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Spatio-temporal analysis of land use and land cover changes in the Little Andaman Island, Andaman, India using geospatial techniques

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Abstract: Land Use and Land Cover (LULC) changes play an important role while planning for sustainable development of an area. Present study examines the spatial and temporal dynamics of LULC changes in the Little Andaman Island, Andaman, India, using remote sensing and Geographical Information System (GIS) techniques for a period of past 41 years. Landsat satellite data of 1976, 1989, 2005 and 2017 were used to investigate the changes. LULC classes mapped are forest, built up, mangrove, coral reefs, creek/river, sandy area/beach/sand dune and mining area. Little Andaman is mostly covered by forest (83.29 %) in 2017 and remaining 16.71% area is under other different classes. Results show that forest area has gradually decreased from 87.59% (623.65 km^2) in 1976 to 83.29% (593 km^2) in 2017 whereas the built up area which occupied about 16.54 km^2 (2.32%) in 1976 has gradually increased to 42.58 km^2 (5.98%) in 2017. Built up area is observed on the eastern side of the island and has increased due to increasing population and associated infrastructural development, agriculture development, establishment of permanent tsunami shelter and tourism development. The findings of this study are intended to contribute to effective and appropriate decision-making with respect to resource management and in preparing holistic island development plan.

Keywords: Land Use and Land Cover change, Little Andaman, Island Coastal Regulation Zone (ICRZ), GIS

1. Introduction

Land Use and Land Cover (LULC) changes have attracted wide attention due to its importance in global and regional environmental change (Turner et al., 1990; Liu et al., 2003). The LULC changes of an area reflects the assimilated product of the relation between natural environment and human activity (Mahapatra et al., 2013). The land cover is defined by the attributes of the earth's land surface and immediate subsurface, including biota, soil, topography, surface and groundwater and human structures, whereas land use is defined by the purposes for which humans exploit the land cover (Lambin et al., 2003). Anthropogenic activities such as destruction of forest, infrastructure development etc. are continuously altering the environment at alarming rates, magnitudes, and spatial scales (Turner et al., 1994). A better understanding of LULC change is of crucial importance to the study of global environmental change (Foley et al., 2005). Information on land use and land cover in the form of maps and statistical data is crucial for planning, management, and utilization of land for various purposes (Roy and Giriraj, 2008; Mahapatra et al., 2013).

Remote sensing and Geographic Information Systems (GIS) are powerful tools to derive accurate and timely information on the spatial distribution of LULC changes (Rawat and Kumar, 2015; Reis, 2008). Orbital remote sensing technique are used to study coastal zone due to it's synoptic, multi-spectral and repetitive coverage (Nayak and Bahuguna, 2001). On the other hand, GIS techniques are utilized to store, retrieve, and handle large datasets of heterogeneous origin and to represent these in visual format (Burrough and McDonnell, 1998; Fabbri, 1998). Satellite remote sensing data and GIS techniques have been utilized in numerous studies for coastal land use and land cover mapping and monitoring in Andaman island, India (Mageswaran et al., 2015; Yuvaraj et al., 2014; Prasad et al., 2010).

In this study, the LULC changes in Little Andaman were investigated using remote sensing and GIS techniques. This assessment would assist the Andaman Administration in policy formulation for land use planning and preparing island management plan.

2. Study area

The Andaman and Nicobar Islands are the largest archipelago system in the Bay of Bengal. The northern group of islands is called the Andaman group which has an area of 6408 km^2, whereas southern group of island is called Nicobar group covering 1841 km^2 area (Jayaraj and Andrews, 2005). The study area, i.e., Little Andaman is the southernmost island of the Andaman group of islands and is the fourth largest island of that group. Little Andaman is located between 10°30' to 10° 54' N and 92° 29' to 92° 31'E and at a distance of 120 km away from Port Blair, the capital of Andaman and Nicobar Islands (Figure 1).

The total geographical area of the Little Andaman is 73,799 ha, out of which 70,365 ha (95% of geographical area) is reserved forest area, including 50,323 ha (68 % of geographical area) as a tribal reserve area (Department of Environment & Forests, Andaman and Nicobar Islands, 2011). According to Census of India (2011), Little Andaman Tehsil consists of 16 inhabited and 3 uninhabited villages which cover an area of 34.34 km^2 area with total population of 18,823 (9964 males and 8859 females). Apart from the settlers, tribal people such as Onges and Nicobarese live within this island.

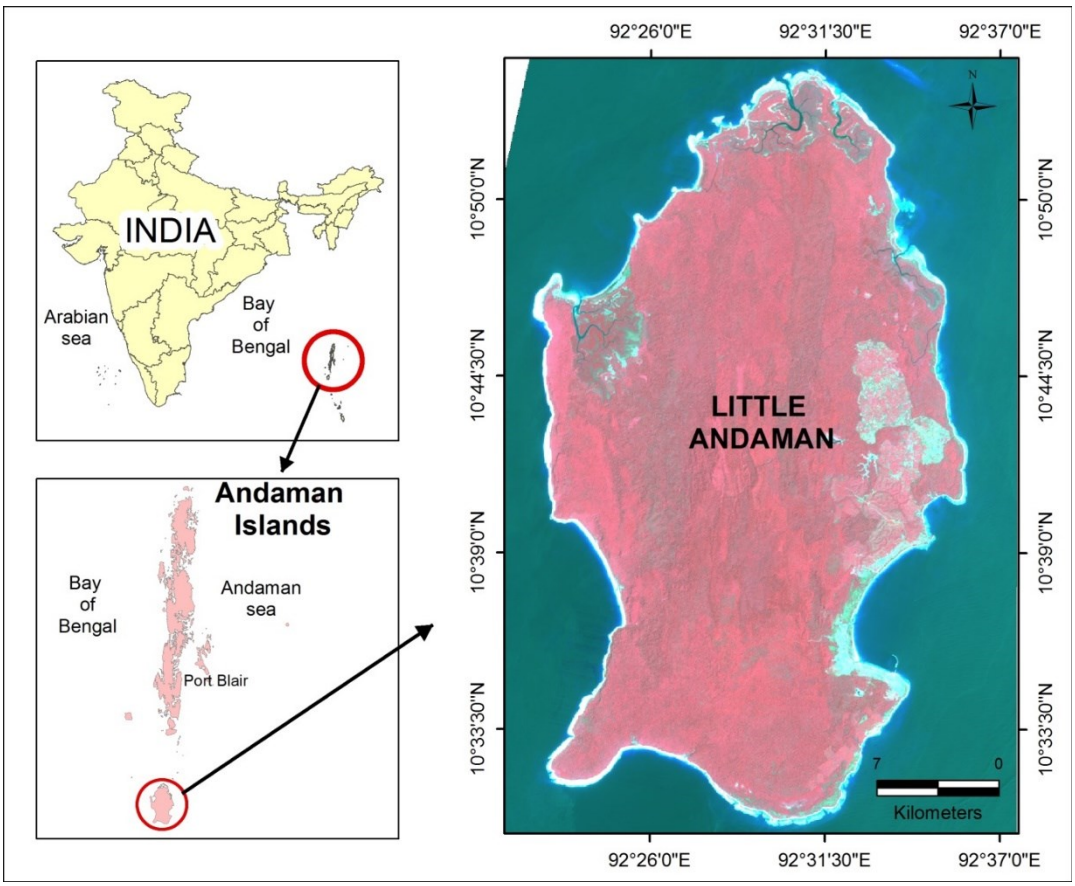

Figure 1: Study area

The island has tropical climate with very little variation in temperature. The mean maximum temperature is 30°C and the mean minimum is 23°C. Rainfall is received from both southwest (May to October) and northeast monsoons (November to December). Average annual rainfall is 3000 mm. The general topography of the island is undulating. The central and southern portions of the island are hilly with the highest point rising to 210 m above sea level, whereas the north and northwestern portions show low elevation. Hut Bay and Dugong Creek in Little Andaman island are two Ports notified under the Indian Ports Act, 1908. This island has a waterfall, dam, beautiful beaches, coral reef, palm oil plantation, coconut plantation etc. which attract tourists.

3. Materials and methods

Multi-temporal satellite data of Landsat-2 MSS of 1976 with a spatial resolution of 60 m, Landsat-5 TM of 1989 with a spatial resolution of 30 m, Landsat-5 TM of 2005 with a spatial resolution of 30 m and Landsat-8 OLI of 2017 with a spatial resolution of 30 m were acquired and used to evaluate LULC changes in Little Andaman Island (Table 1). In addition, Survey of India toposheets on 1: 50,000 scale were also used to prepare base map and used for nomenclature. Topographic maps were geo-referenced/ geo-coded based on grid coordinates in the toposheet and were later re-projected into a cartographic projection of UTM Zone 46 N, WGS 84. In pre-processing phase, the individual band with GeoTIFF (Geographic Tagged Image File Format) of Landsat-8 OLI of 2017 was stacked and converted into image format using ERDAS Imagine 10 software and a similar work was carried out with other Landsat satellite images i.e. Landsat-2 MSS of 1989 and Landsat-5 TM of 2005. Since MSS satellite images does not have geographical coordinates, they were geometrically corrected using images of Landsat-8 OLI of 2017.

All the satellite images were re-projected into a cartographic projection of UTM Zone 46 N, WGS 84. The geo-coded images were subjected to enhancements to improve the interpretability of the image. The enhancement techniques adopted in the present study included contrast stretching. The satellite data products after due processing as described above were interpreted using visual interpretation techniques for preparation of LULC map using the Arc Map 10 software. The visual interpretation keys prepared by Space Applications Centre (SAC, 1991) were used to identify various LULC features. Field visits were conducted to confirm the presence of classes shown in the prepared LULC map and additional ancillary information were collected. The broad methodology is shown in figure 2.

Table 1: Details of satellite images used

Sl. No	Satellite/Sensor	Date of Acquisition	Path/Row	Spatial Resolution (m)	Data Source
1	Landsat-8 / OLI	23/08/2017	134/53	30	http://earthexplorer.usgs.gov/
2	Landsat-5 / TM	20/02/2005	134/53	30	
3	Landsat- 5 / TM	21/11/1989	134/53	30	
4	Landsat- 2 / MSS	18/03/1976	144/53	60	

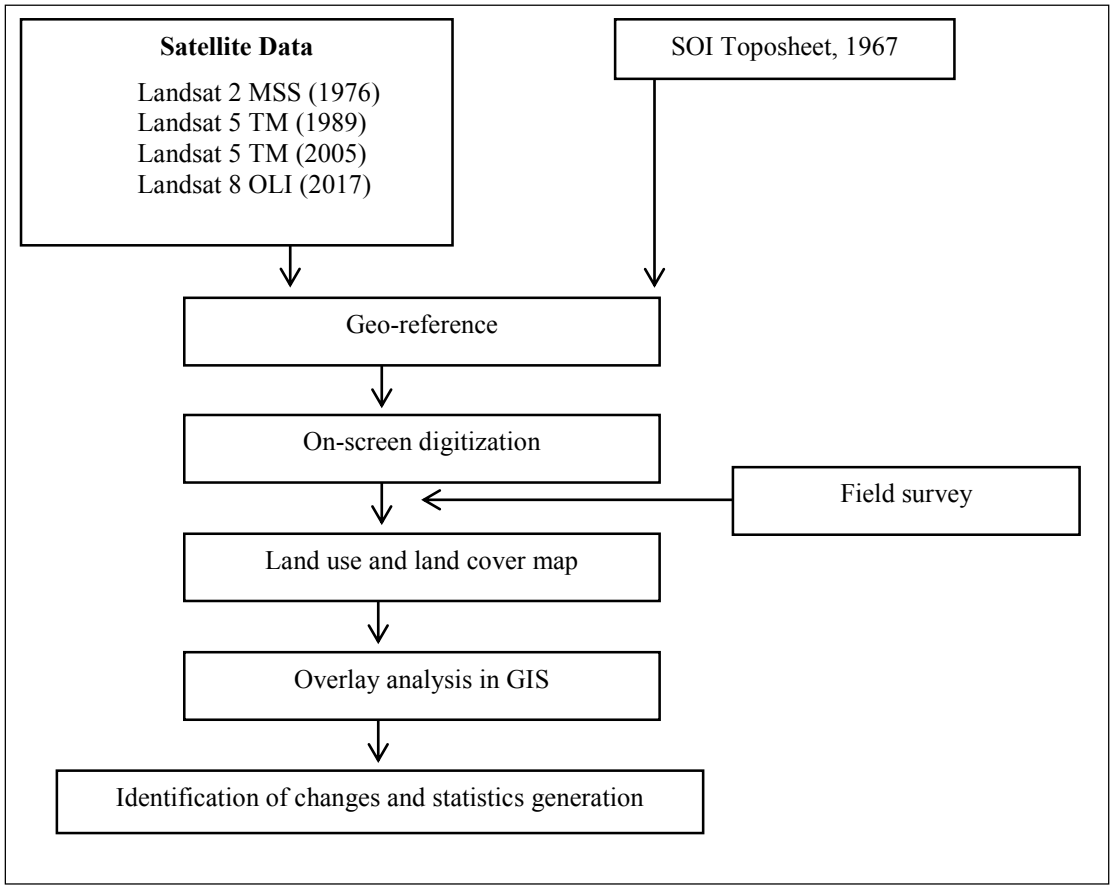

Figure 2: Methodology flow chart for LULC change mapping

4. Results and discussion

LULC changes of Little Andaman were analyzed using Landsat satellite imagery over a period of 41 years. The LULC maps for 1976, 1989, 2005 and 2017 are shown in figure 3. Land cover features mapped are forest, mangrove, coral reefs, sandy area/beach/sand dune, creek/river. These are listed in table 2. Land use classes include mining area and built up area. The results of the change detection studies and the trends identified with reference to particular classes are discussed here in detail.

4.1 Built up area

Built up area comprises of settlement area, industries, road, jetty, and ponds/tanks and is observed on the eastern side of the island. The study reveals that the built up area which occupied about 16.64 km^2 (2.32%) in 1976 gradually increased to 20.97 km^2 (2.95%) in 1989, 36.95 km^2 (5.19%) in 2005 and presently is 42.58 km^2 (5.98%) in 2017. The built up area has increased due to increasing population and associated infrastructural development, establishment of permanent tsunami shelter and tourism development. The total population of Little Andaman Island was 12,247 (6703 males and 5544 females) in 1991 and it has increased to 17528 (males: 9540 and females 7988) in 2001 and 18,823 (males 9964 and 8859 females) in 2011 (Census of India, 2011). The population primarily comprises of people from West Bengal and Tamil Nadu. December 2004 Indian Ocean tsunami had huge impacts on Little Andaman Island. About 56 people were dead, 14 missing and 6569 people stayed at camp (ICMAM 2005). After the tsunami, a large number of permanent shelters were constructed at Little Andaman including community hall, sub center and primary schools by Andaman Public Works Department (APWD).

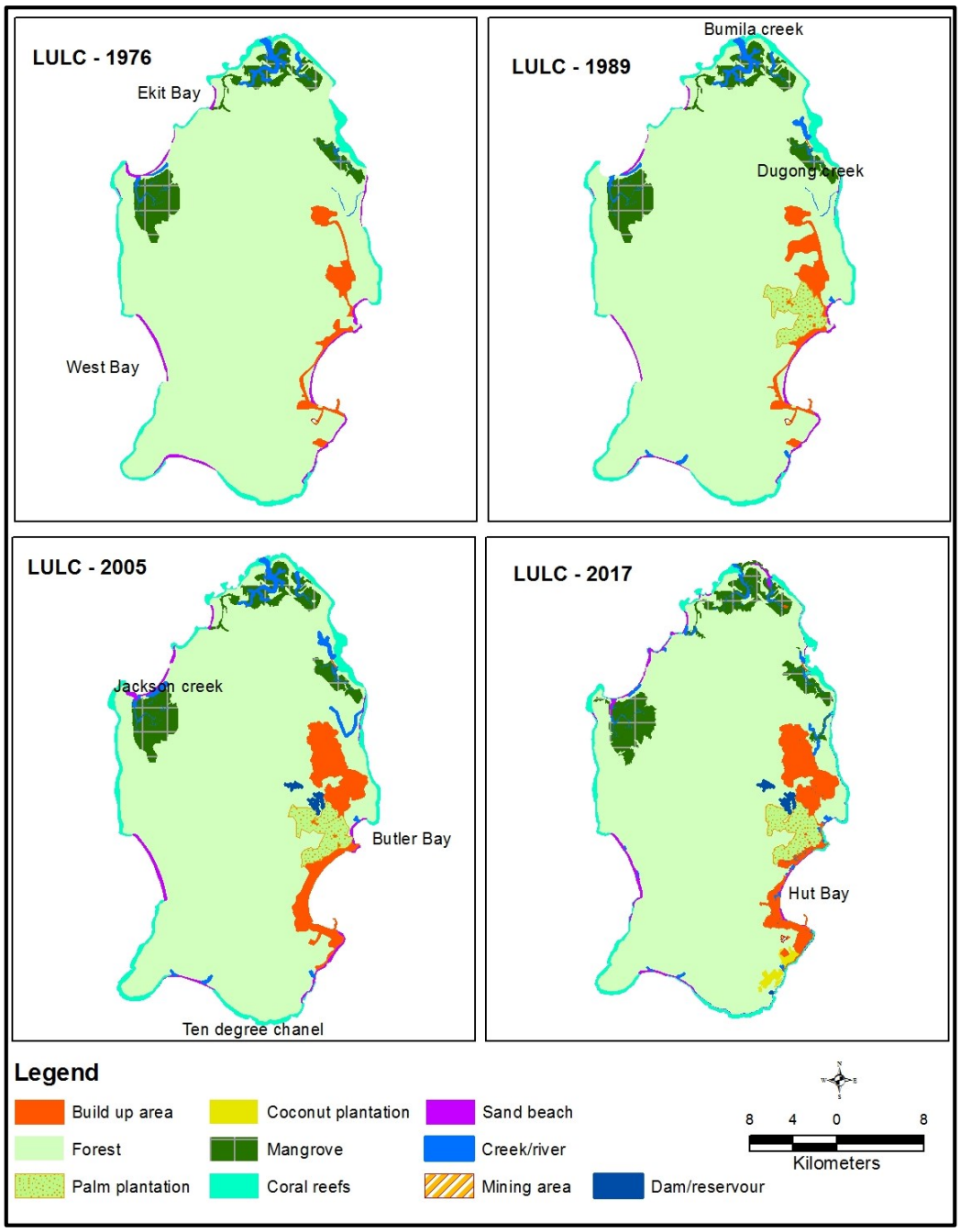

Figure 3: Spatial patterns of LULC changes in the Little Andaman Island for 1976 to 2017

Table 2: Landsat derived LULC change statistics of four different time period for the study area

LULC classes	Area in 1976 (Km^2)	Area in 1989 (Km^2)	Area in 2005 (Km^2)	Area in 2017 (Km^2)
Forest	623.65 (87.59%)	617.48 (86.72%)	600.13 (84.29%)	593.00 (83.29%)
Built up area	16.54 (2.32%)	20.97 (2.95%)	36.95 (5.19%)	42.58 (5.98%)
Mangrove	38.36 (5.39 %)	39.58 (5.56%)	39.44 (5.54%)	42.36 (5.95%)
Coral reef	21.37 (3.00%)	22.76 (3.20%)	23.42 (3.29%)	22.54 (3.17%)
Creek/River	5.00 (0.70%)	5.84 (0.82%)	5.70 (0.80%)	5.75 (0.81%)
Sandy area / Beach / sand dune	6.89 (0.97%)	5.13 (0.72%)	6.11 (0.86%)	5.51 (0.77%)
Mining area	0.19 (0.03%)	0.23 (0.03%)	0.25 (0.04%)	0.26 (0.04)
Total area (km^2)	**712.00**			

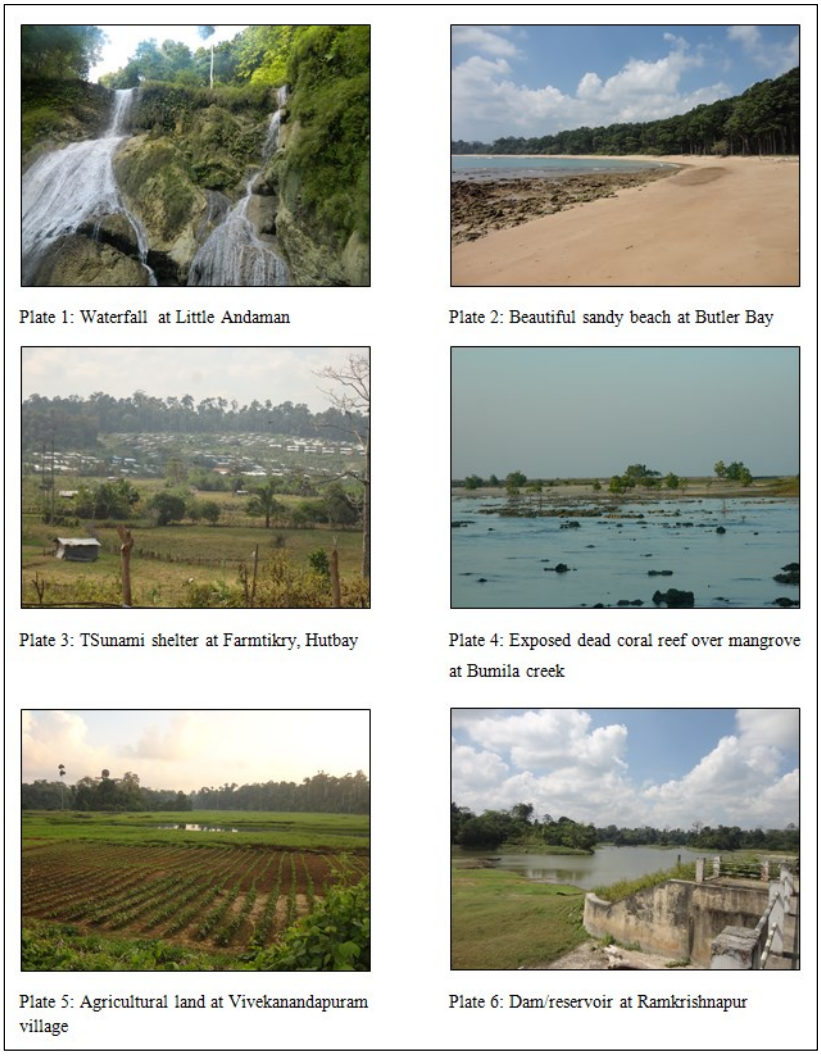

Figure 4: Field photos of LULC feature and scenic beauty of the Little Andaman island

From the field survey, it is observed that a good network of roads cover the island. Transport Department runs public bus service on the island. The Little Andaman has many tourist areas such as Harminder Bay (Nicobari settlement), Hut Bay waterfall, Christ Nallah waterfall (Elephant ride/safari), Oil Palm plantation, Palm oil processing unit, Butler Bay beach (boating through lagoons), Spices orchard, Ramakrishnapur and Rabindra Nagar Dams, wilderness trail through the tropical giant evergreen forests. Hence, the tourism industry has been increasing. Agriculture is the mainstay of the local people at Little Andaman, despite tourism, fishing activities (Figure 4). Major agricultural crops in Little Andaman are arecanut, red oil palm, paddy, vegetables, coconut and fruits. The arecanut plantation is observed in Vivakanandapur and Rabindranagar villages while large area under coconut plantation is observed in the south of Hutbay village.

4.2 Forest

The forest area, which is the largest component of the LULC of the island gradually decreased from 87.59% (623.65 km^2) in 1976 to 86.72% (617.48 km^2) in 1989 and 84.29% (600.13 km^2) in 2005 and further it reduced to 83.29% (593 km^2) in 2017. It is observed that the forest area in Little Andaman is well protected. According to Forest Code (2011) total forest area of Little Andaman is 703.65 km^2 (95% of geographical area) and the forest is classified as reserved forest. While analyzing the temporal changes for forest class between 1976 to 2017, there are no remarkable changes observed in the forest class and in general, it shows 1 to 4 percent of decrease in last 41 years. To produce more edible oil in the country, the Government of India sanctioned a project for raising Red Oil Palm plantation in Little Andaman Island. Under this programme, an area of 15.93 km^2 has also been brought under Red Oil Palm plantation in 1979 (Department of Environment & Forests, Andaman and Nicobar Islands, 2011).

The protection of forest in the island is achieved by the strong legal provisions existing in India. The responsibility of Indian citizen to protect forest is very well stipulated in the Constitution of India and it is the fundamental duty of every citizen of India to protect the forests of our country. Article 51-A (g) of Constitution of India says that “It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures”. The Government of India issued forest policies in different time periods. The first National Forest Policy was enacted in 1894. Thereafter, it was revised and new National Forest Policy was published in 1952 by the Ministry of Food and Agriculture. Then, the National Forest Policy, 1988 (NFP)

was enacted with the basic objectives of maintenance of environmental stability, restoration of the ecological balance. It laid emphasis on people's participation through Joint Forest Management Programme and together with Forest (Conservation) Act, 1980 helped in stabilization of country's forest area in spite of huge demand on forest land for development and the ever increasing pressure for forest produces.

The major forest types of Little Andaman include tropical evergreen, semi-evergreen, moist-deciduous and littoral forests (Champion and Seth, 1968). Among the tree species recorded in Little Andaman, the dominant species include *Dipterocarpus spp*., *Knema andamanica*, *Fagraea racemosa*, *Elaeocarpus rugosus*, *Ficus hispida*, *Euodia glabra* under the evergreen forest. Species such as *Canariun euphyllum*, *Pterocymbium tinctorium*, *Oroxylum indicum*, *Terminalia procera*, *T. bialata* and *Neonauclea gageana* are dominant in semi-evergreen forest. Further, species viz., *Tetrameles nudiflora*, *Bombax insigne*, *Terminalia bialata*, *Pterocymbium tictorium* and *Anthocephalus chinensis* are dominant in deciduous forest. Whereas the littoral forest, species in *Manilkara littoralis*, *Gyrocarpus americanus*, *Pongamia pinnata*, *Terminalia catappa*, *Ficus nervosa* and *Bombax insigne* are dominant (Rasingam & Parthasarathy 2009). The conversion of forest land to the other LULC classes between 1976 to 1989, 2005 and 2017 is shown in table 3.

Table 3: Pattern of forest change from 1976 to 2017

Forest area change into following classes (area in km^2)	1976 to 1989	1989 to 2005	2005 to 2017
Built up area	5.03	17.29	3.28
Palm oil plantation	16.52	0	0
Dam/reservoir	0	0.85	0
Coconut plantation	0	0	4.04
Mining area	0.04	0.05	0.04

The study reveals that according to the LULC map of 1989, about 16.52 km^2 area of palm oil plantation and 5.03 km^2 area of built up area were previously (1976) forest land. The study found that about 17.29 km^2 built up area and about 0.85 km^2 dam/reservoir in 2005 LULC map were previously forest area. Similarly, about 3.28 km^2 built up area, 4.04 km^2 coconut plantation and 0.04 km^2 mining area in 2017 were previously forest land. The driving forces of forest cover change are numerous. Some forces act slowly (and often obscurely) over centuries, while others trigger quick and visible events. The major reasons for forest changes were the government policies. They are (a) colonization policy of 1954, 1972, (b) tsunami rehabitation shelter, (c) infrastructure development programme such as expansion of road, (d) tourism development programme, (e) agricultural development programme etc. other reason are natural calamities such as cyclone, tsunami etc.

4.3 Coral reefs

Coral reefs are among the most productive and biologically diverse ecosystems on earth (Moberg & Folke, 1999). Little Andaman exhibits narrow, linear and extensively well-developed fringing reefs all around the island except at few locations in the east and western coast. Reef flat is generally broader on the western side and narrower on the eastern side. The coral reefs cover an area of about 21.37 km^2 in 1976. The reef area has increased to 22.76 km^2 in 1989. It further increased into 23.42 km^2 and decreased to 22.54 km^2 in 2017. According to Meltzner et al., (2006) due to December 2004 Indian Ocean tsunami, entire island of Little Andaman rose, with the eastern part (including Hut Bay) up at least by 18 cm based on analysis of satellite images acquired on 1 January 2004 and 3 January 2005. This lead to exposure of coral reef surrounding the island. According to the report by Obura et al., (2008), 12.85 km^2 reef area was damaged in Little Andaman due to uplift of 24th December 2004 Indian Ocean Tsunami.

4.4 Mangroves

Mangroves are coastal forests found in sheltered estuaries, along river banks and lagoons in the tropics and subtropics. The term 'mangrove' describes both the ecosystem and the plant families that have developed specialized adaptations to live in tidal environment (Tomlinson, 1986). Mangrove of Little Andaman are mainly estuarine associated with creeks. Mangroves are found in the northern portion on Bumila creek, western side in Jackson creek and eastern side in Dugong creek. Broadly the mangrove species belong to the genus of Rhizophora and Bruguiera. The study found that mangrove covering an area about 5.39 % (38.36 km^2) in 1976, 5.56% (39.58 km^2) in 1989 and it has decreased to 5.54% (39.44 km^2) in 2005, because of the impacts of the Indian Ocean tsunami of December 2004. It has increased into 42.36 km^2 (5.95%) in 2017 due to natural recruitment and plantation in the tsunami affected areas particularly in the northern Bumila creek and western side of Jackson creek.

4.5 Other classes

The other classes viz., creek and sandy beaches or sand dune do not show any major change. It is observed that the sandy beach/ sand dune area which occupied about 0.37% (6.89 km^2) of area in 1976 has decreased to 0.72% (5.13 km^2) by 1989 but increased to 0.86 % (6.11 km^2) by 2005. It further decreased to 5.51 km^2 (0.77%) in 2017. Rock mining/quarrying which is observed south of Hut Bay has gradually increased from 0.19 km^2 in 1976 to 0.26 km^2 in 2017. This quarry is maintained by the Andaman and Lakshwadeep Harbour Works (ALHW) and named as Andaman and Lakshadweep Harbor Works Limestone Quarry.

The Ministry of Environment, Forest & Climate Change, Government of India has published the Island Protection Zone (IPZ) Notification, 2011, to ensure livelihood security to the local community, to promote conservation and protection of island unique environment and to promote development through sustainable integrated management plan of the Andaman & Nicobar (A&N) and Lakshadweep group of Islands (MoEF & CC, 2011). This

IPZ Notification, 2011 has two major components i) the Island Coastal Regulation Zone (ICRZ) and ii) the Integrated Island Management Plan (IIMP). The ICRZ is regulatory in nature and is predominantly prepared to delineate areas along the coast as ecosystem dominant (ICRZ I), urban (ICRZ II), rural (ICRZ III) and waterbody (ICRZ IV). The Little Andaman island fall under the ICRZ category. As all the development activity along the coastal area of this island are to be regulated by the ICRZ plan, there is a need to follow the guidelines of IPZ notification 2011. In order to prepare island management plan or resource management plan of this island, information of coastal land use and land cover, its present status and changes over a period of time is highly required. In the present study, land use and land cover changes are analyzed in detail and may be used to prepare ICRZ zonation and preparation of resource management plan such as mangrove restoration or plantation, conservation of coral reef area, prohibition of mining of sand from beaches etc.

5. Conclusions

Spatio-temporal dynamics of land use and land cover of Little Andaman are studied by using Landsat satellite images over the past 41 years. Results show that forest area, which is the largest component of the island, has gradually decreased from 87.59% (623.65 km^2) in 1976 to 83.29% (593 km^2), whereas the built up area which occupied about 16.64 km^2 (2.32%) in 1976 increased to 42.58 km^2 (5.98%) in 2017. This may be attributed to natural calamity such as cyclone, tsunami and anthropogenic activities such as an increase in the population, infrastructure development, agriculture development by construction of two dams/reservoirs, tourism development by construction of hotel, guest house, resort, good communication with Port Blair, and establishment of tsunami shelter, etc. The prominent changes in LULC are observed after the 24 December 2004 Indian Ocean tsunami. This assessment would help the Andaman Administration for policy formulation towards resource management and land use planning of the island. The study suggests the integration of ICRZ regulation along with the land use plan may help in sustainable development of the region.

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