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Research Paper

REMOTE SENSING AND GIS BASED STUDY OF LAND SUITABILITY EVALUATION IN COASTAL DOMAINS OF PUDUKKOTTAI DISTRICT, TAMIL NADU, INDIA

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This paper presents an approach for land suitability evaluation model by geomorphology and landuse/landcover mapping in parts of Pudukkottai district, Tamil Nadu using the state and art of remote sensing and Geographical Information System (GIS) as a powerful tool. Remote sensing images provide useful information and make many researchers to identify and interpret various geomorphic features/landforms and various landuse/landcover classes. Optical satellite images and SRTM - DEM were used for mapping of various geomorphic and landuse/landcover classes in this study. Various image processing techniques such as band ratioing, filtering and multi band enhancement techniques were applied on the raw images for the better identification and demarcation of various geomorphic and landuse/landcover features. Thematic maps such as geomorphology and landuse/landcover maps were prepared using GIS and geomorphological units and landuse/landcover classes were integrated and the area occupied by each landuse/landcover classes was calculated. The evaluation and utilization of landuse features according to their geomorphic setup has been carried out. Thus, this study gives an integrated approach for land suitability evaluation with the aid of remote sensing techniques and GIS. The methodology suggested here can be used to suggest landuse practices in various geomorphic units which are suitable for such purposes.

Keywords: Remote Sensing, GIS, Geomorphology, Landuse/Landcover, Land Suitability Evaluation

INTRODUCTION

Land suitability evaluation is one of the important studies for the sustainable environmental development. It is believed that the remote sensing images provide valuable information in identifying and mapping various geomorphic and landuse features based on the image interpretation keys and elements. Processing of digital satellite images give valuable information to the researchers, and these techniques are very important to delineate various geomorphic units and various landuse/landcover classes in a better way. Clawson and Stewart (1965) have stated that the dynamic situation, accurate, meaningful,

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satellite data on land use practices are essential for reliable information and future action in appropriate spatial landuse practices.

Underlying causes of landuse changes leading to land degradation include rapid economic development, population growth and poverty (Giri *et al.,* 2003, Bolland *et al.*, 2007). The land use/ cover has been greatly affected by recent government policies that aim to balance the need to encourage rural development with geomorphological stability (Xu and Wilkes, 2004; Xu and Ribot, 2004). Geographic information system plays a very important role in the preparation and factorisation of various thematic maps and integrating all the information which allow user to understand in connection to the real world condition (Adeniyi *et al*., 1999, Singh, 1989). The aim and objectives of the present study is to prepare various thematic maps on 1:50,000 scale in parts of Pudukkottai district of Tamil Nadu using remotely sensed data, SOI toposheet, existing maps coupled with other collateral data. Base map and Drainage map have been prepared from the Survey of India (SOI) toposheet on 1:50,000 scale. Thematic maps such as Geomorphology, Landuse / Landcover maps are prepared using IRS 1D LISS-III satellite data with the help of visual interpretation techniques. Using the digital image processing techniques the LISS III data was enhanced to get reliable interpretation and SRTM data was used to create 3 dimensional visualisation of the area and to prepare shaded relief maps to update various geomorphic units and landuse/landcover classes as thematic maps. Further, spatial overlay analysis is performed to integrate geomorphology and landuse/landcover to optimise the each and every landuse/landcover over geomorphic features.

Table 1: Details of Data Products Used in this Study

Toposheets	SOI Toposheet No	58 N/4 & N/8
	Scale	1:50,000
Satellite images	Product 1	
	Satellite	IRS 1D
	Sensor	LISS III
	Path and Row	102/67
Date of Acquisitio	31 Aug 2001	
	Path and Row	102/67
Date of Acquisitio	31 Aug 2014	
	Resolution	23.5
Scale	1:50,000	
	Product type	Geocoded
	Product 2	
	Satellite	SRTM (Shuttle Radar Topographic Mission)
	Resolution	30 mts

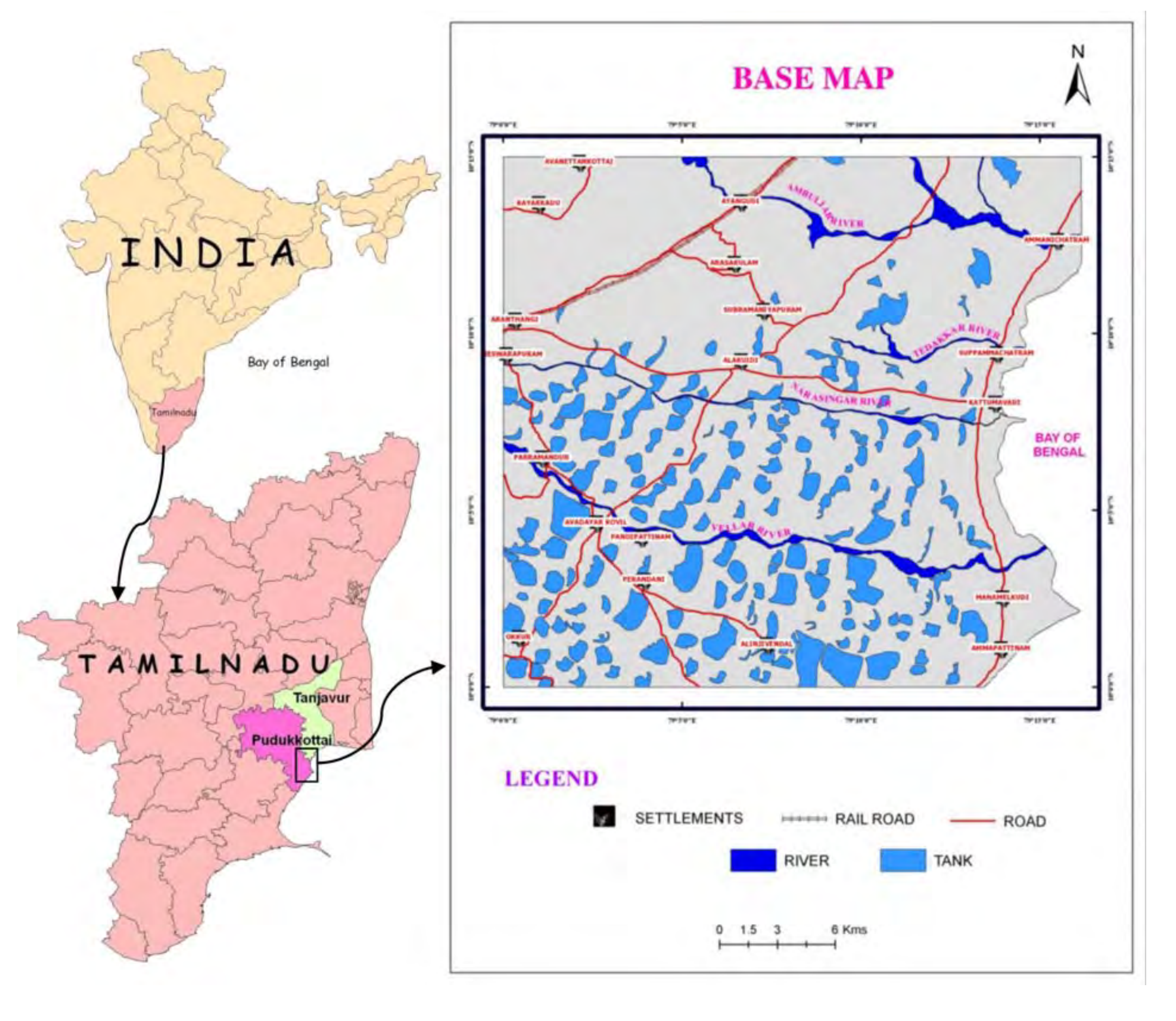
DATA PRODUCTS

The data products used for the study comprised both satellite data and the other conventional data collected from various departments. The datasets used for the present study is summarised in Table 1.

STUDY AREA

The study area comprises the part of Pudukkottai district of Tamil Nadu state. It is covering an area of nearly 4460 sq. km and the study area fall in the SOI topographic sheet no 58 N/4 and N/8 and the study area is bounded by the latitudes $10^0$02'30" to $10^0$15'00" and longitudes $79^0$02'30" to $79^0$17'30". Ambuliar and vellar are the prominent rivers flowing at Northen and Southern part respectively in the study area. Pudukottai district is a major tourist centre (Pudukkottai Fort and Museum) and the area is well connected by roads and railways from Trichirapalli is the city which connects all major towns by roads, railways and airlines via Chennai (Figure 1). Physiographically major part of the study area is

Figure 1: Key Map Showing The Location Of The Study Area



a plain terrain and with a Butte in the northern part of the study area.

Regional Geology

The study area consists of three types of formations. In the North western part of the study area mainly consists of lateritic formations. The western and central part of the study area is covered by Quaternary alluvium and fluvial sediments and eastern part consists of marine formations (Figure 2). Based on the regional geological information the suggested land use practices were made in appropriate coastal geomorphic domains.

Hydrogeological Conditions

In most places Groundwater is available as fresh at a depth within 6 to 7 m and beyond 7 m it is saline. That too the fresh water available within 6 to 7 m depths dries up quickly within 2 to 3 months after monsoon. There is acute drinking water shortage felt in most part of the year. Hydrogeologically the district can be classified as Omtofoir zones as detailed below: There are four Ground water zones available.

Shallow Fresh Zones

The shallow fresh zone areas are covered by sand dunes, beach ridges, pockets of strand plains, pockets of natural levees, pockets of Palaeo channels, pockets of pediments and valley fills in the crystallines and tertiary sand stone areas. The depth of water level varies from few cm to 5m the deeper aquifers are saline.

Deep and Confined Fresh Water Zones

It occurs in the northern part of the district in Thiruvadanai Taluk. The thickness of the cretaceous aquifer is in the order of 20 to 30 M. This is underlined by crystalline basement. In the artesian belt area of Thiruvadanai Taluk of Ramanathapuram District, fresh ground water is available at a depth range of 350 m – 450 m in and around Thiruvadanai, Neerkundram, Vellaiyapuram and in some other places of Thiruvadanai Taluk.

Moderate Quality Groundwater Zone

This occurs in certain pockets of river course, pockets of Palaeo channels, parts of pediments and valley fills and in major parts of stand plains.

Saline Water Zones

This is marine and fluvio-marine origin. This formation explored up to 780 m is found to the unsuitable for any purpose.

Mineral Resources

Almost along the entire Tamil Nadu coast bundles of beach ridges are observed to a breadth of 2-40 km from the shore line. These beach ridge complexes are potential sites for the placer mineral deposits which are being mined in many parts of Tamil Nadu coast. Currently, exploration studies are going on along the entire Tamil Nadu coast for locating economically viable placer mineral deposits by the Government agencies. Deltas present in the study area which are the favorable zones for the hydrocarbon occurrence. Flood plains present in the area are favourable for Groundwater prospecting and they act as good recharge zones. Aquaculture in the area is also economically viable.

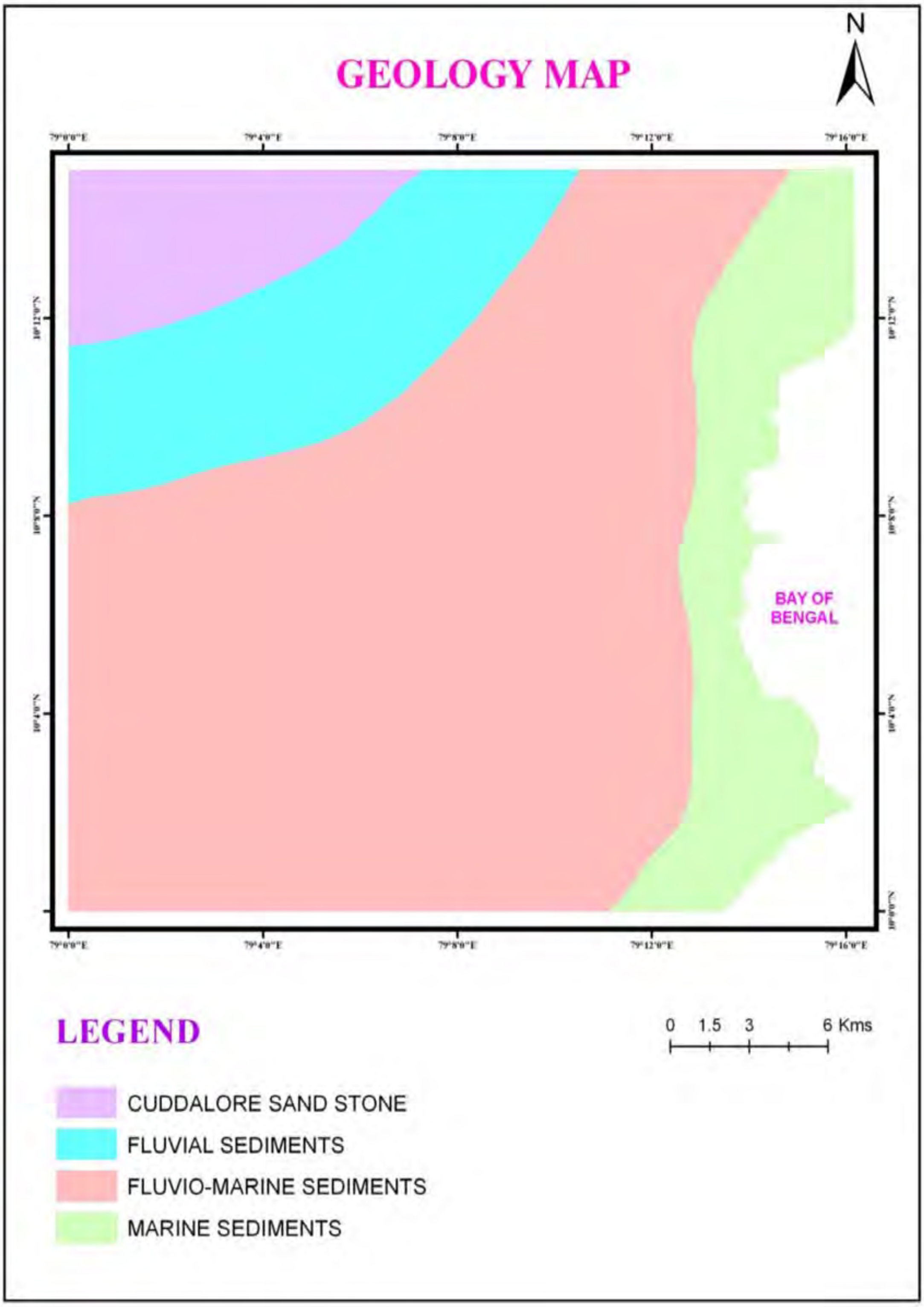
Present Environmental Problems

The following environmental problems are being faced in the study area:

Soil salinity due to salt pan, salt water intrusion, aquaculture and also over exploitation of ground water along the coast.

Degradation of coast.

Figure 2: Map Showing The Geology Of The Study Area



Stagnation of ground water movement resulting swampy environment.

Therefore based on the above information it is realised that the mapping of landuse/landcover and geomorphological units are vital process to assess and evaluate the appropriate landuse practice in specific geomorphic setup. Care was taken while interpreting the landuse/landcover and geomorphic units and the it was compared with the high resolution Google Earth image of the study area.

METHODOLOGY

The following step by step procedure was adopted in identifying the various geomorphic features and land use and land cover pattern. Based on the digital processing and visual interpretation of the IRS – 1D (LISS III) geocoded imagery, the following thematic maps were prepared, they are geology map, geomorphology map and Landuse/ Landcover map.

From the Survey of India toposheet, the base map has been prepared. From the Geological map of Tamil Nadu (prepared by Geological Survey of India) and satellite data, the geological map of the area was prepared (Figure 2). The overall methodology adopted in this study is presents in the flowchart (Figure 3).

Digital Processing of Satellite Images

Figure 3: Methodology Flow chart

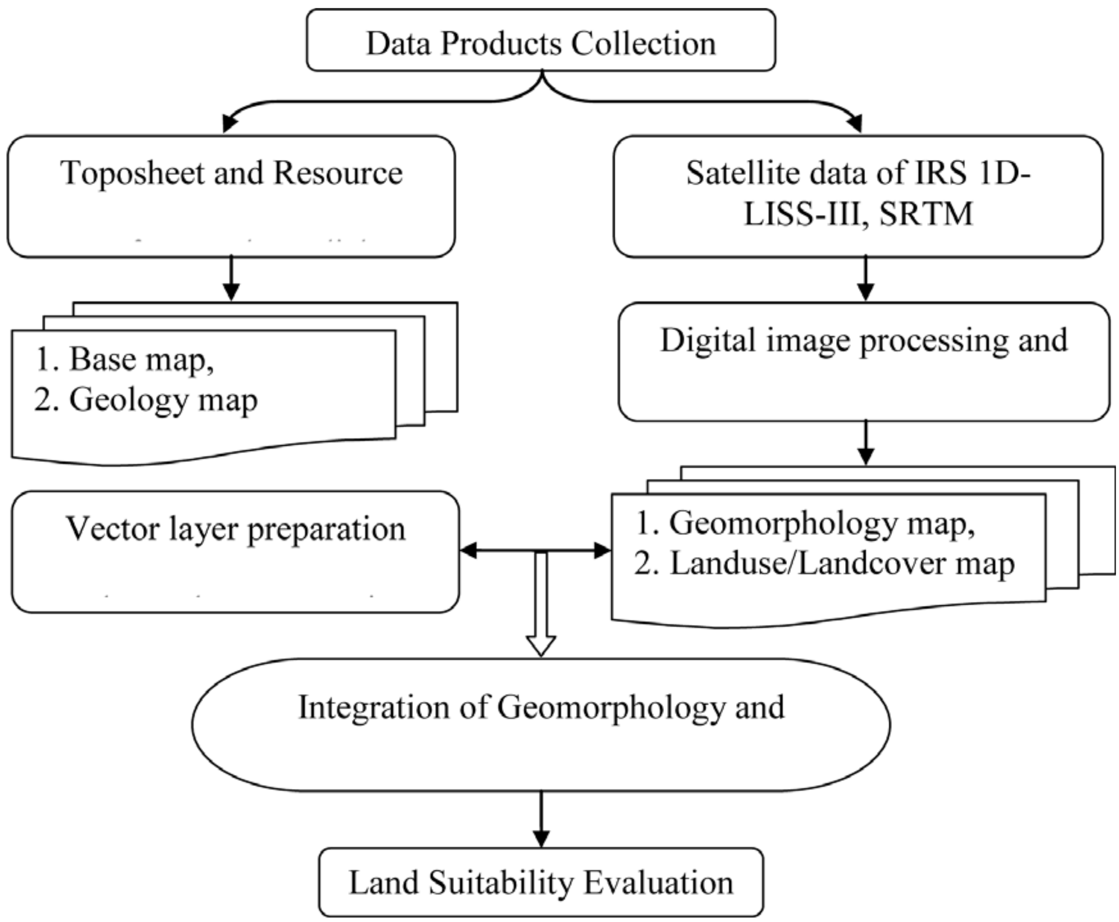
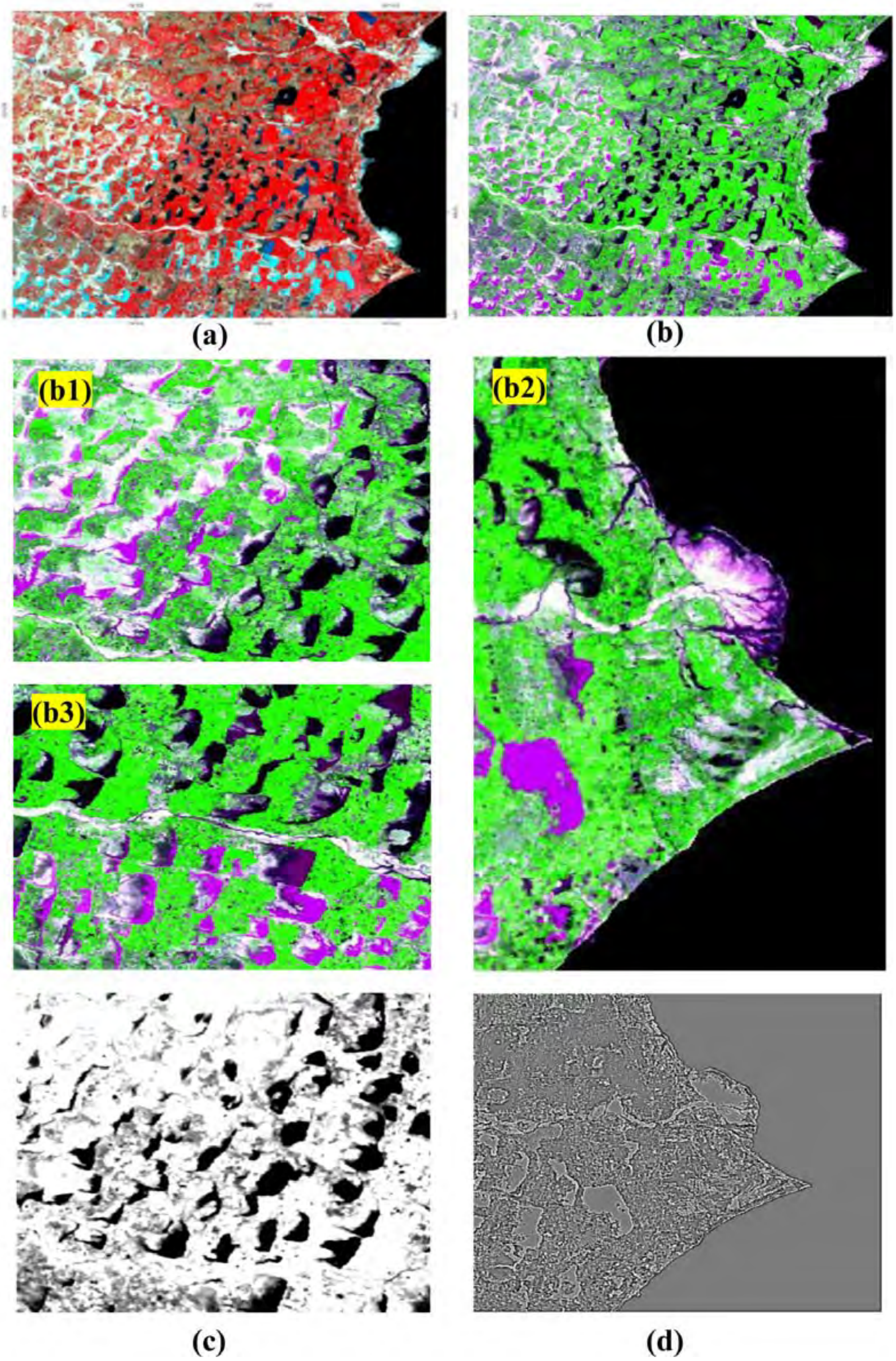


Figure 4: (a) Raw FCC image of Landsat TM, (b) PCA image: (b1), (b2), (b3) – subset of PCA image, (c) Lowpass filter image subset and (d) Highpass filter image subset



The IRS 1D LISS III FCC of path 102 and row 67 with 30 x 30 m resolution was used for digital image processing. Three bands have been used to get the FCC, they are blue band (0.45 – 0.52 μm), green band (0.52 – 0.60 μm) and red band (0.63 – 0.69 μm). The LISS III data has been used for this study has the dramatic improvement in the interpretation. The advantage of this LISS III imagery is the features such as agricultural field pattern that was indistinct on the MSS imagery are clearly seen on this LISS III imagery.

The blue – green water of the lake, river and ponds in the scene has moderate reflection in the bands 1 and 2 (blue and green), a small amount of reflection in band 3 (red) and virtually no reflection in bands 4, 5 and 7 (Near Infra Red, Mid Infra Red), reflection from the roads and urban streets is least in band 4 and overall reflection from the agricultural crops is highest in band 4. The image enhancement procedures are applied to image data in order to more effectively display or record the data for visual interpretation. Normally, image enhancement involves techniques for increasing the visual distinctions between features in a scene (Lillisand, 2007). There are different enhancements techniques have been adopted to get additional features compared to the raw data. Various other image processing techniques such as contrast manipulation, filtering techniques, band ratioing, and principal component analysis were applied to the raw data to emphasize various features distinctly (Figure 4). DEM wrapped by False Color Composite, shaded relief maps were prepared from the SRTM DEM data (Figure 5). These techniques provide very good information on topographic analysis which helps in fine tuning various geomorphic features.

Thematic Map Preparation

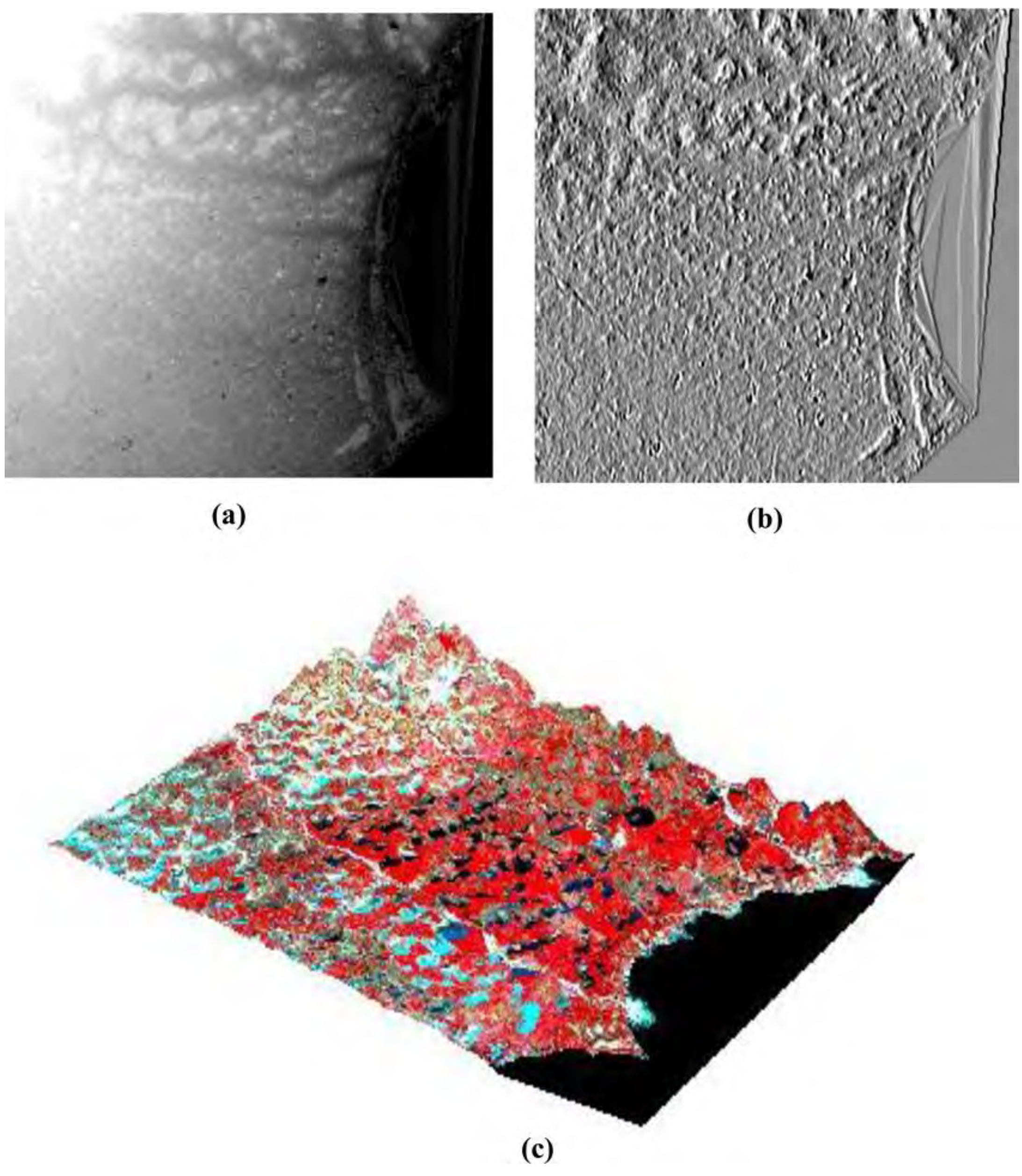
Thematic map are "specific purpose map" which contain information about a single theme or subject. The themes may be qualitative or quantitate. For the present study various thematic maps have been prepared. They are geology map, geomorphology map and land use land cover map, etc., these thematic maps were prepared at 1:50,000 scale by following the technique of visual interpretation with the use of interpretation keys such as tone, texture, size, shape, associated feature etc. The geocoded satellite data of IRS ID were used for the thematic map preparation.

Geomorphic Mapping

Geomorphic Mapping involves the identification and characterisation of the fundamental units of the landscape. Geomorphic units are defined as an individual and genetically homogenous landform produced by a definite constructional and destructional geomorphic process (Thornbury, 1995). Each part of the land surface is the end product of an evolution governed by parent geological material, geomorphic processes past and present climate and time. Detail information on geomorphic units and their processes in an area is very useful in evaluation, planning and management of the land resources, environmental planning and developmental activities.

The remote sensing technique have become the most efficient tools for Geological, Structural, Geomorphological studies and their mapping because of its synoptic view, multispectral and multi-temporal capabilities. The geomorphic units have specific set of characteristics that determine its image signature. High resolution satellite data provides reliable source of information to

Figure 5: (a) SRTM DEM data of the study area, (b) Shaded relief map (Elevation-450, Azimuth-2700), (c) FCC wrapped over SRTM DEM



delineate and generate comprehensive and detailed inventory of geomorphic units in an area. SRTM DEM provided better understanding of various geomorphic features.

The major geomorphic units identified from the given study area by visual interpretation techniques of satellite image (Figure 6) includes; mesa, butte, uplands, pediments, gullied/ ravenous land, river, paleo-channels, floodplains, interlobal depressions, deltaic plains, beach ridges, palaeo-swales, supra tidal flats, inter tidal flats, creek, protruding delta, and mangrove swamps.

Landuse/Landcover Mapping

Land use Land cover assessment is one of the most important parameters to meaningfully plan for land resource management, Information on land use land cover also provides a better understanding of the cropping pattern and the spatial distribution of fallow lands, forests, waste lands, surface water bodies, which is vital for developmental planning.

Land use changes are due to the natural and human activities, it can be observed using current and archived remotely sensed data (Luong, 1993). The information on landuse / landcover patterns, their spatial distribution and changes over a time scale are prerequisite for making development plans, landuse planning and land management strategies hold key for development of any region (Anon, 1992). For the last thirty years, remote sensing techniques at broad spatial scales together with sequential maps have been used to model and monitor land cover change (Lambin, 1997). Remote Sensing and GIS are the two mutually compatible technologies, can be used more effectively in natural resource management. The timely accurate and up to date information on landuse/landcover can be obtained from various satellites based high resolutions remotely sensed data on a cost effective basis at a shortest possible time. Landuse/Landcover map of the study area is prepared in 1:50,000 scales (Figure 7) includes various landuse/landcover classes such as, towns, villages, crop land, plantation, mangroves, salt affected land, water logged area, marshy/swampy area, gullied/ravenous land, land with scrub, land without scrub, sandy area, river/stream, canal, tanks, tanks with energy plantation and salt pan.

After the preparation of all the thematic layers by visual interpretation, using the image processing techniques the updation of the features have been made for each and every layers, viz., lithology, geomorphology and Landuse/Landcover.

RESULTS AND DISCUSSION

Overlay Analysis

The thematic layers prepared are converted to vector form by a series of steps such as geo-referencing, topology generation, error correction, and updating of features was done. As this study aims is to analyze and evaluate the land suitability, thematic maps of landuse/landcover and geomorphology were taken in to the GIS environment for integration. Using overlay analysis these two thematic maps were integrated and the resulting integrated output map consists of geomorphology and landuse/landcover features in various combinations (Figure 8). The attribute of the integrated output were carefully extracted as per the landuse/landcover classes in each geomorphic units.

Land Suitability Evaluation

After the integration of geomorphology and landuse/landcover maps, the areas occupied by each landuse/landcover class in various geomorphic units were calculated. This step gives us the descriptive assessment of landuse/landcover classes over the geomorphic units, the percentage of area occupied by each landuse/landcover over each geomorphic unit are tabulated (Table 2). From the analysis, it is found that the geomorphic features like mesa, butte, and upland are having waste land 18.19%,

Figure 6: Geomorphological Map of the Study Area

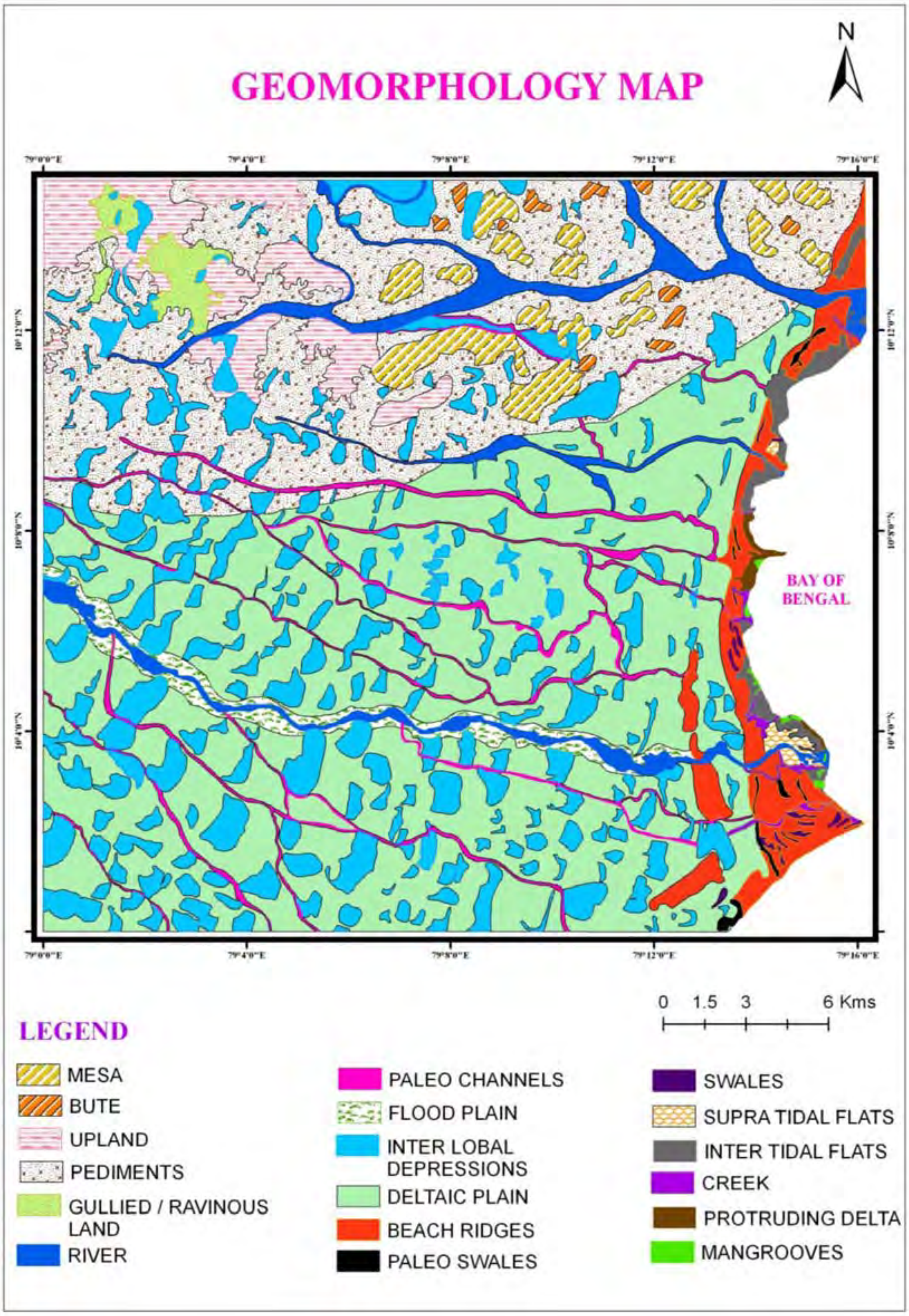


Figure 7: Landuse / Landcover Map of the Study Area

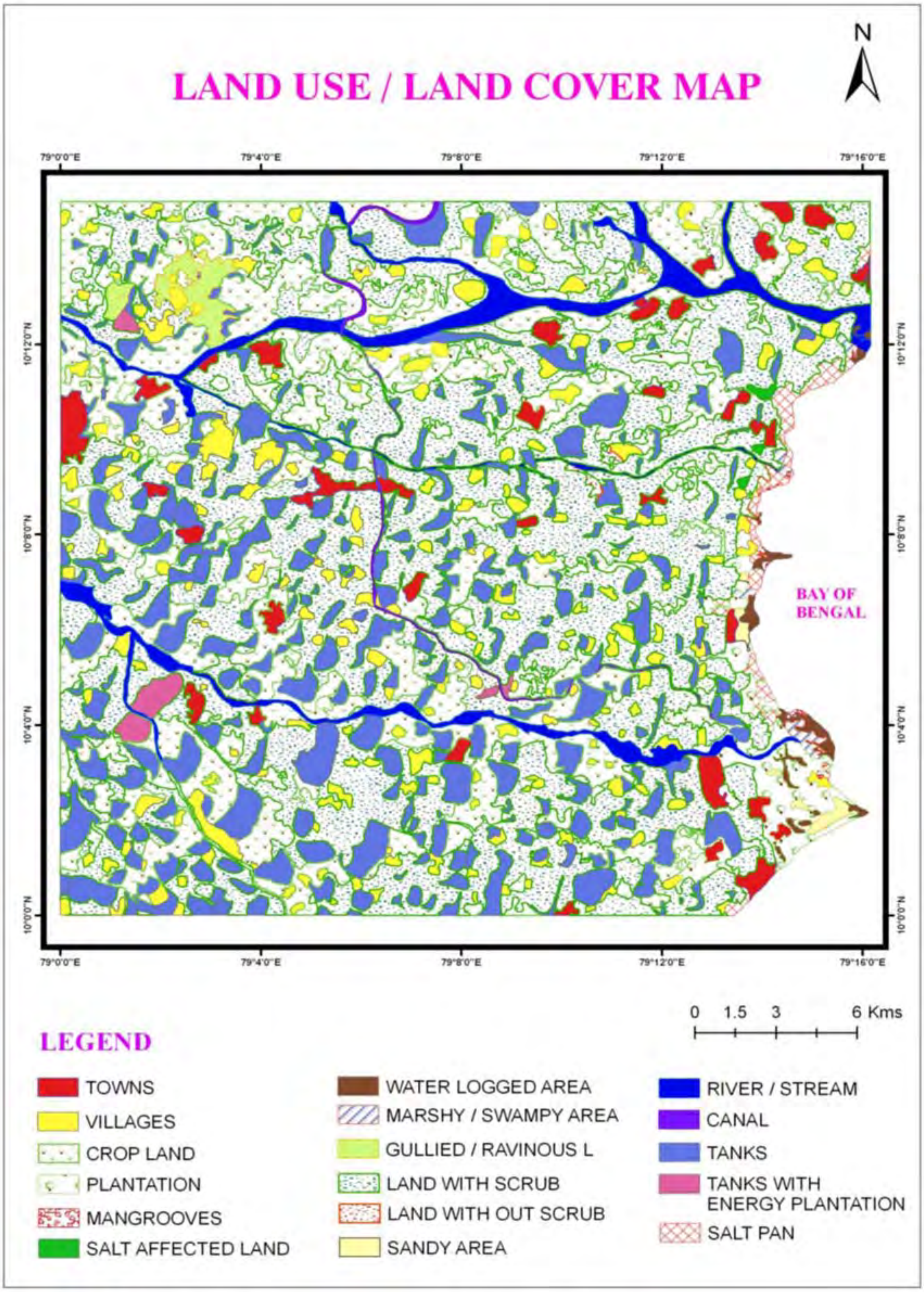


Figure 8: Integrated Output Of Geomorpholohy and Landuse / Landcover Maps by Overlay Analysis

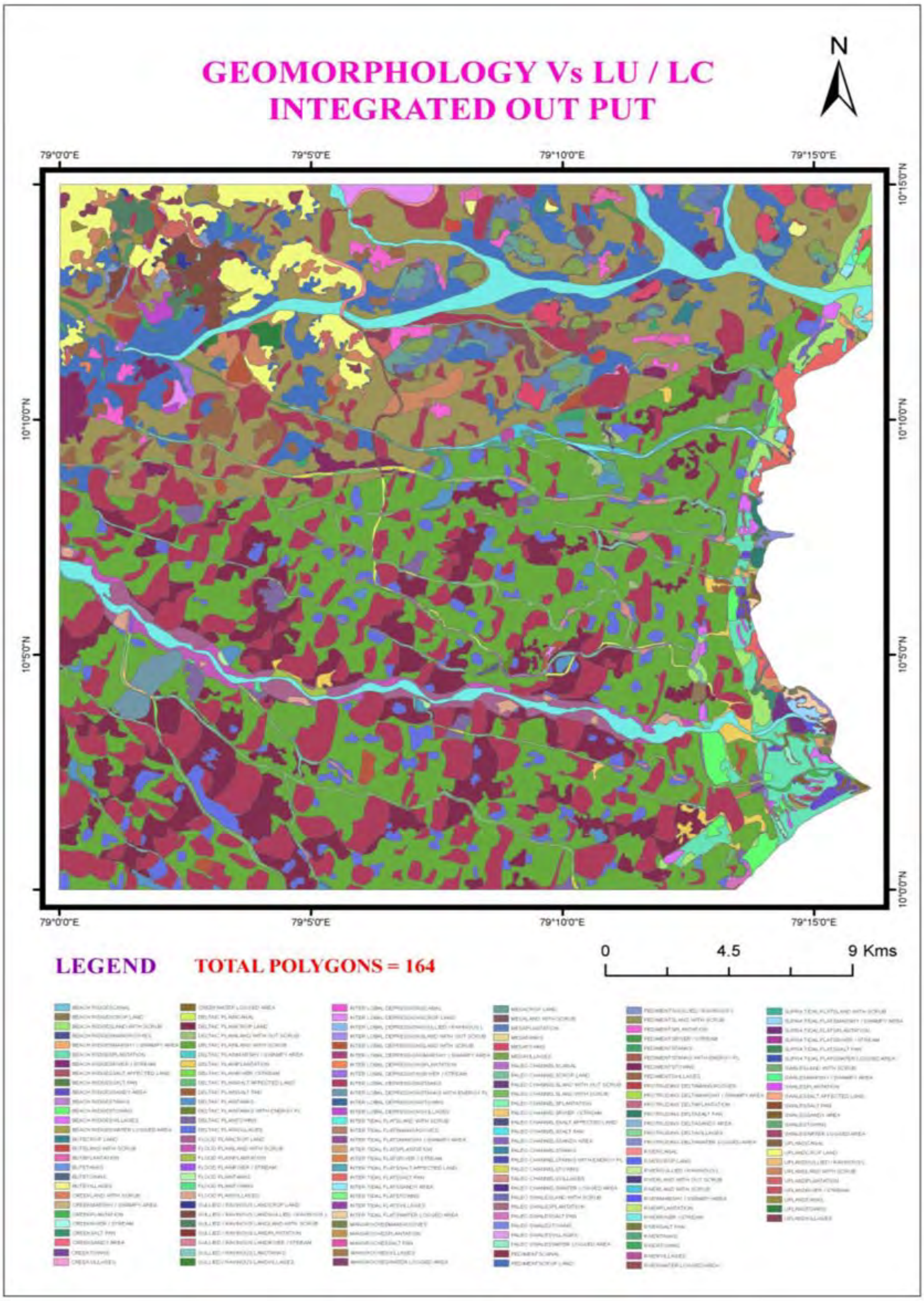


Table 2: Percentage Of Area Occupied By Each Landuse / Landcover Over Each Geomorphic Units

GEOMORPHIC UNITS	AREA		LAND USE						LAND COVER										
			TOWNS	VILLAGES	CROP LAND	PLANTATION	CANAL	SALT PAN	MANGROOVES	SALT AFFECTED LAND	WATER LOGGED AREA	MARSHY / SWAMPY AREA	GULLIED / RAVINOUS LAND	LAND WITH SCRUB	LAND WITH OUT SCRUB	SANDY AREA	RIVER / STREAM	TANKS	TANKS WITH ENERGY PLANTATION
			LANDUSE / LAND COVER AREA (Sq.Kms)																
			22	44	146	31	3	6	.08	1	4	2	6	319	1	2	29	131	4
	In sq.km	%	PERCENTAGE (%)																
MESA	24.44	3.59	15.82	18.51	22.58	24.90	-	-	-	-	-	-	-	18.19	-	-	-	-	-
BUTTE	3.67	0.54	9.18	15.73	26.01	30.86	-	-	-	-	-	-	-	18.20	-	-	-	-	-
UPLAND	34.30	5.04	3.08	5.50	57.66	5.33	0.85	-	-	-	-	-	1.13	23.25	-	-	0.21	3.08	-
PEDIMENTS	156.8	23.06	4.06	5.34	27.22	3.30	0.24	-	-	-	0.36	-	0.60	57.13	-	-	0.72	1.06	0.36
GULLIED / RAVINOUS LAND	8.19	1.20	-	4.04	7.92	0.58	-	-	-	-	-	-	57.04	29.00	-	-	-	1.41	-
RIVER	30.25	4045	-	0.92	0.08	-	3.00	0.10	-	-	0.72	0.44	-	0.34	5.39	-	86.87	2.14	-
PALEO CHANNEL	21.25	3.12	3.60	10.85	16.64	0.76	2.00	0.20	-	0.35	0.10	-	-	61.83	0.39	0.13	0.95	1.75	0.46
FLOOD PLAIN	13.12	1.93	1.02	10.47	51.30	3.79	-	-	-	-	-	-	-	31.18	-	-	0.80	1.44	-
INTER LOBAL DEPRESSION	132.7	19.52	-	0.76	1.90	0.08	-	-	-	-	-	-	-	3.18	-	-	0.47	91.29	2.31
DELTAIC PLAIN	285.2	27.24	1.85	7.62	22.06	-	0.41	0.11	-	-	-	-	-	64.11	0.30	-	-	-	-
BEACH RIDGES	26.71	3.93	14.92	6.45	1.40	37.59	0.34	1.58	0.13	0.15	3.11	1.70	-	26.75	-	5.06	0.05	0.75	-
PALEO SWALE	16.02	2.36	6.59	4.23	-	28.34	-	20.85	-	-	15.59	-	-	-	24.40	-	-	-	-
SWALES	14.76	2.17	14.49	-	-	33.19	-	0.64	-	0.78	15.23	2.16	-	11.99	-	21.51	-	-	-
SUPRA TIDAL FLATS	1.804	0.27	-	-	-	45.00	-	1.87	-	-	5.67	46.49	-	0.97	-	-	-	-	-
INTER TIDAL FLATS	6.86	1.01	0.92	0.36	-	7.06	-	59.98	2.20	0.05	-	4.13	-	8.32	-	3.85	0.02	-	-
CREEK	1.99	0.29	3.83	0.03	-	33.39	-	16.94	-	-	28.51	8.68	-	6.63	-	1.98	-	-	-
PROTRUDING DELTA	1.365	0.20	-	0.88	-	0.41	-	48.32	0.52	-	-	3.81	-	-	-	1.61	-	-	-
MANGROOVES	0.512	0.08	-	1.77	-	4.53	-	18.50	-	-	22.89	52.31	-	-	-	-	-	-	-

18.20%, 23.25% respectively. In order to escape from natural calamities like tsunami, flood, cyclone and other natural hazards we can suggest the people to adopt their habitations in those areas, though the area is in coastal domain it is much safe for natural disasters. The pediment areas are having 57.13 % waste land, the people can use it for plantations. The paleo-channels and floodplains are having wasteland 61.83% and 31.18%, respectively. Since these areas are having good water prospecting zones and more fertile lands they can be effectively used for cultivation. In the deltaic plain areas, the waste lands are occupying 64.11%. By understanding the drainage condition and nature of the soil we can go for the agricultural activities. In the beach ridges 26.75% waste lands are occupying. In order to stabilize the beach ridges we can do nourishment with plantations and which can protect the village/people from natural hazards like tsunamis, flood, etc.

From these results the similar kind of landuse/landcover practices can be followed for natural resource management and geo environmental development for the areas having the similar geomorphic set-up.

CONCLUSION

This study reveals that the integrated geomorphology and landuse/landcover analysis using the state of art remote sensing and geographic information system, can be a powerful tool for land suitability analysis. Remote sensing images provide useful information and make many researchers/earth scientists to identify and interpret various geomorphic features/units and various landuse/landcover classes. Various image processing techniques such as band ratioing, filtering and various multi band enhancement techniques were applied on the raw images for the better identification and demarcation of various geomorphic and landuse/landcover features. The enhancement techniques suggests that credibility and importance of digital image processing for improved mapping and interpretation of thematic layers in this study. An evaluation and utilization of landuse features according to their geomorphic setup was prepared, which suggests that the areal coverage of various landuse/landcover classes in various geomorphic units. The current landuse/landcover practice is best understood and the future development of landuse plan can effectively be taken from the integrated output in the study area. Thus, this study gives an integrated approach for land suitability evaluation with the aid of remote sensing techniques and GIS. The methodology adopted here can be used to suggest similar kind of landuse practices in the similar geomorphic set-up. It is also clear that, how the parcel of land can be effectively utilised for the welfare of human beings in different ways.

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