomes necessary because GPS uses the one-way ranging technique and the receiver clock is not synchronized with the satellite clock. This synchronization error is the reason for 'Pseudo-range'.

Ground Visit to Plan for Ground Control Points (GCP's) in the Study Area.

The map reading and visit to ground were executed as a *'pre-planning'* before commencing the collection of GCP's of the study area to be surveyed . No obstacles like trees, buildings, mountains etc should block the line between GPS antenna and GPS satellite./ free from obstructions / orient the antennas in north direction / Centering and leveling the tripod should be made precisely above the survey work

The complete procedure on GPS may be divided into following four activities

a) Field Observations, b) Downloading, c) Data Processing and d) Conclusion

a) Field Observations: The co-ordinates of IISM is taken as the reference point for all the subsequent observations in the slum area. The co-ordinates are taken in UTM / WGS84 System. Latitude: 17^0 24' 12''.27517; Longitude: 78^0 33' 17''.86675; Height: 509.491 were measured using GPS - Trimble Model 5700 (Figure 2 & Figure 3). Its components are: Recon Controller, Antenna - Zephyr Geodetic Dual Frequency & Receiver, Down Loading & Processing TGO-Software.

In GPS trilateration (a measure of distances to pinpoint their exact position) the observation were taken in relative static mode by using, 'braced quadrilateral' on placing four receiver at the corners of the quadrilateral. The simultaneous observations with four receivers were taken for 45 to 60 minutes at every every station.

One receiver was kept at one known station and three receivers kept at unknown stations. Three dual frequencies receivers were used for observations.

Fig. 2. GPS Trimble Model 5700 Instrument Configuration

Fig. 3. GCP observation on IISM-Top by GPS Trimble 5700

b) Downloading: Trimble GPS field data transfer was carried into the computer using Trimble Geomatic Office, S/W for further processing. Similarly, data from Ashtech GPS data was downloaded using GNS Studio S/W.

c) Data Processing: The data observed through Trimble GPS (in different modes) was processed through TGO .The reference co-ordinates point data (IISM-Top) was processed under Single Point Processing (SPP) and stored for further processing along with the data from other base line. The azimuth of both ends of every base line was recorded from the processed data. Base line precision is dependent upon factors of constellation of satellites tracked, its geometry, observation time, ephemeris accuracy etc.

d) Conclusion: 10 GCP's have been collected by; *'Trilateration*' and *'Radial Method'* and the co-ordinates have been attached.

Geo-referencing of the Imagery of Study Area Using GCP's Using ArcGIS 9.2:

Ten GCP's collected in the study area (Figure 4), were co-located on the High Resolution Imagery (HRI) for Geo-referencing

Fig. 4. Geo-referenced / Geo-coded HRI (GCP's) of Gandhi Nagar Slum Area

Geo-Referencing: It means geographic referencing. It is a process of referencing, wherein a relationship is established between the geographical data and corresponding locations of the real world objects on the surface of the earth. Geo-referencing helps in accurate representation and in accurate analysis. After geo-referencing the data is termed as geo-coded data. The geographic data is geo-referenced by using a mapping coordinate system. (geographic or projected). In case of geographic coordinate system a point is expressed in terms of latitude and longitude, whereas, in case of projected it is expressed in easting and northing - two basic parameters for all map projections. The Universal Transverse Mercator (UTM) is a conformal projection uses a 2-dimensional Cartesian coordinate system to give locations on the surface of the Earth. A unit of measurement, normally is in meters. Information about the co-ordinate system of data is sometimes referred to as spatial reference.

Amathematical surface is called geoid - an equipotential surface, which coincides well with MSL (Mean Sea Level). Another,imaginary mathematical surface is known as ellipsoidal.Datum isthe position of an ellipsoid with reference to the physical surface of the earth, which may be either a global datum of WGS-84 or a local datum of Everest spheroid for use in India.

Digital Data: A digital data can be obtained from a scanned map, ortho photo, and satellite image. A raster coordinate system is represented by means of cells in rows and columns. These data can be geo-referenced by using a co-ordinate transformation from a raster coordinate system to a map co-ordinate system either geographic or projected co-ordinate transformation by linear or non-linear methods. In addition to co-ordinate transformation, geo-referencing also involves re-sampling by attribute, which is known spatial interpolation. Geo-referencing of raster images is done either by, image to image or image to map rectification. Root Mean Square (RMS) error is calculated to indicate the overall accuracy of the geo-referencing.

Geo-referenced and Digitized Data has been Taken as an Input for Further Densification of Control Points and Detail Traverse Survey by ETS (Electronic Total Station)

From the geo-referenced image, the slum area map has been digitized / vectorized using UTM projection and WGS 84 horizontal datum in ArcGIS 9.2.

Electronic Total Station (ETS)

Total Station is an electronic instrument having the capability of function all survey operations such as measuring the linear distances, horizontal and vertical angles,area, perimeter, elevation (contours), traverse, control survey. It also has an internal microprocessor to perform the formulated mathematical operations. It also has internal and external memory to store the observed/computed / recorded data in digital format. When measuring linear distances, it works on the principle of EDM (Electronic Distance Measurer). So, it also has a prism or prism set for reflected wave modulation. Some Model of ETS has the capabilities of measuring distances without any reflector. For angle measurement it works similar to the Theodolite. Being an electronic device, it has a battery power pack and supports external battery.

Principle: The main principle of total station is that it depends on ground terms. If the co-ordinates of the occupied position and the other inter-visible position coordinates are known (where one can keep the reflector / prism), to start the survey work. Even, if no data is available with the surveyor, by accepting the coordinates of the occupied position, the survey work can be commenced.

Total Station TOPCON 7500 / Nikon 552 and Tripod Stand
Measuring Tape to Measure Instrument Height
Thermometer to Record Temperature and Barometer to Record Pressure
Foresight Software

Total station can be used for cadastral survey, mine survey, engineering survey, road/rail/canal survey. Its sources of error include instrumental, refractive index, prism constant, centering, battery etc. The output of ETS is a .txt file, derive map of the area of the ground surveyed in soft / hard copy. In the field traverse procedure, the traverse is based on the 10 GCP's provided by GPS, after completing the initial survey of study area.

It is divided in Two Parts i) Traverse by Total Station provide additional traverse control points spread for a detain survey. ii) Detail Survey by Total Station using the additional traverse control points provided , as station set-up points for picking of features from the ground. For different ground features of point, line, polygon and annotation is coded to assist survey team to enter the code for the feature, before picking the detail to the total station. During the detail survey each ground feature is assigned with a unique code. Where there is no traverse control point to capture the detail, an offset is established to capture the detail (Figure 5).

Fig. 5. Traverse of the Gandhi Nagar Slum by Total Station

Table 1. Selected Control Points, Coordinates and Feature Description

Description	Point	Northing	Easting	Elevation
GK2	1,925,700.264	241,670.933	482.669	Electric Pole
GK 1	1,925,858.575	241,706.118	480.149	Water Pump
JK10	1,925,687.905	241,712.450	481.965	Man Hole
GK 3	1,925,671.129	241,665.663	482.313	Transformer
GK 4	1,925,643.488	241,777.721	481.253	Street Corner

An example of selected control points, co-ordinates and description of features are given in Table 1. The surveyed traverse lines and the detailed plots of the Gandhi Nagar slum are shown in Figure 6 (A & B).The final plot of the slum using the total station is shown in Figure 7.

(A)

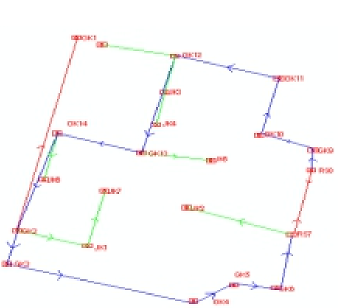

Fig. 6A. Traverse Lines

(B)

Fig. 6B. Detailed Surveyed Plots using Total Station

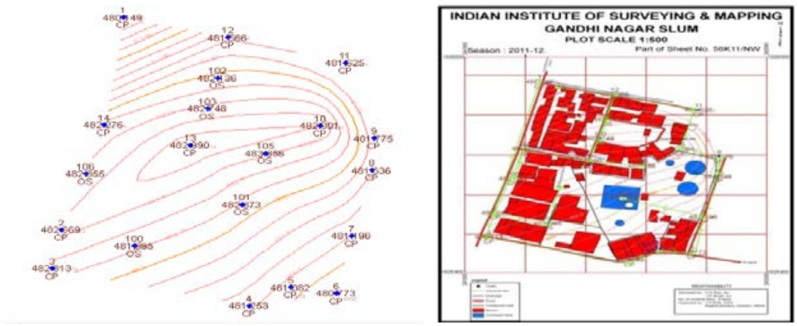

Fig. 7. Final Plot (1:500 scale) of Gandhi Gandhi Nagar Slum, Uppal Municipality

Collection of Attribute Data for Integration with the Updated Map, Analysis & Query in GIS

The downloading and processing of the fieldwork data was done using ASCII format so that it can be used in any software. A Sample of joining of excel data with polygon feature collected through total station is shown in Figure 8 & Figure 9.

house_SL	Shape *	House_No	House_Numb
75	Polygon	Pucca House	2-4-64
77	Polygon	Pucca House	2-4-57/2
74	Polygon	Kutcha House	4-65
80	Polygon	Pucca House	2-4-45
75	Polygon	Pucca House	2-4-64
79	Polygon	Kutcha House	2-4-51
79	Polygon	Kutcha House	2-4-51
76	Polygon	Kutcha House	4-53
76	Polygon	Kutcha House	4-53
78	Polygon	Pucca House	2-4-52
84	Polygon	Kutcha House	4-47/1
73	Polygon	Kutcha House	2-4-69/1
70	Polygon	Pucca House	4-65/1
81	Polygon	Pucca House	4-48
83	Polygon	Kutcha House	2-4-47
69	Polygon	Pucca House	4-66
70	Polygon	Pucca House	4-65/1

Fig. 8. Sample of Joining of Excel Data with Polygon Feature collected through Total Station

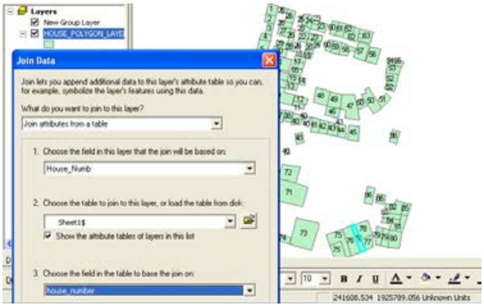

Fig. 9. Sample of Polygon Features (House/Plot) with House Type and House Number of Gandhi Nagar

For each polygon feature, by interacting with individual house hold in Gandhi Nagar , a house based survey details. in a questioner have been collected. Table 2 show the sample excel file of Gandhi Nagar collected from GHMC, Hyderabad.

Table 2. Sample Excel file of Gandhi Nagar collected from GHMC, Hyderabad

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	slumcode	household_id	household_code	house_number	household_head_name	father_name	gender	caste	religion	minority_status	female_head_status	male_members	female_members
2	280518196334	180	280518196334180	2-4-96	N LAKSHMAN	POCHAIAH	1	2	1	1	0	2	2
3	280518196334	216	280518196334216	2-4-120/10/A	B LASAR	VENKATAIAH	1	2	1	1	0	2	2
4	280518196334	175	280518196334175	4-93	K VIJAY	K BUCHAIAH	1	2	1	1	1	2	1
5	280518196334	176	280518196334176	4-94	A MALLESH	GOPAIAH	1	2	1	1	0	2	1
6	280518196334	177	280518196334177	4-94/1	K RAVI	BHUCHAIAH	1	2	1	1	1	2	3
7	280518196334	178	280518196334178	4-95	G BHIKASHAPATHI	ACHAIAH	1	2	1	1	0	2	2
8	280518196334	173	280518196334173	4-93	G RAJU	G MUTHAIAH	1	2	1	1	1	1	3
9	280518196334	18	28051819633418	4-25	S SWAMY	NARSIMHA	1	2	1	1	0	2	3
10	280518196334	172	280518196334172	4-77	T MANORA	DANAIAH	1	2	1	1	0	1	3
11	280518196334	181	280518196334181	2-4-96	N NARAYANA RAO	POCHAIAH	1	2	1	1	0	2	3
12	280518196334	182	280518196334182	2-4-97	E ANAND	VENKAIAH	1	2	1	1	1	2	1
	28051819		28051819		L NUKA								

Geographic data record, the location and characteristics of natural features or human activities that occur on or near earth's surface. Depending on their nature and use, geographic data can be categorized into three distinct types namely the geodetic control, topographic and the graphical. The central purpose of GIS is to turn geographic data into useful information.

Conclusion

With rapid urbanization, today, more than 26% of urban population lives in slums. Further, it is expected around 93 million people are projected to live in slums across India by the end of 2011. The thrust of RAY scheme is to provide permanent housing, utilities/facilities and livelihood opportunities to urban poor (Raghavaswamy, 2014). The study demonstrated, it is possible to use Total Station (TS) for generating a large scale and an accurate digital base map of a slum. Also, using HRSI (High Resolution Satellite Imagery), shown it is possible to map detail spatial areal features of the slum with point spatial features using GPS. The spatial analysis and query have been integrated using ArcGIS software. It was possible to complete the slum covering 2.91 hectares in nine days.

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REMOTE SENSING APPLICATION IN SATELLITE OCEANOGRAPHY

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Abstract

Oceanography also known as oceanology, is a study of physical, chemical and biological aspects of the oceans. It comprises of ocean currents and waves, ecosystem dynamics and bio-geochemical cycle, air-sea interaction, sea level rise and climate change; ocean bottom and land form deformation and plate tectonics. Satellite Remote Sensing has been playing a great role on improving the understanding of oceanography subjects through the measurement of key parameters of the oceans. Here, we have provided a review on remote sensing of ocean parameters and applications of these data for specific studies.

Keywords**:** Satellite Remote Sensing, Chlorophyll, Sea Surface Temperature, Sea Surface Winds, Sea Surface Salinity, Sea Surface Height

Introduction

Oceanography is one of the subjects of the natural sciences that deal with the study of physical, chemical, and biological aspects of the oceans. Existence of the oceans makes our life possible on Earth. Human civilization largely depends on the ocean resources for food, energy and security; transportation, navigation, and surveillance; climate, environment and weather conditions; industrial and commercial requirements. The ocean, being a fluid and an open thermodynamic system, has many similar properties as the atmosphere (Pickard and Emery, 1993), both, on the rotating frame of the earthas itpossesses several key dynamic properties (Pond and Pickard, 1993). Understanding of such properties is the subject of interest in the geophysical fluid dynamics. It helps to have a comprehensive knowledge on the ocean currents and waves, air-sea interaction, sea level variability, ocean heat content, thermohaline circulation, synoptic weather system, climate variability and its changes. Study of the chemical composition and trace material such as Ferrous, Nitrate, Carbon, and Oxygen available in the sea water, their variability and changes, formation and annihilation mechanisms constitute the subject of chemical oceanography. The study on the existence of life, such as phytoplankton, zooplankton, higher level of organisms in the food chain and their relationship with the aquatic environment are studied in the framework of ecosystem dynamics and biogeochemical cycle.

Understanding and prediction of the ocean state including chemical and biological properties of the ocean is very important as ocean has pivotal role in all biosphere, hydrosphere and other earth science regimes. Traditionally, the knowledge on this subject has been acquired by making systematic measurements of oceanographic parameters through in-situ sensors from the shipboard or stationary or moving platforms known as buoys, drifters and Argo floats and also sensors integrated with the satellite. The latter is known as the satellite remote sensing of the oceans which has the advantage over the in-situ measurements with its synoptic and repetitive characteristics and easy-to-maintain technology and commercial viability (Shutler et al., 2016). However, the procedure has a big limitation in terms of measuring all interesting properties of the oceans at all depths. Present technology only allows measuring limited number of properties of the ocean surface layer. The key oceanographic parameters that can be measured from the space include Sea Surface Temperature (SST), Sea Surface Salinity (SSS), Sea Surface height Anomaly (SSHA), Radiation Budget at the ocean surface, Sea Surface Roughness, Sea Surface Winds.

The following sections provide the historical perspective of the modern oceanographic measurements, basic principles and applications of ocean remote sensing from the Indian communities.

Historical Perspective of the Modern Oceanographic Measurements

Modern oceanographic research has a long history. It began from the Challenger Expedition between 1872 and 1876 with the aim to gather data on a wide range of ocean features including ocean temperature, seawater chemistry, currents, marine life and geology of the seafloor. For the expedition, HMS Challenger, a British Navy corvette was converted into the first dedicated oceanographic ship with its own laboratories, microscopes and other scientific equipment on-board (Thomson and Murray 2018). The data collected by the international expedition had provided several key findings. First time it provided the general nature of the ocean bottom morphology and topographical features and information of the depth up to 4,500 fathoms (about 8,200 m) instead of earlier 3,000 fathoms (about 5,500 m). The material composition of the sea floor was known to be denser than the composition of the continent. Such expeditions provided scientific explanation on the possibility of life in the dark zone of the ocean deeper than 1000 m and had provided information on the nature of the subsurface or deep ocean currents and temperature-salinity profiles. Since then, a number of international and national programs such as JGOFS (Joint Global Ocean Flux Study), ARMEX (Arabian Sea Monsoon Experiment), BOBMEX (Bay of Bengal Monsoon Experiment) and IIOE (International Indian Ocean Expedition, 1959-1965) were conducted to understand ocean circulation, inter-annual variability of oceanic parameters and ocean's coupled dynamics with land and atmosphere (Rao 2005). The contribution of Indian institutions and scientists in this endeavor was modest. Post-independence, several national importance institutions were established to carry out focused research on the subject namely National Institution of Oceanography (NIO), National Centre for Polar and Ocean Research - NCPOR (erstwhile NCAOR), National Institution of Ocean Technology (NIOT), Indian National Centre for Ocean and Information Services (INCOIS), National Center of Coastal Research (NCCR), various

Departments in the Indian Institute of Technology (IIT), University Centers and Teaching departments dedicated on this subject.

With pursuing efforts by international co-operations, expeditions and programs dedicated so far, only 60% of the ocean has been explored. Further, for realization of requirement of high frequency and synoptic measurements, continued efforts were made to measure oceanographic properties using satellite platform. The first ever dedicated oceanographic satellite was NASA's oceanographic satellite Seasat-A, which was launched into a polar orbit in 1978. Seasat-A was the first Earth-orbiting satellite to carry four complementary microwave experiments: the Radar Altimeter (ALT) to measure ocean surface topography; the Seasat-A Satellite Scatterometer (SASS) to measure ocean wind speed and direction; the passive Scanning Multichannel Microwave Radiometer (SMMR) to measure a variety of ocean surface and atmospheric parameters; and SAR to image the ocean surface, polar ice caps, and coastal regions (Evans et al., 2005).

While originally designed for remote sensing of Earth's oceans, Seasat-A had a large impact in many other areas, including solid Earth science, hydrology, ecology, and planetary science. Following Seasat, several Earth-observing missions were launched in the 1990s by the European Space Agency (ESA) and the National Space Development Agency (NASDA) of Japan. The first and second satellites by ESA were the European Remote Sensing satellites ERS-1 (1991) and ERS-2 (1995), which carried the Active Microwave Instrument (AMI) - a joint SAR / Scatterometer and Radar altimeter. The third Earth remote sensing satellite by NASDA was the Advanced Earth Observing Satellite (ADEOS, 1996), which carried the NASA scatterometer (NSCAT) and a passive Advanced Microwave Scanning Radiometer (AMSR). Today, Oceansat and Scatterometer series (SCATSAT, 2016) of Indian Space Research Organization (ISRO) and other satellite microwave ocean-observing systems are used for both research and operational applications (Barreti, 1984). Meteorological agencies throughout the world use both active and passive microwave observations in their numerical weather models and forecasts. Researchers studying global climate change use these data in ocean and atmospheric circulation models to study short- and long-term interactions of the atmosphere and ocean. In recent years, microwave sensor data is also being used to study sea and glacial ice, ocean, and land ecology and other non-oceanic applications.

Principles of Ocean Remote Sensing and Applications

Sea Surface Temperature (SST)

SST describes thermal state of the ocean. It is a key parameter of air-sea exchange of heat, moisture, and gasses. It drives evaporative loss of water and heat (latent heat flux); loss of heat due to the long wave radiation; sensible heat flux and various gas exchanges such as CO_2, O_2 etc. from the ocean surface. Oceans absorb solar short-wave radiation and emit energy mostly in the Infra-Red (IR) and MicroWave (MW) range. The emissivity of the ocean at these wavelengths is almost uniform at 0.98. Since this energy is emitted from the ocean surface without contributions from the suspended particulate matter of the water column, and further there exist atmospheric window on these spectral bands, such properties were explored to developed satellite sensors to retrieve SST from the polar orbiting or from geostationary platforms. Thus, at IR or MW range of the electromagnetic spectrum, water emits radiation which is captured by sensors on board satellites. These captured signals are from the surface, in fact from the skin of the ocean, and have value equal to the black body radiation times the emissivity of the water. After necessary atmospheric correction, the Skin Temperature of the ocean can be derived and then is converted to the SST (Schluessel et al. 1990). IR sensors have high spatial resolution but are obscured by clouds, while MW sensors have low spatial resolution but can measure SST through non-precipitating clouds. Modern SST data sets are thus combination of both IR and MW SSTs to have desired temporal and spatial resolution (Guan & Kawamura 2004). Typical SST accuracies are 0.5 K. Few examples of SST sensors are (with satellites in bracket): AVHRR (NOAA satellites), TMI (TRMM) and MODIS (TERRA/AQUA). Indicationof SST's AVHRR sensor and its background can be found in Casey et al., 2010. Extensive use of these satellite retrievals and blended products are done by numerous researches for investigating variability of the global and regional oceans, climate change and ecological studies.

Sea Surface Salinity (SSS)

Sea Surface salinity is the amount of salt content in the surface layer of the ocean. Typical values of salinity vary between 32 to 37 PSU (Practical Salinity Unit-1PSU is 1 gm. of salt per 1000 g water) in the open seas while it possesses a wider range in the coastal seas, from 0 to 32 PSU. Salinity together with the temperature determines the density of seawater, variation of which governs the circulation of seawater through different processes. Different terminologies are used for such phenomena such as convection, thermohaline circulation, instability and so on. Salinity of water mass gives information about its source of formation, and it is driven by net freshwater influx at the air-sea interface due to evaporation and precipitation, river influx and glacier melting from the Polar Regions. The oceanic environment with suitable salinity value provides diverse eco-regions suitable for specific aquatic plants and animals. The most trusted and conventional shipboard measurement of the ocean salinity has been carried out with the in situ CTD (Conductivity, Temperature and Depth) sensor at very high precision level. The conductivity of the sea water varies with variation of salinity; and this principle is employed in CTD sensors. Working principle of retrieving SSS is based on relationship between dielectric constant and salinity of seawater.

The satellite sensors such as SMAP, SMOS from NASA were made operational for the measurement of sea surface salinity of the global oceans. These are basically passive microwave radiometers which are being operated from the space to measure EM emission from the ocean surface at specific frequency bands which are highly sensitive to SSS. At the MW spectrum, the sea water of different salinity has different dielectric properties (co-efficient) which led to variation of the EM emissivity sensed by the satellite. Some extent of atmospheric correction is required for development of the geophysical model to function for the measurement of sea surface salinity. An insight into the satellite retrieval of SSS can be found in Klemas 2011.

Ocean Surface Winds

Ocean surface winds over global oceans drive heat and momentum transfer between the ocean and atmosphere, thereby forcing the surface circulation of the oceans. Sea surface wind is one of the main inputs for operational oceanography as well as climate studies in terms of improving weather forecasting using numerical weather prediction models (Bentamy et al., 2012; Mathew et al., 2012). Wind stress distribution over the ocean surface is an important factor for identifying areas of up-welling/down-welling. The curl of wind stress is helpful in identifying areas of cyclogenesis and their propagation and useful in several operational oceanographic applications such as water-mass transport and mapping of PFZ. Over a period of time, with the improvement in sensor technology, surface winds over the oceans are being measured by employing different sensors starting from wind anemometers fixed on moored buoys and ships to Radars and Space based scatterometers.

RADAR Scatterometers such as QuickScat, ASCAT, SAESAT, OSCAT and SCATSAT have been developed by different space agency to measure synoptic ocean surface wind field over the global oceans. RADAR Scatterometers are the active microwave sensors that measures the normalized scattering cross section generated at the satellite sensors by the constructive and destructive interference of the scattered energy from the ocean surface characterized by sea surface roughness at the order of few centimeters and equivalent to the RADAR wavelength *(frequency)* used for this purpose. This is based on the Bragg resonance principle.

One of the major applications of measuring ocean surface winds is deriving Ekman Currents. The wind blows across the ocean and moves its waters as a result of its frictional drag on the surface (Price et al., 1987; and Ralph and Niiler, 1999). Ripples or waves cause the surface roughness necessary for the wind to couple with surface waters. Once the wind sets surface waters in motion as a current, the Coriolis Effect, Ekman current transport and the configuration of the ocean basin (topography) modify the speed and direction of the current. There are two-components of a wind driven current, a directly-driven Ekman component and an indirect component, due to the divergence and convergence of the Ekman transport that either leads to piling up of water, creating a high-pressure system in the ocean or to a low-pressure system where surface waters diverge.

Sea Surface Height (SSH)

Sea Level is an essential climate variable. Ocean surface topography or sea surface topography, also called dynamic topography, is highs and lows on the ocean surface, similar to the hills and valleys of Earth's land surface depicted on a topographic map. These variations are expressed in terms of SSH relative to the Earth's geoid or ellipsoid. The main purpose of measuring ocean surface topography is to understand the large-scale circulation of the ocean.

SSH is calculated through altimetry satellites such as TOPEX Poseidon, JASON, SARAL etc., which determine the distance from the satellite to a target surface by measuring the satellite-to-surface round-trip time of a radar pulse (nadir distance). The satellites then measure the distance between their orbit altitude and the surface of the water. Due to the differing depths of the ocean, an approximation is made. This is called the Arbitrary Reference Surface (ARS). The Arbitrary Reference Surface is an estimated surface that is calculated to factor in the shape of the Earth. The general shape of the earth is spherical but flattened out at the North and South Pole. This approximated surface is called the reference ellipsoid. This enables data to be taken precisely due to the uniform surface level. The satellite's altitude then has to be calculated with respect to the reference ellipsoid. It is calculated using the orbital parameters of the satellite and various positioning instruments. The sea surface height is then the difference between the satellite's altitude relative to the reference ellipsoid and the altimeter range. The satellite sends microwave pulses to the ocean surface. The travel time of the pulses ascending to the ocean's surface and back provides data of the sea surface height.

One of the major applications of measuring SSH is deriving Geostrophic Currents. Sea water naturally tends to move from a region of high pressure (or high sea level) to a region of low pressure (or low sea level). The force pushing the water towards the low-pressure region is called the pressure gradient force. In a geostrophic flow, instead of water moving from a region of high pressure (or high sea level) to a region of low pressure (or low sea level), it moves along the lines of equal pressure (isobars). This occurs because the Earth is rotating. The rotation of the earth results in a 'force' being felt by the water moving from the high to the low, known as Coriolis force. The Coriolis force acts at right angles to the flow, and when it balances the pressure gradient force, the resulting flow is known as geostrophic. The direction of flow is with the high pressure to the right of the flow in the Northern Hemisphere, and the high pressure to the left in the Southern Hemisphere. The direction of the flow depends on the hemisphere, because the direction of the Coriolis force is opposite in the different hemispheres (Lukas and Firing,1984; Picaut et al.,1989).

Ocean Surface Features from Synthetic Aperture Radar (SAR)

The small scale processes (few meters to several km) occur in oceans that include eddies or isolated vortices called as meso-scale processes. Meso-scale processes play key role in driving the deep ocean circulations. The information of such ocean surface features can be measured by airborne and space-borne sensors called SAR and is useful for mapping eddies, fronts and ocean waves in different part of the global oceans. SAR is an active sensor that provides very high-resolution ocean surface roughness information by transmitting electromagnetic wave to the target and receiving it back, the receiver being in the same or in another airborne platform. By the time the transmitted signal reaches the receiver after back-scattering, the satellite or aircraft has moved further and hence receiver receives the signal at different position. These successive signals are stored and later processed using techniques of Signal Processing to reconstruct the landscape. This length difference between transmitter and receiver positions creates large synthetic aperture of antenna which gives better resolution compared to small physical antennas (Vincent 2015). SAR airborne systems are known to provide resolutions of the order of 10 cm.

Due to SAR's high resolution (typically 50-100 m), apart from mesoscale processes of ocean, many other ocean science problems can be addressed. One of good examples of SAR data usage is oil-spill detection (Brekke and Solberg, 2005). Oil spills are hazardous for oceanic ecosystem. The lack of small-scale surface roughness due to oil-spill or suspended material prevents the radar echo from the surface to retain sufficient strength, leading to low backscatter. Characteristics of such ocean having a layer of oil make it suitable to detect such spills using SAR data. The efforts are continuing to improve the algorithm to differentiate oil-spills from look-alike and oceanic fronts in global community. Other examples of SAR (satellites such as RISAT-1, Envisat, Sentinel-1 and NISAR (upcoming)) data usage are detection of ship, mapping of shallow-water bathymetry, sea-ice monitoring, high-resolution wind fields, detection of internal waves and eddies, coastal wave fields and monitoring ocean currents (Kerbaol and Collard 2005).

Chlorophyll Concentration (Ocean Chlorophyll)

Phytoplankton is a microscopic organism living in the upper sunlit layer of the oceans which floats on the ocean surface forms the base of oceanic food web (Sigman et al., 2012).Phytoplanktons are responsible for the primary production in the ocean. It creates organic compounds which in turn are used further by aquatic food chain. Phytoplanktons are usually not visible by human eyes, but it can be seen as large colored patch in remote sensing images due to presence of green pigment called Chlorophyll. During photosynthesis, chlorophyll absorbs sunlight mostly at blue and green bands. Their presence in abundance indicates the presence of fishes in the ocean.

Chlorophyll-a (hereafter Chl-a) concentration is a convenient index of measuring phytoplankton biomass in the oceans (Strickland, 1965; Cullen, 1982). Satellite remote sensing is a very useful method for measuring Chl-a over the global oceans. It is based on the absorption and scattering principles of sunlight from the water column at the blue and green spectral bands (Martin, 2014). The solar radiance that scattered back from the water column towards the satellite sensors (also called water leaving irradiance) is highly modulated by the atmosphere. Thus, signals reaching satellite sensors have all of such contributions due to the atmosphere. After correcting for the atmospheric effects, the Chl-a is estimated. Many studies have been done to target specific research problems such as to study coral reef near Andaman Sea (Mahendra et al., 2010), studies for identification of phytoplankton blooms and primary productivity over the global oceans. Chlorophyll concentration data along with other complimentary data such as SST can be used to monitor and study Potential Fishing Zone (PFZ), Ocean State Forecast,and Cyclone Trajectory, oil-spill, sea level riseand coastal ecosystem.

Coastal Zone Color Scanner (CZCS) on-board the Nimbus-7 satellite was the first successful multi-channel ocean color sensors operated during 1978-1986 and provided information on the spatial patterns of Chl-a. Subsequently, Sea-Viewing Wide Field-of-View sensors (SeaWIFS), Moderate Resolution Imaging Spectroradiometer (MODIS), Ocean Color Monitor-I (OCM) on-board the IRS-P4 and OCM-2 are examples of sensors working to give chlorophyll concentration data.

Conclusion

The paper discusses the description of various space based sensorsand their working principles which are important, for measuring few of the key parameters of the ocean surface. The use of data have been demonstrated for numerous applications such as mapping Potential Fishing Zone (PFZ), Ocean state forecast, Coastal zone Management and Climate assessment studies. Today, remote sensing provides many advantages over conventional techniques such as area averaging, repeated observations of a given location from the same angle and synoptic coverage. However, the procedure has a big limitation in terms of measuring all interesting properties of the oceans at all depths.Therefore, satellite derived data together with the data collected through in-situ measurements are used in the numerical models for providing ocean reanalysis.

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THE INDIAN GEOGRAPHICAL SOCIETY

Department of Geography, University of Madras, Chennai - 600 025

Conduct of 9th Talent Test - 2019 for Geography students on 23th January, 2019

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The Indian Geographical Society is organizing the state wide **Ninth Talent Test - 2019** for final year UG and PG students of the Geography Departments in Tamil Nadu on **Wednesday, the 23th January, 2019**. The Executive Committee of the Society has identified the following coordinators to organise this event successfully with the support of Principals of the respective colleges and Heads of Geography Departments.

Regional Coordinators

1**. Dr. G. Bhaskaran (Chennai Region),**
Assistant Professor, Department of Geography, University of Madras, Chennai - 600 005,
***Mobile**: 94444 14688, **E-mail**: grbhaskaran@gmail.com*

2. **Dr. R. Jegankumar (Central and Western Tamil Nadu)**
Head, Department of Geography, Bharathidasan University, Tiruchirappalli - 620 024,
***Mobile**:98947 48564, **E-mail**:* jegankumar@bdu.ac.in

3. **Dr. K. Balasubramani (Eastern Tamil Nadu)**
Assistant Professor, Department of Geography, Central University of Tamil Nadu,
Thiruvarur - 610 005, ***Mobile**:99440 60319, **E-mail**:* geobalas@gmail.com

The Heads of the Geography Departments to contact the coordinator/regional coordinators and conduct the Talent Test successfully.

General Information

1. Talent Test **will be conducted in English language only for PG students and in English and Tamil for UG students**for 1.30 hours consisting of 100 questions without any choice.
2. Syllabi for UG and PG talent tests are UGC NET Paper II & III respectively.
3. Final year UG and PG students of Geography are eligible for Talent Test.
4. The students should enroll their names with the concerned Head of the Geography Department on or before 21th January, 2019.
5. The co-ordinators would contact the Heads of nearby Geography Departments and send the representatives for conducting Talent Test.
6. The Head of the Geography Departments would collect the registration fee from the students of their Department and inform the coordinators accordingly.
7. Talent Test is scheduled on **23th January, 2019 (Wednesday) between 11.00 a.m. and 12.30 p.m.**
8. Registration fee for UG Students is Rs.50/- and for PG Students it is Rs.75/-. Only Cash should be collected from the interested candidates.

Details of Awards and Prizes

Prize	Award and Prize Amount	
	UG **The IGS Founder Prof. N. Subrahmanyam Award**	**PG** **Prof. A. Ramesh Award**
I	**Rs. 5,000/-**	**Rs. 7,000/-**
II	**Rs. 3,000/-**	**Rs. 5,000/-**
III	**Rs. 2,000/-**	**Rs. 3,000/-**

Prizes will be awarded to the winners of Talent Tests during *National Seminar* on Mapping, Modelling and Management of Natural Resources through Geoinformatics organised between 15 and 16 March, 2019 at Department of Geography, Bharathidasan University, Tiruchirappalli. All other participants will be given Certificate of Participation. Please visit IGS website for registration forms and further information: http://www.igschennai.org/

Dates to Remember

Last Date for the Enrolment: 21-01-2019 (Monday)

Date of the Talent Test: 23-01-2019 (Wednesday)

New Geography Departments in University and College in Tamil Nadu
1) Department of Geography, PSA College of Arts and Science for Women, Sollaikottai, Naickanahalli, Dharmapuri - 636 704.