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# Influence of anthropogenic activities on the land use patterns of South Andaman Islands

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## Abstract

*Anthropogenic activities have brought about large scale changes to the landuse/landcover changes in coastal environment. This has to be monitored and analysed from time to time. An analysis of Landuse temporal data offer insight into the performance and the influence it has on the environment. Georectified LISS III images at 1:50,000 scales were visually interpreted to understand the landuse/Landcover of the South Andaman Islands during a 32 year period. Scrutiny of secondary data has shown that, South Andaman has undergone significant alteration in various landuse features. During the study period, there has been considerable increase in human population in the area resulting in manifold anthropogenic changes in the natural ecosystem of the islands such as large scale alteration in landuse patterns. Reserved forests which once constituted 69.9% of the study area in 1978 have now dwindled to only 45.3% in 2010. Settlements in the area have increased by 208% since 1978 leading to an increase in plantations from 4.2% in 1978 to 6.6% in 2010 owing to the increase in food demand. Mangroves decreased from about 7% in 1978 to 6.2% in 2010. Sandy beaches have decreased at an overall rate of 22.91%. With rise in tourism in the islands, anthropogenic pressures are increasing exponentially. Therefore, efficient sustainable land administration strategies and practices should be adopted to avoid endangering the environment. This information generated on land use/land cover pattern of the region would be of enormous assist for the formulation of policies and programmes required for disaster resilient progress of the islands.*

**Keywords:** Anthropogenic pressure, Landuse/Landcover maps, GIS, Remote sensing, South Andaman, Sustainable development.

## Introduction

Landuse/Landcover (LULC) changes are a direct result of the human activities on the environment. Over the centuries man has altered the natural land cover according to his needs clearing forests for agricultural practices, plantations, settlements etc.The chief practices of anthropogenic land use change are the expansion of urban settlements, agriculture and aquaculture by clearing naturally occurring vegetation.

Land use changes, particularly by removal of the original vegetation, have a range of direct consequences such as soil erosion, habitat fragmentation and biodiversity declines The industrial revolution of England (1760-1830) brought about a trend that saw the dwindling of forest areas all around the globe driven by man's need[1]. It was a precedent then and the effects are seen now in the form of climate change, global warming, and other problems related to it. Back then, there was no way the changes could be monitored. But with evolution of technologies such as Remote sensing and Geographic Information System (GIS) landuse land cover changes can be better monitored and managed for sustainable development.

Time series LULC studies is one of the most important services that the Global Earth Observation System offers to mankind[2]. LULC data are also some of the most critical variables for climate change related studies[3-6]. Landcover data products play a critical role in improving performances of the whole environment including the physical, chemical and biological aspects[7-9]. They are also essential in habitat and biodiversity composition related studies[10,11] carbon cycling[12] and public health[13]. The anthropogenic impacts are easily discernible in the time based temporal images of different dates which can be used as information about change in landuse/land cover. This could further be used to upgrade land cover datasets and in the supervision of resources[14].

Change detection helps us to understand and verify alterations that come up during the study period. These analyses are of use to environment managers to assess the current and model the future landuse/landcover developments. During the course of time numerous efforts have been taken to build up techniques for acquiring data in landuse and related changes[15]. Various workers have during the course of time already verified the efficiency remote sensing data to distinguish land use features such as built up areas and their expansion, vegetation cover changes and critical areas such as ecological hotspots[16-18].

The changes or alterations does not follow a linear pattern and is not always progressive either. In fact there have been instances of reversed conversion as well as halt of changes. The transition usually brings drastic increase in livelihood infrastructures after gradual reduction of the naturally occurring resources. Such changes whether large or small has considerable adverse consequences such as the exhaustion of ecosystem services. In some instances LULC changes may result in environmental, social, and economic impacts of greater damage than benefit to the area[19]. Thus, data on land use change can provide critical inputs in decision making and is of value to planners in monitoring the consequences of LULC change in the region[20,21]. This study aims to produce a landuse/landcover map of South Andaman to identify the alterations that have occurred in the region by using the change detection method. The specific objectives aimed at were- to map the landuse / land cover and determine the trend, nature, rate and magnitude of landuse / land cover change.

## Materials and methods

**Study area:** The southern part of South Andaman group of Island in Andaman and Nicobar Islands located between 92° 31' 30" E to 92° 42'30" E and 11°28'30"N to 11° 44' 30" N and encompassing an area of 6408 km$^2$ is the region of under study. The southern part of South Andaman has the capital city Port Blair. It is the most densely populated area of Andaman and Nicobar Islands and is home to 62.53 % population of the entire Andaman and Nicobar Islands (Source: Census of India, 2011). It is the gateway to the Andaman and Nicobar Islands as the airport and main harbour are located in Port Blair. Characterized by high and rough terrain, the region has been subjected much landuse alterations in the last 30 years making way for residential, commercial, recreational and educational structures. The high influx of tourists and migration from other Islands are issues that need to be managed keeping in mind the sustainability of the ecosystems in the Islands.

**Study period:** An attempt to study the landuse changes from 1978-2010 has been made. Based on the convenience of satellite images, three years viz. 1978, 1998, and 2010 were chosen and landuse has been studied. A comparative analysis of surface area of various landuse forms during these years has been made to detect the changes.

**Mapping and data analysis:** One of the most widely used methods to identify features on a satellite image is the Visual Interpretation technique[22]. In the paper change detection was done in Arc GIS 9.1 software. Accuracy levels were estimated by conducting ground surveys using Global Positioning Systems (GPS). The Survey of India (SOI) topographical maps published on a scale 1:50000 have been used for preparing base maps. To prepare the drainage, geology and geomorphology maps, data from IRS P6 LISS III, IRS-1D-LISS-III have been used respectively. For preparing the LULC maps 1978 toposheets from Survey of India (SOI), IRS-1D-LISS-III digital data (1998, 2010) have been used. Upon acquisition the satellite images were processed, geometrically rectified and geo-referenced in ERDAS 9.1.The features in the satellite data were inferred viz-a-vis the visual interpretation keys specified by the Space Application Centre[23]. The interpreted features' boundaries were digitized and labeled using ArcMAP 9.3 and landuse/land cover maps were generated after checking on the accuracy levels. Geological, geomorphological and drainage maps were also made. Projection used was Polygon projection and then the areal extent of the landuse/land cover calculated. MS excel was used for analysing the data and generation of graphs. The findings of the study is expected to emphasize on the (1) areal distribution of land cover (2) identification and estimation of degradation (3) possible management measures based on ground truth and earlier studies.

## Results and discussion

**Demographic environment:** There has been wide variation in population growth since 1881 when the total population of A and N islands was 14,628. Immigration has become regular feature since 1951. After that the towns and small villages have started flourishing due to the harbour facilities and slow progress of shipping and other transport facilities. The total population of the study area is 237586 as per 2011 census. It was 93,138 in 1981 while in 1991 it was 128,138. From the total population of the study area, Port Blair city alone accounted for about 50% of the study area (Census of India). Among all the villages of the study area, the villages adjacent to Port Blair and in the vicinity of harbour areas had tremendous growth due to the influence of urban activities. In general, the population growth rate of rural population is 2.2% and that of urban area is 3.7% per annum. The Population density is 46 person per km$^2$ (2011 census) while it was 43 person per km$^2$in 2001.

**Landuse/Landover:** Deforestation, biodiversity loss, global warming are the direct consequences of anthropogenic conversion of the LULC which has also resulted in exponential rise in incidences of natural disasters[24-26]. Analysis of the data suggests significant modifications in the earlier LULC of the study area since 1978. During the study period 1978-2010 the area has been a subject of much development works in the region. Roads have been built for transportation and communication. Rising population has increased the food demands of the area. Numerous Schools and a few colleges have also been developed during the period. Some major disasters that hit this area during the period, such as cyclones, earthquakes and tsunami (2004) have also defined the landuse pattern. More forests were cleared during the period to build houses away from the low lying areas. The Pradhan Mantri Gram Sadak Yojana has brought about roads all around the study area but at the expense of forest cover. During the tsunami 2004, forest areas especially. Mangroves were lost but those are resurfacing. The status of the various landuse land cover features have been discussed in details.

**Mangroves:** Mangroves vegetation covers an area of 4827 sq.km$^2$ in India. As per the estimate of the Forest Survey of India 966 km$^2$ mangrove vegetation occurs in Andaman and Nicobar Islands. The mangrove forests were recognized with the help of vivid red tone and uneven outline, located in close proximity to intertidal region. Interpretation of satellite data confirm that in the study area, Mangrove cover has decreased since 1978. In 1978 it constituted about 7% (3399 hectares) of the total study area. It decreased to 6.3% (3050.12 hectares) and 6.2 % (2997.96 hectares) in 1998 and 2010 respectively (Table-1). There was a substantial decrease in the mangrove area post the 2004 tsunami but an effort to increase the mangrove population has brought back the dwindling mangrove population. Mangroves have decreased about 13.6% from its total area in 1978 (Table-4). Some prominent areas with mangroves are Carbyn's Cove area, Manjery, Sippighat, Pongibalu, Chidiyatapu, Tirur, Namunaghar and Govindpuram. The total mangrove area has also shown an increasing trend. It could be because of the awareness created among the people that mangroves could play a significant task in reducing the impacts of tsunami waves as well as storm surges, and due to the plantation programs that have been taken up by the forest department after the tsunami.

**Sandy beach:** Beaches are areas sandwiched between the lowest low tide level and a landward limit consisting of sediments transported at the shoreline and shaped to distinctive shape by waves produced by water activity. They generally have smooth gentle slope and the sediments basically consist of sand, gravel or coral debris. Inland, the beaches are stable but the shoreward component is constantly eroded by wind or water. The beaches in protected areas experience deposition too. Carbyn's cove, Wandur, Chidiyatapu, Jolly boys Island etc. is the prominent beaches of the study area that attract tourists from all over the world. Sandy beach is found as white linear patch with smooth texture adjacent to the coast in the images. The total area under sandy beach LULC has decreased from 3% (1427.49 hectares) of the total study area in 1978 to 2.5% (1200.58 hectares) in 1998 .It further decreased to 2.3% (1100.37 hectares) in 2010 (Table-1).The overall decrease in sandy beach area has been 22.91% since 1978 (Table-4).

**Reserved forests:** The tropical rainforests of Andaman and Nicobar Islands have incredible species diversity and most of them are endemic in nature. To protect its endemic biodiversity in 1972, an area of 733.12 km$^2$ was included under the Wild Life (protection) Act which included 6 National Parks and 94 Sanctuaries. The forests are spread from the coasts to hill tops following a distribution pattern that is defined by the landscape and soil profile. Major timber yielding trees of these evergreen, semi evergreen, moist deciduous and littoral forests are Teak, Red Padauk, White Padauk and Sagan Bamboo. In the image the Reserved Forest area was recognized by their red tone, uneven outline and smooth texture. In spite of the wildlife protection act, the forest cover is reducing. In 1978 reserved forests constituted 69.9 % (33707.96 hectare) of the total study area. But it has now dwindled to only 45.3% (21819.12 hectare), while it covered 55.2% (26619.87) in 1998 (Table-1, 2 and 3). The decrease rate has been 35.3% (Table-4). The dwindling forest cover could be because of the constant increase in populace pressure, exercise of irrational cultivation techniques and increase in settlements, industries and roads. Post tsunami 2004, forest were cleared and settlements were made in areas such as Brookshabad, Minnie bay, Bamboo flat.

**Table-1:** Area covered by various LULC features

| S. No. | LULC features | Area(hectare) | Area(hectare) | Area(hectare) |
|---|---|---|---|---|
| | | 1978 | 1998 | 2010 |
| 1 | Mangroves | 3399 | 3050.12 | 2997.96 |
| 2 | Sandy beach | 1427.49 | 1200.58 | 1100.37 |
| 3 | Reserved forest | 33707.96 | 26619.87 | 21819.12 |
| 4 | Settlement | 5566.99 | 12175.75 | 17274.82 |
| 5 | Coral reefs | 2025.69 | 2194.08 | 1685.69 |
| 6 | Mud | 79.71 | 92.61 | 131.71 |
| 7 | Plantation | 2013.12 | 2886.95 | 3210.29 |
| Total | | 48219.96 | 48219.96 | 48219.96 |

**Table-2:** Change in LULC features area covered 1978-1998

| S. No. | LULC | Area(hectare) 1978 | Area(hectare) 1998 | Change in area(hectare) 1978-1998 | % change |
|---|---|---|---|---|---|
| 1 | Mangroves | 3399 | 3050.12 | 348.88 | -10.26 |
| 2 | Sandy beach | 1427.49 | 1200.58 | 234.91 | -15.89 |
| 3 | Reserved forest | 33707.96 | 26619.87 | 7088.8 | -21.02 |
| 4 | Settlement | 5566.99 | 12175.75 | 6798.76 | 118.71 |
| 5 | Coral reefs | 2025.69 | 2194.08 | 168.39 | -8.31 |
| 6 | Mud | 79.71 | 92.61 | 12.9 | 16.1 |
| 7 | Plantation | 2013.12 | 2886.95 | 873.83 | 43.4 |

**Table-3**: Change in LULC features area covered 1998-2010

| S. No. | LULC | Area (hectare) 1998 | Area (hectare) 2010 | Change in area (hectare) 1978-2010 | % change |
|---|---|---|---|---|---|
| 1 | Mangroves | 3050.12 | 2997.96 | -52.2 | -1.71 |
| 2 | Sandy beach | 1200.58 | 1100.37 | -100.2 | -8.35 |
| 3 | Reserved forest | 26619.87 | 21819.12 | -4800.8 | -18.03 |
| 4 | Settlement | 12175.75 | 17274.82 | 5099.1 | 41.88 |
| 5 | Coral reefs | 2194.08 | 1685.69 | -508.4 | -23.17 |
| 6 | Mud | 92.61 | 131.71 | 39.1 | 42.22 |
| 7 | Plantation | 2886.95 | 3210.29 | 323.3 | 11.20 |

**Table-4:** Change in rate of change in area covered by LULC features

| S. No. | Rate of change (%) | | | |
|---|---|---|---|---|
| | LULC Features | 1978-1998 | 1998-2010 | 1978-2010 |
| 1 | Mangroves | -10.26 | -1.71 | -13.56 |
| 2 | Sandy beach | -15.89 | -8.34 | -22.91 |
| 3 | Reserved forest | -21.02 | -18.03 | -35.27 |
| 4 | Settlement | 118.71 | 41.87 | 210.3 |
| 5 | Coral reefs | -8.31 | -23.17 | -16.78 |
| 6 | Mud | 16.1 | 42.22 | 65.23 |
| 7 | Plantation | 43.4 | 11.20 | 59.4 |

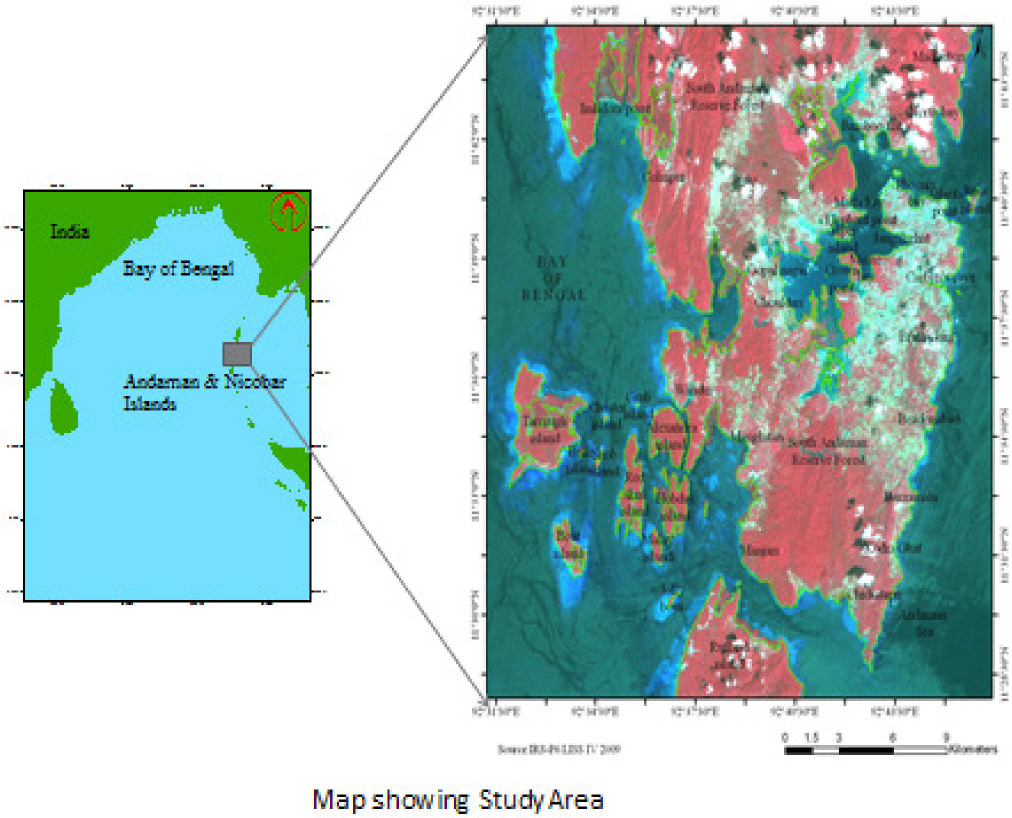


**Figure-1:** Map showing the study area.

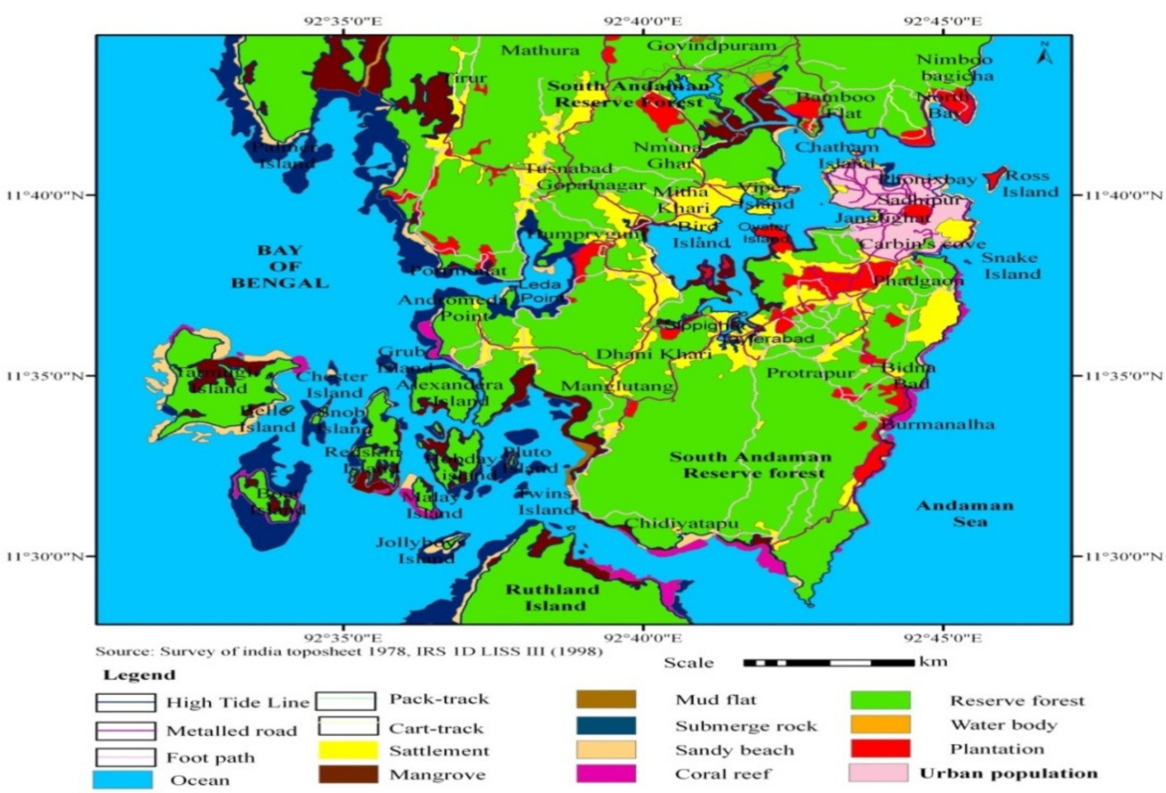


**Figure-2:** Landuse/Land cover map of South Andaman (1978)

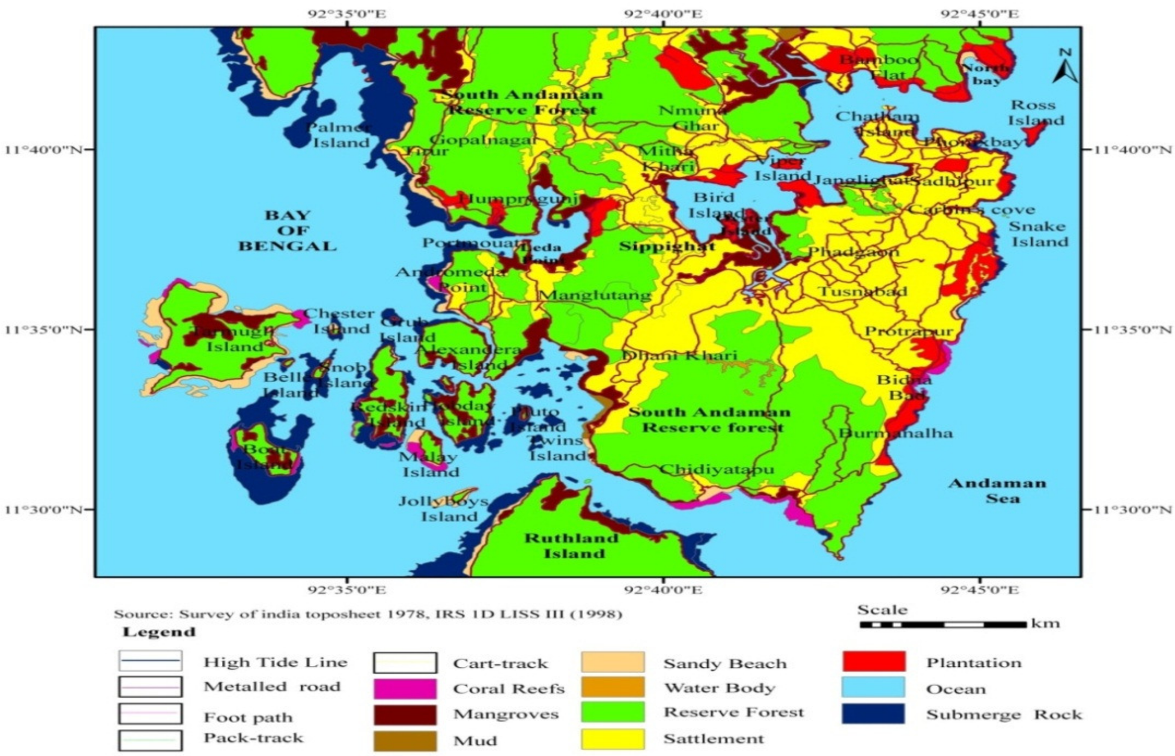


**Figure-3:** Landuse/Land cover map of South Andaman (1998)

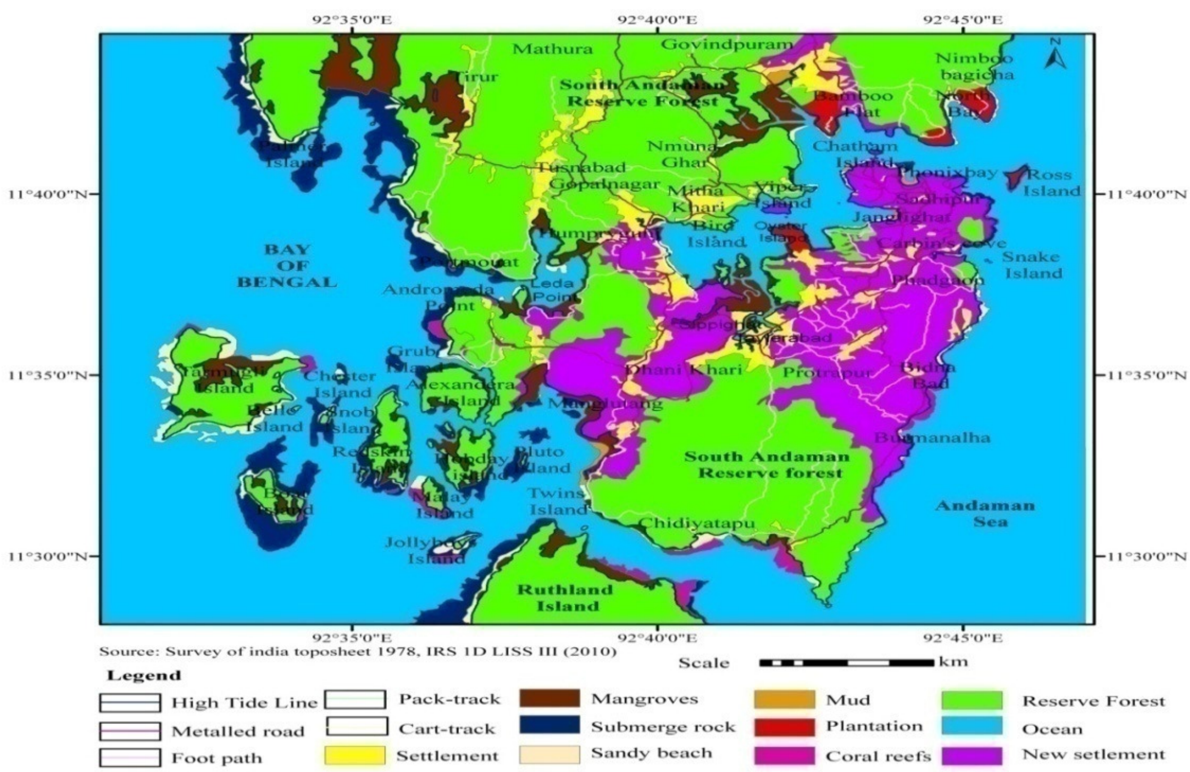


**Figure-4:** Landuse/Landcover map of South Andaman (2010)

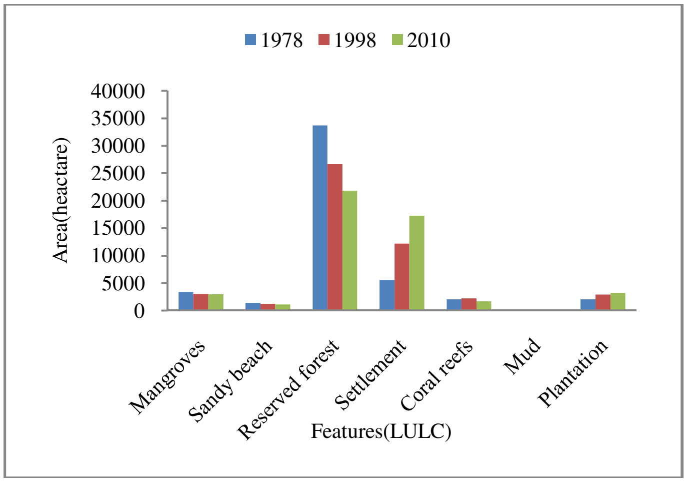


**Figure-5:** Area covered by various LULC features

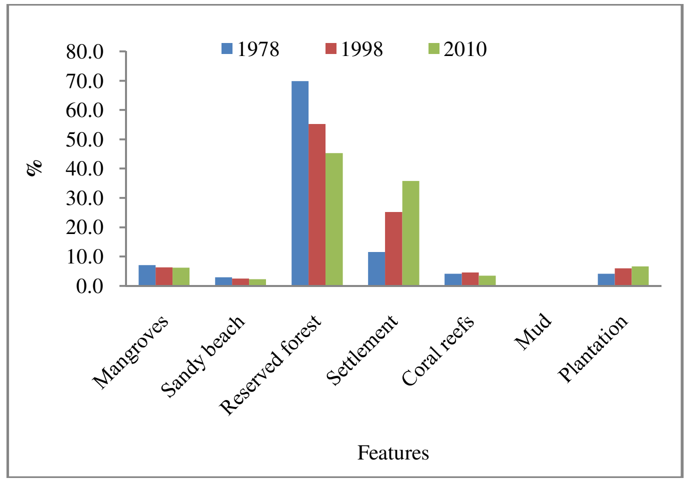


**Figure-8:** % of land occupied by the LULC

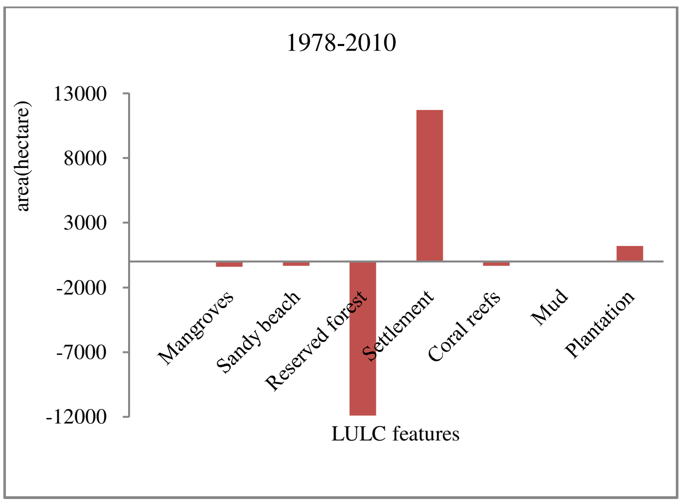


**Figure-6:** Change in area of LULC features (1978-2010)

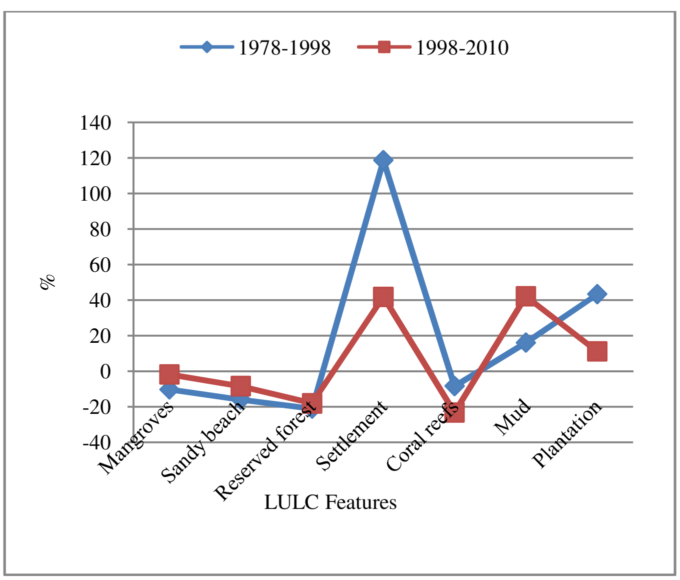


**Figure-7:** Comparative change in LULC

**Settlements:** The settlement land was recognized by its radiant grey, yellow tone along with asymmetrical form in the image. Settlements are mostly dense on the southern part of the study area. Plantations and agriculture vegetation are in association of the settlement area. During the period, a host of residential, commercial, industrial buildings and infrastructures have come up. Roads for transportation and communication have also been made. Hospitals, parks, Colleges, Stadiums etc have been made. There has been an influx of population from other parts of the Islands for employment, education and economic purposes. Rapid urbanization and increase in population has led to increase in settlement area to about 208% (approx) from what it was in 1978. An increase of 121.91% was seen in 1998. In case of area, the total landuse under settlement was 5566.99 hectare in 1978. It increased to 12175.75 hectare in 1998 to 17274.82 hectare in 2010 (Table-1, 2 and 3). In 1978, settlements covered 11.6% of entire region, but amplified to 35.8% during 2010 while it was 25.3% in 1998 (Table-4). Many new residential areas have come up. Many villages such as Chidiyatapu, Bambooflat, Wandur, Burmanalha, Manglutang, Namunaghar, Manjery, Humprygunj, Tusnabad, Gopalnagar, Ograbaj and Chouldari have come up. Commercial complexes as well as industrial areas have been built in and around Port Blair city and urban residential areas such as Shadipur, Dollygunj, Protrapur, Pahadgaon, Pahargunj and Brichgunj have also come up.

**Coral reefs:** Coral reefs in the study area are in the form of fringing reef and patch reef and occur up to 500 m from the shore. Most of the reefs are found in close proximity to the coastline of South Andaman Islands. They dwell in low depth sea waters over the submerged rock and are recognized on the basis of their blue tone by means of uneven, wide to constricted outline. It is generally fine textured though texture is absent at the edge and the corals in deep water usually appear turquoise blue. Validation of coral reef classes by ground based surveys have demonstrated that reefs occur in depths up to 13 meters in clear waters and could be easily discriminated visually from satellite images. These types of fringing reefs were recognized at numerous places of the region. According to the investigation the area under coral reef class is 1685.69 ha (2010). Reef area is generally broader on the west and narrower on the eastern side. It spread over an area of 2025.69 ha (4.2 %) in 1978 and increased to 2194.08 ha (4.6%) during 1998. It further decreased to 3.5% of the total landcover in 2010. It was probably because corals in Andaman Sea saw large amounts of coral bleaching in the summer of 1998, 2002, 2005 and also 2010 where 70% corals were bleached during April-May, 2010 due to high sea surface temperature (SST)[27,28]. The notable growth of reefs to the west of the islands is primarily attributed to the submarine landscape and also due to the folded mountain range of ArakanYoma[29]. The major species are *Porites* spp., *Acropora* spp.and *Diploastrea heliopora* and cover 5-10% area. The rate of change has been -23.17% during the study period.

If mud is deposited over the reefs than it indicates degraded state of the reefs. Such depositions of mud were observed near adjacent to Navy Bay, Flat Bay and Chatham Island. In the study area, sedimentation plays a major role by depositing sand over reef[30] and it may be due to sediment loads in the water, as land and agricultural runoff, rise in sea surface temperature and overexploitation of reef resources[31-33].

**Mud:** Mud usually comprise of debris of corals and mollusc shells and might be drifting in nature[34]. The mud patches were identified by its pale tint, linear form and even texture[35]. Seasonally algae may cover the sanded reef flat. Seagrasses are also known to colonize this zone. Mud patches were identified in carbyn's cove, Jolly Boys Island, Pongibalu and Neil Island also. The area under the sand over reef class was 79.71 ha. (0.2 %) in 1978 which increased to 92.61 ha (0.27 %) and 131.71 ha (0.38 %) in 1998 and 2010 respectively. The rate of change of area from 1978-2010 has been 42.22% (Table-4).

**Plantations:** Plantations such as coconut plantation, beetle nut, horticultural practices, nurseries and agriculture etc can be found scattered all over the study area in association with the settlements. In the satellite images it was identified by its light pink tone and regular shapes. It is mostly found scattered near settlements such as Collinpur, Manjery, Namunaghar, Tushnabad, Burmanalha, Wandur, Birchgunj and other areas such as North Bay, Ross Island (Figure-13 a), Viper Island etc. The plantation area has shown an increasing trend since 1978. It was about 4.2 % (2013.12 hectares) of the overall study region in 1978. It increased to 6 % (2886.95 hectares) in 1998 and finally to 6.6 % (3210.29 hectares) in 2010. The plantations have increased about 54% from what it was in 1978 (Table-4).

## Conclusion

The global environment in spite of its dynamic nature can be continuously observed and studied with Space based land observation systems. Based on the geology and geomorphology of the South Andaman Islands it can be devised that the conditions are favourable for human activity. The slopes are gentle and conservation of top soil favours the growth of forest vegetation on the small hills scattered throughout the region. Due to limited economic, educational and employment facilities in other parts of the Andaman group of islands, the study area has seen a permanent invasion of migrants as it is the capital region. This has led to increased levels of pressure on land resources of south Andaman Islands ultimately leading to impromptu as well as unrestrained alteration in Land use/ Land cover, thereby resulting in environmental problems[36]. The alterations computed in the study with Geospatial technologies confirm crucial ecological impacts as major degrading of naturally occurring ecosystems such as Mangrove forests, coral reefs, sandy beaches etc. has been manifold. Hence, efficient sustainable land administration strategies are obligatory to evade degradation of the environment and to bring about sustainable progress of the Islands. The basic data on LULC pattern of the area produced in this study can be of massive assist in formulation of plan and agenda requisite for disaster resilient growth of the islands. A course of action focussed in the direction of local growth; by encouraging various urban settlements to come up with cottage industries at its helm as growth centres, educational centres in other islands may well contain this dilemma and bring about sustainability of resources.

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