

ASSESSMENT OF TSUNAMI DAMAGE TO MANGROVE IN INDIA USING REMOTE SENSING AND GIS

B. Chatterjee¹ M.C.Porwal¹ Y. A. Hussin²

⁽¹⁾ Indian Institute of Remote Sensing, 4, Kalidas Road, Dehradun - 248 001 (India)

⁽²⁾ The International Institute for Geoinformation Science and Earth Observation (ITC), Hengelosstraat 99, 7500 AA Enschede, Netherlands, Fax: (31)53-4874-388-Hussin@itc.nl (Presentar)

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ABSTRACT:

Indian Ocean is the home to rare flora and fauna that act as the bio-shield to many coastal communities. Indian Ocean experienced the world's most deadly natural disaster "Tsunami" on 26th December, 2004, which on one hand is unparalleled in the history considering its magnitude and devastation and on the other hand, caused an unprecedented impact on the aqua and aqua terrestrial ecosystems. One of the worst effected flora is the *mangrove* species that is among the richest in the world. There are places where vast pristine tracts of mangroves have been destroyed and it may pose a long-term threat for the region, not only in terms of forest and biodiversity conservation but also in terms of the ability of the ecosystem to support the livelihoods and the coastal communities. The tragedy of Tsunami invoked the rationale for conserving and sustainably managing natural ecosystems among the researchers and scientific community. The present research was carried out to make a post Tsunami evaluation of India's most ecologically fragile areas of Gulf of Mannar and South Andaman Island. Indian Remote Sensing Satellite (IRS 1C) and (IRS 1D) LISS (Linear Imaging Self Scanner)-III and Resourcesat -I LISS IV data have been effectively used to detect, assess and monitor the changes in the mangroves in the Pre and Post Tsunami period using multi-temporal optical satellite data. On-screen visual interpretation was done using FCC of the data to identify the heterogeneous patches for the preliminary classification of fieldwork. A supervised classification was performed using Gaussian Maximum Likelihood (GML) classifier to obtain the pre and post Tsunami land cover maps. Accuracy assessment of the classified maps was performed on pixel level using ground truth. The changes in the pre and post classification maps were performed by comparison of area basis based on different land use classes. The result highlighted the changes in the spatial extent of the mangroves and other land cover categories in the study areas as a result of Tsunami. The Damage map showed the degree (intensity) and extent of damage in mangroves on a qualitative basis.

1. INTRODUCTION

The coastal regions of planet earth are amazing areas. The interface between land and sea, the coast is unique geologic, ecological and biological domain of vital importance to an astounding array of terrestrial and aquatic life forms including mankind (Beatley et al. 2002) The coastal ecosystem is highly fragile because of the multivariate dynamically active and pulsatory tectonic and geomorphic processes.

Coastal zones of India are constantly undergoing changes due to natural forces as well as human development activities. Mangroves which are the most sensitive and fragile ecosystem may be affected by coastal environmental change including sea level rise and hydrological variations in the coastal zones of India. There is increasing evidence that mangroves may be affected by coastal environmental change, including hydrological variations and sea level rise. The response of mangroves to such impacts tends to be gradual and, particularly in undisturbed systems, is manifested typically as a change in their extent, structure and species composition and hence their distinct zonation. As mangroves are sensitive to even minor transitions in coastal conditions (e.g., altered drainage patterns, saltwater intrusion, accretion or erosion in response to sea level variations), changes in the zonation of these ecosystems are often indicative of broader scale changes and associated impacts in coastal regions.

On 26th December, 2004 India have experienced the world's most deadly natural disaster which has no parallel in the history

for its magnitude and devastation. In addition to the tremendous loss of life and property, the tsunamis have caused extensive environmental damage to the near shore marine environment. The 2,260 km of Indian coastal zone harbor many key marine ecosystems. According to IUCN, the effect of tsunami on these ecosystems is likely to be severe ecologically as well as economically although they varied in the region.

Tsunamis have caused unprecedented impact on the aqua and aqua terrestrial ecosystems in the coastal environment. The direct environmental impact of tsunami varied notably due to the bathymetry and geomorphology of the coastline and also some natural and manmade features. The mangroves that are the most productive of all the ecosystems might have been potentially damaged due to these huge waves. An obvious environmental impact of the tsunami is the physical damage of the mangroves that has resulted from waves and backwash. The deposit of silt may lead to the clogging of pores of the aerial roots of mangroves and cause total destruction of the plant species.

The degree and extent of damage of the mangrove is not known. Their loss can certainly prove to be disastrous in terms of coastline ecosystem functions. The present rate of degradation will certainly result in the total disruption of the sensitive ecosystem and consequent drastic depletion of marine wealth and its biodiversity. Hence, there is an imperative need for the protection and restoration of the green belt that are under tremendous threat.

Remote sensing systems collect vast amounts of biological and physical data on multiple data, thus allowing both inventory and monitoring of the environment. Global Positioning Systems (GPS) aid in the collection of ground data and processing of remotely sensed imagery. It is rather difficult to collect data in a conventional method because of the complexity of the data requirement for decision making and planning for the management of the mangrove ecosystem. Orbital remote sensing technique provides synoptic, multi-spectral and repetitive coverage which is very useful for studying the coastal zone. Nayak and Bahuguna (2001) highlighted the importance of the remotely sensed data for inventorying, mapping and monitoring of the natural resources has been well established. Remote sensing data has provided important information on various components of coastal wetlands like density wise mapping of mangroves, brackish water areas, and suspended sediment dynamics. Orbital remote sensing has made a great contribution in mapping and monitoring of the critical habitats of the Indian coast.

The main objective of this study was to detect, assess and monitor the changes in the mangrove ecosystem in the pre and post tsunami using remote sensing and GIS in southeastern coast and South Andaman Islands of India.

2. STUDY AREA

The Gulf of Mannar is located on the South-eastern tip of India in the state of Tamil Nadu. It is in this region India's first and foremost marine biosphere reserve is situated. Popularly known as the biologist's paradise, the region harbors more than 3,600 species of plants and animals making it one of the world's richest marine biosphere reserve. Owing to its shallowness, semi-enclosed nature less fluctuating temperature regimen, biophysical and ecological uniqueness nutrient enrichment etc, it has acquired special status in the biodiversity map of the Indo-Pacific oceanic realm. It has a chain of 21 islands stretching from Tuticorin to Rameshwaram. The geographical distribution of the area is 8° 55'N-9°15'N and 78°-79°16'E. The area of Gulf of Mannar under the Indian EEZ is about 15000 sq. km. all the 21 islands are classified into 4 major group. 1) Tuticorin 2) Vembar 3) Kilakarai 4) Mandapam. There are 7 islands in the Mandapam group. Poomarichan, Pullivalal and Krusadai are the three islands in the Mandapam group that were taken into account.

The Andaman and Nicobar Archipelago extends from 6-14°N and 92-94°E. It consists of 572 islands and islets and lies in the lap of Bay of Bengal. These islands are often described as "islands of Marigold Sun". The islands have a maximum width of 575 km and are oriented in a north-south direction and simulating an arc stretching over a length of 912 km. The islands have a total land area of 8249 sq km with a coastline of 1962 km that is highly indented and several creeks penetrate into the island from inland bays. Due to its tropical humid climate and insular nature with no contiguity of land with the rest of India, Andaman and Nicobar islands is unique among all the states and union territories.

3. MATERIALS AND METHOD

Type Different remote sensing satellite images were acquired and used in this research. Besides the remote sensing data other ancillary data like toposheets from survey of India were used.

In this research four remote sensing satellite images were acquired and used. Two optical satellite images of IRS IC LISS III acquired on 10th December 1999 and Resourcesat I LISS IV acquired on 28th December 2004 were used as the pre and post Tsunami period for the Gulf of Mannar Study area. Another two optical images IRS IC/ID LISS III were acquired on February and 11th February 2005 for the South Andaman Islands and used respectively because of their availability and they are the closest dates after the Tsunami. Figure 1 shows the general research approach in this study.

4. RESULTS AND FINDINGS

As related to research question: what are the damage and destruction caused to the mangroves as a result of Tsunami and how can it be detected? Using optical remotely sensed data it was possible to detect the damage caused to the mangroves. The onscreen visual interpretation of both pre and post Tsunami images were done to detect the damage caused by the adverse event. The field investigations have confirmed that there is negligible impact of the Tsunami waves on the Mandapam islands of Gulf of Mannar. Since the islands of Mandapam are uninhabited, it is devoid of any human interference. The mangroves are in good condition as it is bereft of any degradation. The Mandapam islands is partially sheltered by the Sri Lankan landmass. So these islands had minimal impact of Tsunami waves on the aqua-terrestrial ecosystem. Although long-term implications are there, further research is going on to investigate the indirect consequences to the aquatic ecosystems. The mangrove forest was in good condition and has protected the coastal land. It is thus concluded that the changes of the mangroves that are visible on the images are positive and it has simply resisted the wrath of Tsunami. On the contrary, the South Andaman Islands have suffered greater casualties of the mangroves. It can be observed from the images that the intact mangroves appeared as bright red patch whereas the damaged mangroves are mainly grayish or pale red in color. Field investigations revealed that there was submergence in many parts of the island at a depth of 0.9-1m and the frontline mangroves along the creeks are drying. There is no damage in the inland coastal forest. The false color composite of the images in a 321 combination gave the best result and brought out the differences well for both the visual interpretation and supervised classification. Spectral signature separability of the mangroves with other classes is quite distinctly marked out. On the basis of ground truth data and spectral signature analysis, classification with Maximum Likelihood Classifier were carried out on the images

However, related to research question: What is the degree and extent of damage of the mangroves caused by the Tsunami and how can it be determined?. The principle objective of this study was to assess the degree and extent of damage of the mangroves caused by the Tsunami. For assessing specific types of damage caused to the aqua-terrestrial ecosystems the damage has been rated on two different parameters: The degree and the spatial extent of damage. The heavy, moderate and least degree of damage of the mangroves was observed in the field and then the information collected from the ground truth data was incorporated in the post Tsunami image. The classified map of degree and extent of damaged mangroves were generated. The degree of damage was classified according to the physical impact of the Tsunami waves on the mangroves. The extent of damaged mangroves was mapped with the aid of visual interpretation and ground truth data collected during the

fieldwork. The spatial area of the affected mangroves was assessed in relation to the direction of Tsunami incursion. Overall damage caused to the mangroves was assessed on the basis of the dual criteria of 'degree' and 'extent'. Proper training sites based on field observations were taken to differentiate between various degrees of damage in the study area. Since the optical satellite data of LISS III has a resolution of 23.5 metres, the areal extent of mangroves can only be detected and assessed.

While the other research question was: How change in the condition of the mangroves be monitored before and after tsunami using optical satellite data?: Post classification comparison was done to monitor the changes of the mangroves and other land cover/ land use categories. The classification comparison has determined the changes in the area that have taken place and the nature of changes that have taken place. A changed matrix gave a clear picture of the changes in the land use / land cover classes.

The comparative study that was done for both the study areas revealed that there are changes in the post Tsunami period and the changes are positive as well as negative. The mangroves and other vegetative species in the three islands of Mandapam group in Gulf of Mannar have undergone positive changes because it has protected the islands from destruction. The mangroves and other associated species have regenerated. The other aquatic plant ecosystems may have long-term effects and may take centuries to fully recuperate. The most interesting observation is that the shoreline has narrowed down to an extent and it is due to the erosion and accretion that is taking place over the years. A comparative analysis was done with the pre and post tsunami images of South Andaman Islands to monitor the changes in the post Tsunami conditions. There is an increase in the water-mass on the agricultural lands and some settlement areas which shows a decline in the area coverage of these land use. The frontline mangroves that have undergone changes along the creeks are all heavily damaged and the inland forests are still in intact position. The southern part of the South Andaman Islands has suffered greater casualties. The mortality of the mangroves is mainly due to low respiration as a result of burying pneumatophores. Although mangroves remain in waterlogged conditions, the non exposure of the breathing roots for six –eight hours a day has lead to the mortality of the mangroves. Example of the pre and post accuracy assessment shown in Table 1. Other results related to the change detection analysis of damage by Tsunami to mangroves is explained in Figure 2, 3, 4 and 5 for the area of South Andaman Islands..

5. CONCLUSIONS

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The extent of damaged mangroves was mapped with the aid of visual interpretation and ground truth data collected during the fieldwork. The spatial area of the affected mangroves was assessed in relation to the direction of Tsunami incursion. Overall damage caused to the mangroves was assessed on the basis of the dual criteria of 'degree' and 'extent'. Proper training sites based on field.

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REFERENCES

- Beatley t, B. D.J, et al. (2002). Introduction to coastal zone management. Island press. Washington D.C. 273 pp.
- Nayak, S. and A. Bahuguna (2001). "Application of remote sensing data to monitor mangroves and other coastal vegetation of India." International Journal Of Remote Sensing, **30**(4): 195-213.

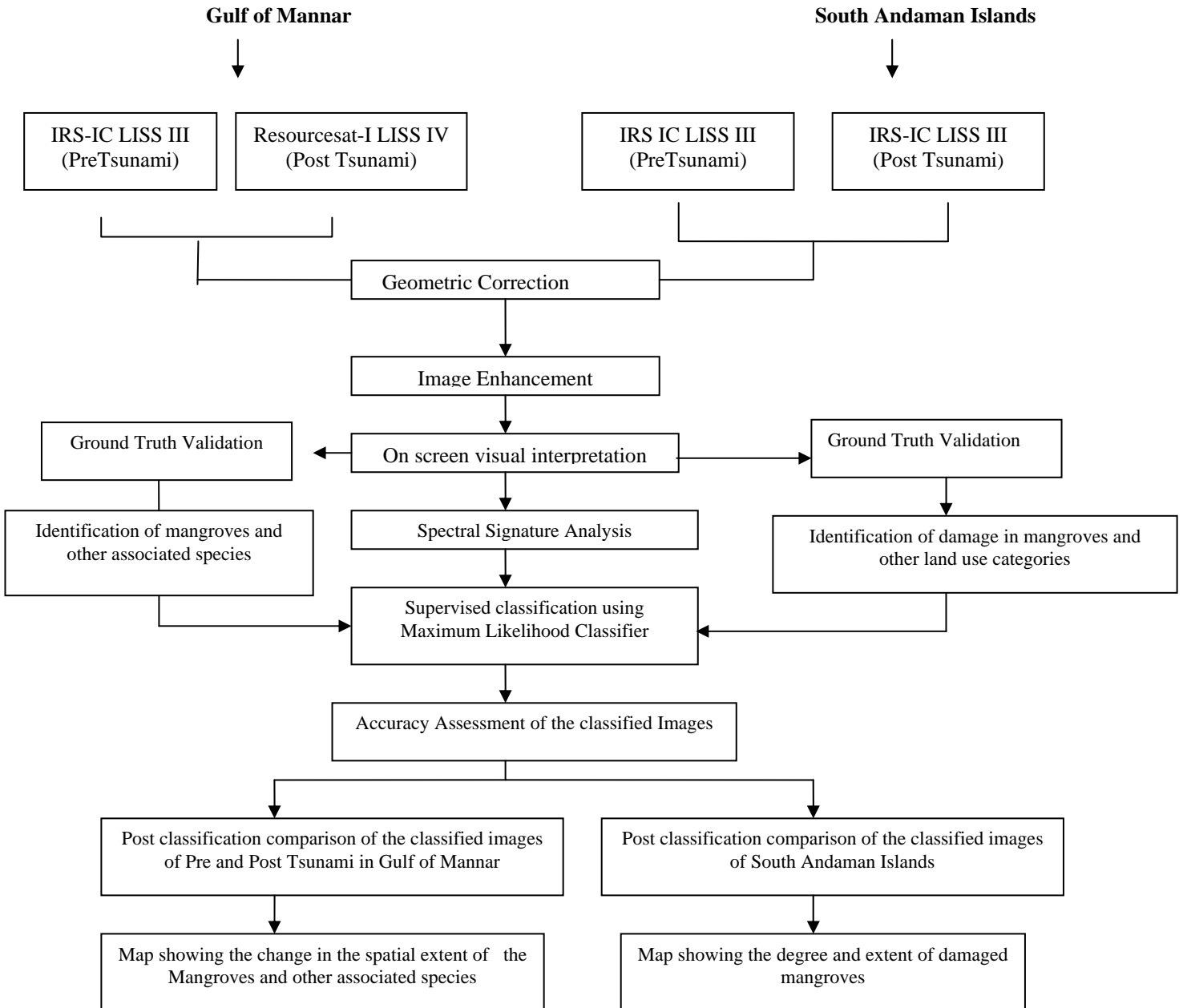


Figure 1. Research Approach

Land cover classes	Pre Tsunami			Post Tsunami		
	Producers accuracy	User's accuracy	Kappa Statistics	Producers accuracy	Users accuracy	Kappa statistics
Mixed mangroves	100	71.43	0.6942	100	100	1.0000
Other vegetation	100	84.62	0.8201	100	100	1.0000
Herbaceous vegetation	100	87.50	0.8623	50	66.67	0.6032
Mangrove associates	100	50	0.5	75	100	1.0000
Suspended sediments	66.67	100	1.0000	100	83.33	0.7917
Sea	95	76	0.6743	100	100	1.0000
Shoreline	87.50	100	0.4583	100	50	0.4792
Overall accuracy	85.53	0.8183	88.00	0.8529		

Table 1. Accuracy assessment of the classified images of Gulf of Mannar

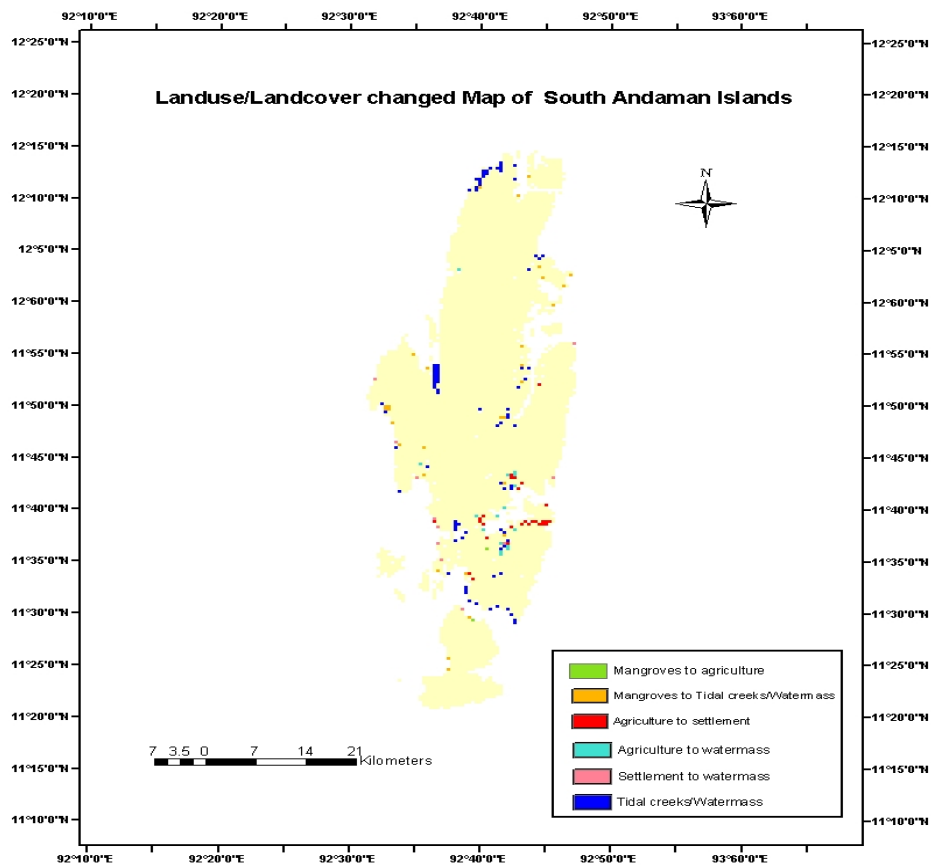
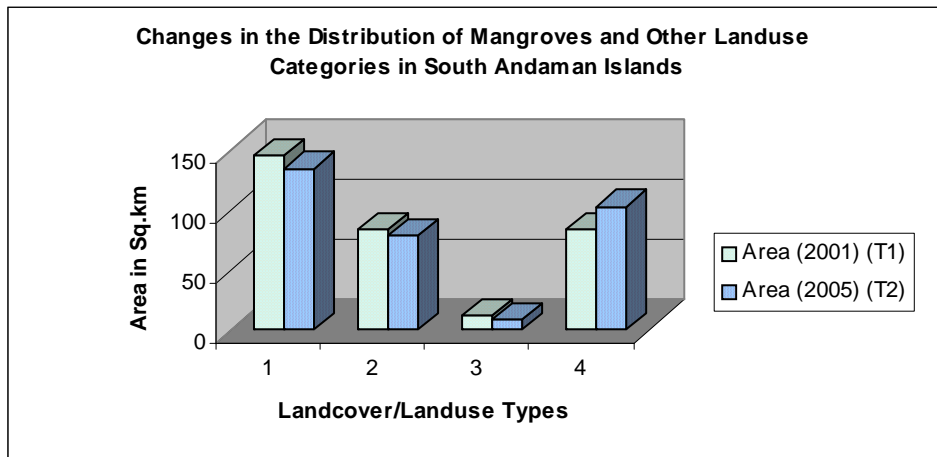


Figure 2. Classified changed Landuse /Landcover Map of Post Tsunami in South Andaman Islands



1- Mangrove Swamps 2-Agriculture 3-Settlement 4- Tidal Creeks/Watermass

Figure 3. Post Tsunami Changes in the distribution Of Mangroves and Other Land cover categories

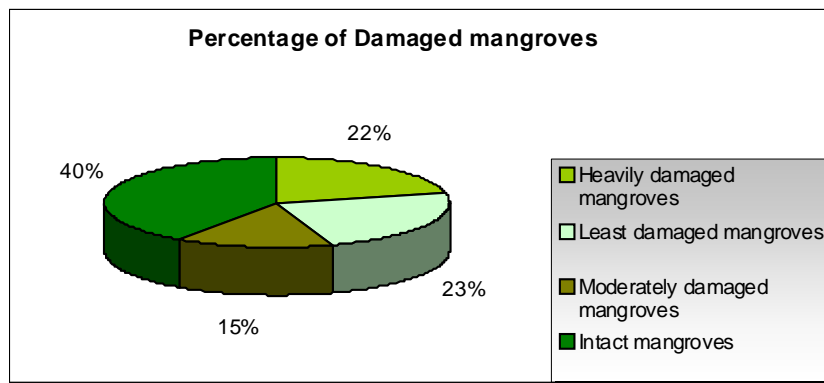


Figure 4. Percentage of Damaged Mangroves

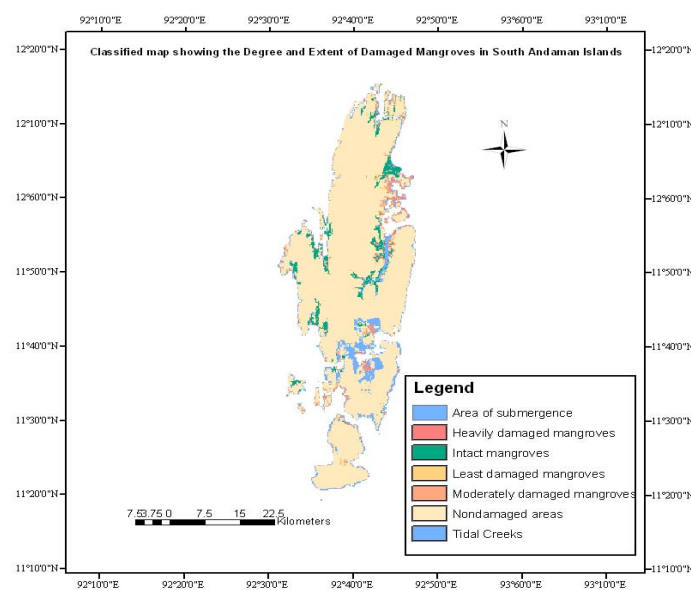


Figure 5. Classified Map showing the degree and extent of Damage Mangroves in South Andaman Island