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RESEARCH ARTICLE

MONITORING OF TEMPORAL CHANGES IN THE MANGROVES ECOSYSTEM, KAKINADA COAST USING GEOSPATIAL TECHNIQUES

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ABSTRACT

The receding glaciers, shrinking cover of natural forests, the rapid loss of biodiversity, the falling ground water levels, inter annual variation in rainfall, rising temperature, falling agricultural productivity, point to the destructing health of the ecosystems, not well known in the past. The Mangroves ecosystem on the Kakinada coast is not out of bounds for the same and experienced high rates of deforestation over period of time. Mangroves are a group of salt tolerant plant species, which occur in the tropical and subtropical initial estuary regions. Mangroves constitute a dynamic ecosystem with a complex association of both floral and faunal species of terrestrial and aquatic systems and the vegetation in this forest is of evergreen type. Mangrove forests, types of coastal ecosystems in tropical zone, play an important role not only for material of biogeochemical cycle but also for human demand and economic activities including aquaculture, fishing as well as improving local living standard. They perform many protective, productive and economic functions. Mangrove forests near estuarine areas act as a barrier against cyclones and mitigate their effects. They prevent storm water from entering the mainland and prevent soil erosion along the coastal areas. Mangrove wetlands serve as spawning and nursery grounds for many economically important estuarine/marine fishes and shellfishes; their impact on ecology is equally significant: they harbour many resident and migratory birds. Though the mangrove ecosystem is highly productive and has multiple uses, mangroves suffered serious neglect till very recently. They are undergoing widespread degradation due to a combination of physical, biological, anthropogenic and social factors. Human-induced stresses and factors - such as unscientific management practices, changes in water quality, soil salinity, diversion of fresh water upstream, and conversion of mangrove wetlands for aquaculture, salt pans and other land use practices - have reduced mangrove vegetation. Mangrove wetlands have also been degraded by indiscriminate destruction of mangrove resources and clear-felling of mangrove forest. Mangroves. It is being envisaged judicious and realistic land cover and land use change data in conservation planning, accurate and efficient techniques to detect mangroves ecosystem change from multi-temporal satellite imagery are desired for conservation optimally. In view of this scenario, a study was taken up in Kakinada coast, primarily to study changes in mangrove ecosystem, vegetation type, density and extent, analyze the extent of deforestation, identify the changes in density of vegetation and to understand the temporal changes. The study assessed the impact of various measures taken up to prevent, principally between 1996 to 2010. After geometric and atmospheric corrections, the satellite imageries were subsetted and subjected to hybrid classification in to 100 classes, grouped in to ten classes for calculating the aerial extent. NDVI was used to identify the changes in density of vegetation and the change matrix identified the variations in the land cover over period of time. DGPS was used for marking critical locations The mangrove distribution was made from investigation in situ or analyzing from remotely sensing images and GIS techniques .Monitoring the locations and distributions of Mangroves changes is important for establishing links between policy decisions, regulatory actions and subsequent land use activities. Planning plays a key role in the management of making best use of limited resources. Integrated use of GIS, Remote Sensing and Image processing technologies enable us to cope with the objectives of change detection.

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INTRODUCTION

Mangrove are salt-tolerant plants of tropical and subtropical intertidal regions of the world. The plants which live in muddy, wet soil in tropical or subtropical tidal waters. Mangrove forests are best developed on tropical shorelines where there are large areas available between high and low tide points. Monitoring the dynamics of mangrove forest is of particular interest owing to their considerable ecological and economic importance. In particular, mangrove forest plays a major role in supplying organic nutrients to costal marine ecosystem. The tropic relationship between Mangrove and coastal ecosystem can be characterized by the biomass and productivity of the mangrove forest. Mangroves are developed due to two main factors: 1. River dominant. 2. Wave dominant. Godavari and Krishna Mangrove Ecosystem Mainly formed in to river dominant factor.

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Causes of Degradation

Mangrove forest degradation is depending up on villagers using some kinds of activities. Anthropogenic factors such as grazing by feral cattle, and collection of mangroves for firewood and fencing materials by villagers. Yet another cause is that the banks of rivers and creeks are relatively elevated because of sediment deposit along the banks whenever floods occur. Lack of tidal flushing in interior mangrove areas, leading to degradation, with only the fringe areas supporting mangrove growth. Areas adjoining the reserve forests with mangroves have been converted to aquaculture ponds.

Need for Study

Mangrove ecosystems on coastline save lives and property during natural hazards such as cyclones, storm surges and erosion. Mangrove Ecosystems Directly and indirectly helpful for Human health and Environmental conditions. These Surrounding Areas have an assured scope of Development economically.

Location and extent

The study area comprises Godavari Mangrove Ecosystem of East Godavari District, Andhra Pradesh, which spreads over an area of 3700sq.kms. This area lies geographically between the $16^{o}18^{'}00^{''}$ N to $17^{o}5^{'}00^{''}$ N Latitude and $81^{o}42'30''$ E to $82^{o}23'00''$ E Longitude.

The objectives of the study are

The main objectives of the study are:

- To Monitor and Detect the Mangrove ecosystem Changes occurred due to Natural and Anthropogenic activities.
- To carry out detailed examination of temporal Changes of Godavari Mangrove Ecosystem from 1998 to 2010
- To Identify the nature of the change in the Mangrove Ecosystem
- To assess the shoreline changes
- To Measure the change in the area of extent.

Methodology and Analytical Framework

The following methodology is adopted in the present study to meet the above mentioned objectives. To study the mangrove forest spread change detection was carried out for different temporal data sets to analyse the extent and density and type of vegetation and the vegetation growth, the integrated use of GIS and Remote Sensing and Digital Image Processing techniques were used for the study. The study was carried out specifically for the years, 1998, 2004, and 2010.

Land Use/Land Cover Classification

Thematic land classes were derived digitally by grouping pixels that have similar spectral signatures from the measurements of individual bands throughout the spectrum. Usually this classification is made with visible, near-infrared, and middle infrared part of the spectrum. Image interpretation was carried out with the help of nine elements of interpretation key.

Supervised Classification

Supervised classification was performed for forming classes that are similar in spectral reflectance. In this approach, pixels are assigned to class (i.e., training classes) verified on the ground in selected areas. The Maximum Likelihood Classifier is used as it is a successful criterion that is based on a priori probabilities. Vegetation density analysis is usually carried out by calculating vegetation indices. A vegetation index is common spectral index that identifies the presence of chlorophyll. The index is composed of reflectance in the red spectral region (620 to 700 nm) and a portion (700 to 1100 nm) of the near–infrared (NIR) spectral region. Spectral satellite measurements in the red and infrared channels were atmospherically corrected for interference from aerosols. Chlorophyll has a relative low reflectance in the red part of the electromagnetic spectrum (strong absorption) and relatively high reflectance in the near- infrared channels have been formulated. The Normalized Difference Vegetation Index (NDVI) is a simple numerical indicator was used to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not.

Normalized Difference Vegetation Index (NDVI)

NDVI = NIR – Red / NIR + Red

NDVI values lies between -1 and +1. Vegetation in good condition shows higher NDVI values. This is used to eliminate the seasonal sun angle difference and minimize atmospheric effects. Higher values indicate more density and vigor of the vegetation. NDVI is extensively used to detect seasonal variations among vegetation.

Change detection

Change detection analysis was carried out with the help of Change Detection Matrix provided with ERDAS imagine. By giving classified image of two different periods as input, the model automatically generates the area where changes are happened. For knowing changes happened in which type of land use classes statistical analysis were also carried out. To get an idea about vegetation, terrain, people and climate, a preliminary field visit was carried out in the early periods of study and necessary literatures and statistical information such as rainfall, temperature, agriculture were collected and incorporated with further studies.

RESULTS AND DISCUSSION

Classification of Image 1998

The following table gives the various classes of land for the year 1998. The analysis result shows that in the year 1998 the main area falling under Mangrove was covered 16075.50ha, and Degraded Mangrove was covered 6151.71ha, and Aquaculture was covered 7634.36ha, and Mudflat was covered into 5524.00ha, Area under Crop land is computed as 94445.94ha. 139242.73ha the falling under Fallow land and the area is occupied by Built up land 6546.17ha, and Open land was covered into 7198.45ha, and Plantation was covered into 2675.97ha, and Scrub land was covered into 4194.57ha, where as 3903.21ha area is occupied by sandy area and finally water bodies covered 46901.12ha.

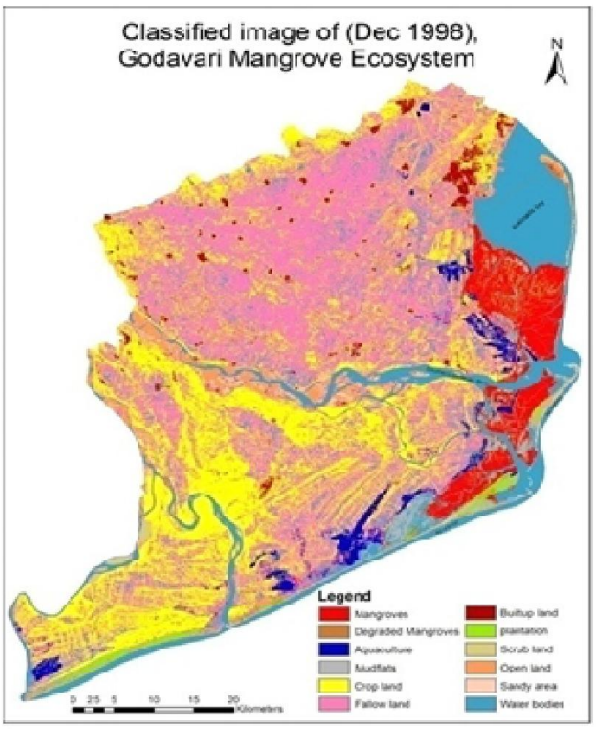

Figure 1. Godavari Mangrove Eco System year of 1998

Classes Names (1998)	Area in Hect
Water bodies	46901.12
Mangrove	16075.50
Degraded Mangrove	6151.71
Crop land	94445.94
Fallow land	139242.73
Open land	7198.45
Sandy land	3903.21
Scrub land	4194.57
Aquaculture	7634.36
Built-up land	6546.17
Mudflat	5524.00
Plantation	2675.97
Total	340493.72

Classification of Image 2005

The following table gives the various classes of land for the year 2001. The analysis result shows that in the year 1998 the main area falling under Mangrove was covered 17512.74ha, and Degraded Mangrove was covered 4088.52ha, and Aquaculture was covered 14206.95ha, and Mudflat was covered into 2303.59ha, Area under Crop land is computed as 99080.33ha. 121442.69ha the falling under Fallow land and the area is occupied by Built up land 12739.46ha, and Open land was covered into 9410.60ha, and Plantation was covered into 3185.54ha, and Scrub land was covered into 11601.92ha, where as 4228.76ha area is occupied by sandy area and finally water bodies covered 45650.85ha.

Classification of Image 2010

The following table gives the various classes of land for the year 2010. The analysis result shows that in the year 2010 the main area falling under Mangrove was covered 15501.96ha, and Degraded Mangrove was covered 6998.06ha, and Aquaculture was covered 17857.25ha, and Mudflat was covered into 5468.42ha, Area under Crop land is computed as 161000.71ha. 66482.27ha the falling under Fallow land and the area is occupied by Built up land 11302.49ha, and Open land was covered into 9010.39ha, and Plantation was covered into 1898.45ha, and Scrub land was covered into 6061.82ha, where as 8456.73ha area is occupied by sandy area and finally water bodies covered 30412.66ha.

Table 1. Landuse/Landcover Changes in 2005

Classes Names (2005)	Area in Hect
Water bodies	45650.85
Mangrove	17512.74
Degraded Mangrove	5588.52
Crop land	99080.33
Fallow land	121442.69
Open land	9410.60
Sandy land	4228.76
Scrub land	11601.92
Aquaculture	14206.95
Built-up land	12739.46
Mudflat	2303.59
Plantation	3185.54
Total	345451.94

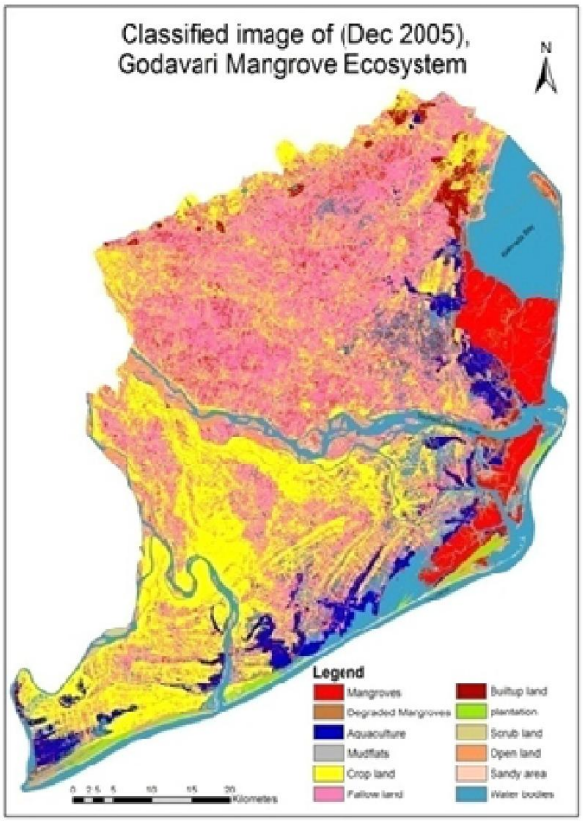

Figure 2. Godavari Mangrove Eco System year of 2005

Table 2. Landuse/Landcover Changes in 2010

Classes Names (2010)	Area in Hect
Water bodies	30412.66
Mangrove	16501.96
Degraded Mangrove	6298.06
Crop land	161000.71
Fallow land	66482.27
Open land	9010.39
Sandy land	8456.73
Scrub land	6061.82
Aquaculture	17857.25
Built-up land	18002.49
Mudflat	5468.42
Plantation	1898.45
Total	340451.21

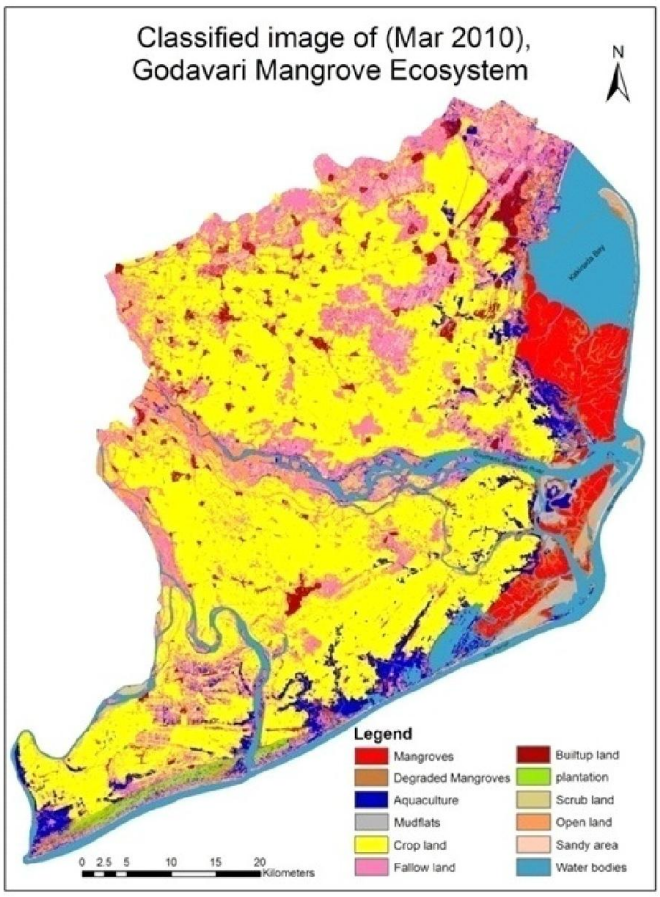

Figure 3. Godavari Mangrove Eco System in the year of 2010

Table 3. Landuse/Landcover Changes in 1998, 2005 and 2010

Classes Names	1998	2005	2010
Water bodies	46901.12	45650.85	30412.66
Mangrove	16075.50	17512.74	16501.96
Degraded Mangrove	6151.71	5588.52	6298.06
Crop land	94445.94	99080.33	161000.71
Fallow land	139242.73	121442.69	66482.27
Open land	7198.45	9410.60	9010.39
Sandy land	3903.21	4228.76	8456.73
Scrub land	4194.57	11601.92	6061.82
Aquaculture	7634.36	14206.95	17857.25
Built-up land	6546.17	12739.46	18002.49
Mudflat	5524.00	2303.59	5468.42
Plantation	2675.97	3185.54	1898.45
Total	340493.72	345451.94	340451.21

Change matrix

Change detection is used to highlight or identify significant differences in imagery acquired at different times; playing an important role in the lifecycle of GIS features and providing the capability to update feature data based on new imagery.

Key application areas include:

- Detecting changes in Mangrove.
- Delineating wetlands loss and encroachment.
- Estimating Mangrove forest loss through Natural or Anthropogenic.
- Identifying of Shoreline changes
- Identifying new Mangrove developed.

The Matrix operation from the GIS Analysis menu allows two thematic images or vector files of different years to be compared. By comparing two classified or vector sets of data, you eliminate false positives due to radiometric differences. For finding out the change detection for given study areas LISS III Data is used. The vector data is created in ArcGIS 9.3 using Editor Tool and vector data is attributed according to different classes viz. Mangrove, Degraded Mangrove, Crop land, Fallow land, Aquaculture, Mud flats, Scrub land, Settlements, Plantation, Open land, Sandy area and Water body by visual interpretation of image. The matrix operation in GIS analysis menu is used to find out changes between two seasons. The matrix operation compares all the classes of image with all classes of another image and shows the change from one class to another class.

Change matrix between 1998 and 2005

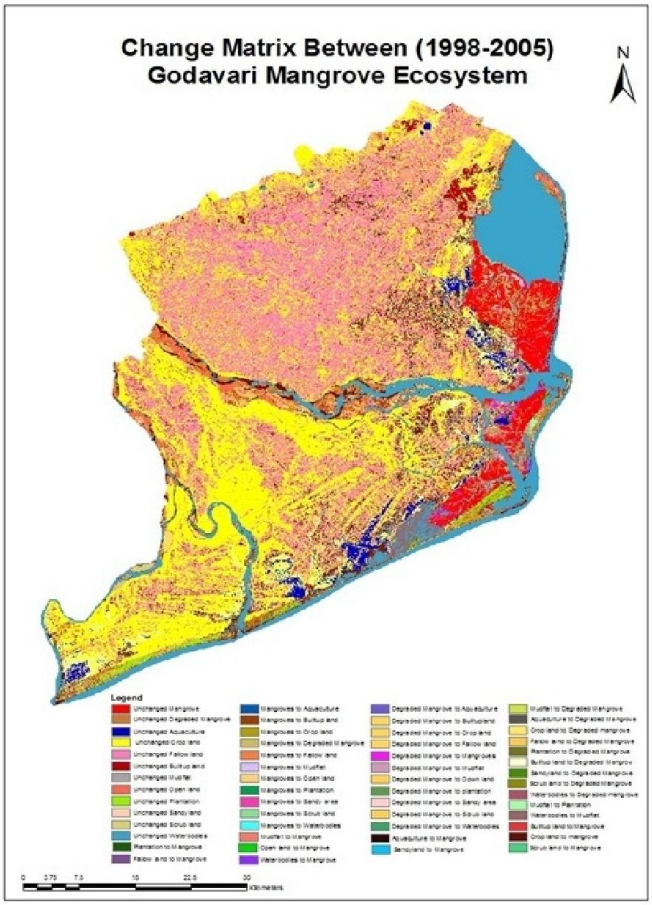

Figure 4. Change Matrix between 1998 and 2005

Changes Related to Mangrove

From the analysis it is observed that the Unchanged Mangrove is 13500.21 ha, the area under Degraded Mangrove changed to Mangrove is 2906.16 ha, the area under Aquaculture changed to Mangrove is 15.72ha, the area under Crop Lands which changed to Mangrove is 180.40 ha, the area under Fallow Land changed to Mangrove is 79.47 ha, the area under Built -up Land changed to Mangrove is 2.68 ha, the area under Open Land changed to Mangrove is 61.25 ha, the area under Mudflats changed to Mangrove is 379.45 ha, the area under Scrub Land changed to Mangrove is 12.86 ha, the area under Plantation changed to Mangrove is 25.72 ha, the area under Sandy area changed to Mangrove is 38.21 ha and the area under Water Bodies changed to Mangrove is 310.58 ha from 1998 to 2005.

Changes Related to Degraded Mangrove

From the analysis it is observed that the Unchanged Degraded Mangrove is 1442.17 ha, the area under Mangrove changed to Degraded Mangrove is 1000.37 ha, the area under Aquaculture changed to Degraded Mangrove is 77.52 ha, the area under Crop Lands which changed to Degraded Mangrove is 255.73 ha, the area under Fallow Land changed to Degraded Mangrove is 255.79 ha the area under Built-up land changed to Degraded Mangrove is 12.25 ha, the area under Mudflats changed to Degraded Mangrove is 586.24 ha, the area under Scrub Land changed to Degraded Mangrove is 5.00 ha, the area under Open Land changed to Degraded Mangrove is 39.86 ha, the area under Plantation changed to Degraded Mangrove is 43.76 ha, the area under Sandy area changed to Degraded Mangrove is 8.29 ha, the area under Water Bodies changed to Degraded Mangrove is 361.47 ha., from 1998 to 2005.

Changes related to the Aquaculture

From the analysis it is observed that the Unchanged Aquaculture is 5116.99 ha, the area under Mangrove changed to Aquaculture is 369.40 ha, the area under Degraded Mangrove changed to Aquaculture is 353.06 ha, the area under Crop Lands which changed to Aquaculture is 1935.53 ha, the area under Fallow Land changed to Aquaculture is 4252.59 ha, the area under Built-up land changed to Aquaculture is 67.59ha, the area under Mudflats changed to Aquaculture is 774.32 ha, the area under Scrub Land changed to Aquaculture is 26.51 ha, the area under Open Land changed to Aquaculture is 235.56 ha, the area under Plantation changed to Aquaculture is 5.67 ha, the area under Sandy area changed to Aquaculture is 20.42 ha, the area under Water Bodies changed to Aquaculture is 1049.31 ha. from 1998 to 2005.

Changes Related to Crop Land

From the analysis it is observed that the Unchanged Crop Land is 63383.42 ha, the area under Mangrove changed to Crop Land is 109.76 ha, the area under Aquaculture changed to Crop Land is 61.37 ha, the area under Degraded Mangrove changed to Crop Land is 59.73 ha, the area under Fallow Land changed to Crop Land is 21607.54 ha the area under Built-up land changed to Crop Land is 9.82 ha, the area under Mudflats changed to Crop Land is 90.51 ha, the area under Scrub Land changed to Crop Land is 893.29 ha, the area under Open Land changed to Crop Land is 158.28 ha, the area under Plantation changed to Crop Land is 65.27 ha, the area under Sandy area changed to Crop Land is 131.34 ha, the area under Water Bodies changed to Crop Land is 1488.00 ha. from 1998 to 2005.

Changes Related to Fallow Lands

From the analysis it is observed that the Unchanged Fallow Land is 79571.67 ha, the area under Mangrove changed to Fallow Land is 104.83 ha, the area under Aquaculture changed to Fallow Land is 491.47 ha, the area under Crop Lands which changed to Fallow Land is 22659.53 ha, the area under Degraded Mangrove changed to Fallow Land is 133.59 ha the area under Built-up land changed to Fallow Land is 61.70 ha, the area under Mudflats changed to Fallow Land is 210.75 ha, the area under Scrub Land changed to Fallow Land is 1979.41 ha, the area under Open Land changed to Fallow Land is 1053.09 ha, the area under Plantation changed to Fallow Land is 281.69ha, the area under Sandy area changed to Fallow Land is 1054.80 ha, the area under Water Bodies changed to Fallow Land is 10823.03 ha. from 1998 to 2005.

Changes Related to Mudflats

From the analysis it is observed that the Unchanged Mudflats is 1462.34 ha, the area under Mangrove changed to Mudflats is 224.47 ha, the area under Aquaculture changed to Mudflats is 46.08 ha, the area under Crop Lands which changed to Mudflats is 276.33 ha, the area under Fallow Land changed to Mudflats is 771.88 ha the area under Built-up land changed to Mudflats is 3.84 ha, the area under Degraded Mangrove Changed to Mudflats is 169.86 ha, the area under Scrub Land changed to Mudflats is 5.49 ha, the area under Open Land changed to Mudflats is 47.29 ha, the area under Plantation changed to Mudflats is 140.85 ha, the area under Sandy area changed to Mudflats is 10.06 ha, the area under Water Bodies changed to Mudflats is 145.11ha. from 1998 to 2005

Changes Related to Built-up Lands

From the analysis it is observed that the Unchanged Built-up land is 5876.23 ha, the area under Mangrove changed to Built-up is 25.05 ha, the area under Aquaculture changed to Built-up is 734.83 ha, the area under Crop Lands which changed to Built-up is 1822.48 ha, the area under Fallow Land changed to Built-up is 10475.39 ha the area under Degraded Mangrove land changed to Built-up is 78.07 ha, the area under Mudflats changed to Built-up is 49.73 ha, the area under Scrub Land changed to Built-up is 261.15ha, the area under Open Land changed to Built-up is 221.24 ha, the area under Plantation changed to Built-up is 4.63 ha, the area under Sandy area changed to Built-up is 203.56ha, the area under Water Bodies changed to Built-up is 1985.08 ha. From 1998 to 2005

Changes Related to Scrub Lands

From the analysis it is observed that the Unchanged Scrub Land is 560.77 ha, the area under Mangrove changed to Scrub Land is 71.12 ha, the area under Aquaculture changed to Scrub Land is 193.44 ha, the area under Crop Lands which changed to Scrub Land is 1935.84 ha, the area under Fallow Land changed to Scrub Land is 6843.66 ha the area under Built-up land changed to Scrub Land is 158.77 ha, the area under Mudflats changed to Scrub Land is 125.73 ha, the area under Degraded Mangrove changed to Scrub Land is 71.86 ha, the area under Open Land changed to Scrub Land is 179.97 ha, the area under Plantation changed to Scrub Land is 63.14 ha, the area under Sandy area changed to Scrub Land is 14.280 ha, the area under Water Bodies changed to Scrub Land is 1283.89 ha. From 1998 to 2005.

Changes Related to Plantation

From the analysis it is observed that the Unchanged Plantation is 1711.37 ha, the area under Mangrove changed to Plantation is 45.59 ha, the area under Aquaculture changed to Plantation is 0.67 ha, the area under Crop Lands which changed to Plantation is 303.82 ha, the area under Fallow Land changed to Plantation is 317.04 ha the area under Built-up land changed to Plantation is 40.65 ha, the area under Mudflats changed to Plantation is 275.29 ha, the area under Scrub Land changed to Plantation is 19.81 ha, the area under Open Land changed to

Plantation is 229.83 ha, the area under Degraded Mangrove changed to Plantation is 129.82 ha, the area under Sandy area changed to Plantation is 94.77 ha, the area under Water Bodies changed to Plantation is 16.88 ha. From 1998 to 2005.

Changes Related to Sandy Area

From the analysis it is observed that the Unchanged Sandy area is 771.46 ha, the area under Mangrove changed to Sandy area is 51.74 ha, the area under Aquaculture changed to Sandy area is 21.09 ha, the area under Crop Lands which changed to Sandy area is 140.54 ha, the area under Fallow Land changed to Sandy area is 599.89 ha the area under Built-up land changed to Sandy area is 72.40 ha, the area under Mudflats changed to Sandy area is 129.75 ha, the area under Scrub Land changed to Sandy area is 91.54 ha, the area under Open Land changed to Sandy area is 1392.38 ha, the area under Plantation changed to Sandy area is 126.10 ha, the area under Degraded Mangrove changed to Sandy area is 59.73 ha, the area under Water Bodies changed to Sandy area is 771.28 ha. From 1998 to 2005.

Changes Related to Open Lands

From the analysis it is observed that the Unchanged Open Land is 2268.97 ha, the area under Mangrove changed to Open Land is 182.47 ha, the area under Aquaculture changed to Open Land is 164.68 ha, the area under Crop Lands which changed to Open Land is 438.57 ha, the area under Fallow Land changed to Open Land is 3414.03 ha the area under Built-up land changed to Open Land is 129.69 ha, the area under Mudflats changed to Open Land is 416.81 ha, the area under Scrub Land changed to Open Land is 215.81 ha, the area under Degraded Mangrove changed to Open Land is 176.87 ha, the area under Plantation changed to Open Land is 160.17 ha, the area under Sandy area changed to Open Land is 700.03 ha, the area under Water Bodies changed to Open Land is 1139.03 ha. From 1998 to 2005.

Changes Related to Water Bodies

From the analysis it is observed that the Unchanged Water Bodies is 27406.27 ha, the area under Mangrove changed to Water Bodies is 387.98 ha, the area under Aquaculture changed to Water Bodies is 712.40 ha, the area under Crop Lands which changed to Water Bodies is 1059.06 ha, the area under Fallow Land changed to Water Bodies is 11075.77 ha the area under Built-up land changed to Water Bodies is 97.39 ha, the area under Mudflats changed to Water Bodies is 1025.18 ha, the area under Scrub Land changed to Water Bodies is 110.19 ha, the area under Degraded Mangrove changed to Water Bodies is 587.16 ha, the area under Plantation changed to Water Bodies is 53.57 ha, the area under Sandy area changed to Water Bodies is 758.78 ha, the area under Open Land changed to Water Bodies is 1304.49 ha. From 1998 to 2005.

Changes Related to Mangrove

From the analysis it is observed that the Unchanged Mangrove is 12004.46 ha, the area under Degraded Mangrove changed to Mangrove is 2465.53 ha, the area under Aquaculture changed to Mangrove is 59.96 ha, the area under Crop Lands which changed to Mangrove is 91.76 ha, the area under Fallow Land changed to Mangrove is 85.88 ha, the area under Built -up Land changed to Mangrove is 3.17 ha, the area under Open Land changed to Mangrove is 3.57 ha, the area under Mudflats changed to Mangrove is 385.06 ha, the area under Scrub Land changed to Mangrove is 2.25 ha, the area under Plantation changed to Mangrove is 2.02 ha, the area under Sandy area changed to Mangrove is 2.02 ha and the area under Water Bodies changed to Mangrove is 396.29 ha from 1998 to 2010.

Change matrix between 1998 and 2010

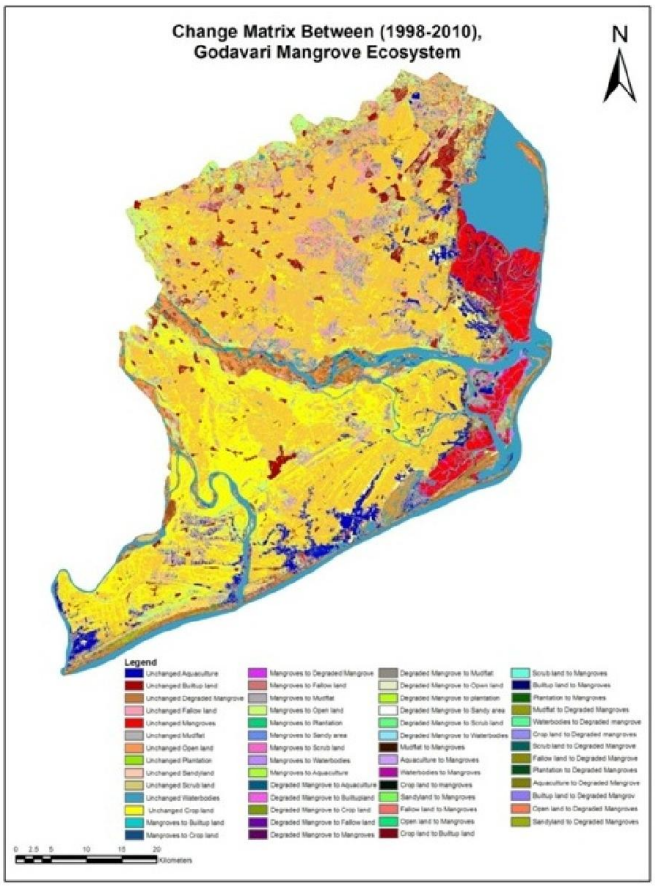

Figure 5. Change Matrix between 1998 and 2010

Changes Related to Degraded Mangrove

From the analysis it is observed that the Unchanged Degraded Mangrove is 1685.68 ha, the area under Mangrove changed to Degraded Mangrove is 1929.44 ha, the area under Aquaculture changed to Degraded Mangrove is 250.50 ha, the area under Crop Lands which changed to Degraded Mangrove is 941.36 ha, the area under Fallow Land changed to Degraded Mangrove is 618.63 ha the area under Built-up land changed to Degraded Mangrove is 70.56 ha, the area under Mudflats changed to Degraded Mangrove is 756.70 ha, the area under Scrub Land changed to Degraded Mangrove is 22.18 ha, the area under Open Land changed to Degraded Mangrove is 83.52 ha, the area under Plantation changed to Degraded Mangrove is 133.00 ha, the area under Sandy area changed to Degraded Mangrove is 28.17 ha, the area under Water Bodies changed to Degraded Mangrove is 477.91ha. from 1998 to 2010.

Changes related to the Aquaculture

From the analysis it is observed that the Unchanged Aquaculture is 4740.12 ha, the area under Mangrove changed to Aquaculture is 392.14 ha, the area under Degraded

Mangrove changed to Aquaculture is 491.45 ha, the area under Crop Lands which changed to Aquaculture is 2278.10 ha, the area under Fallow Land changed to Aquaculture is 5345.96 ha, the area under Built-up land changed to Aquaculture is 404.93ha, the area under Mudflats changed to Aquaculture is 836.36 ha, the area under Scrub Land changed to Aquaculture is 161.17 ha, the area under Open Land changed to Aquaculture is 582.11 ha, the area under Plantation changed to Aquaculture is 292.32ha, the area under Sandy area changed to Aquaculture is 228.44 ha, the area under Water Bodies changed to Aquaculture is 2103.17 ha. from 1998 to 2010.

Changes Related to Crop Land

From the analysis it is observed that the Unchanged Crop Land is 56401.72 ha, the area under Mangrove changed to Crop Land is 77.82 ha, the area under Aquaculture changed to Crop Land is 1170.10 ha, the area under Degraded Mangrove changed to Crop Land is 96.14 ha, the area under Fallow Land changed to Crop Land is 87777.75 ha the area under Built-up land changed to Crop Land is 16.42 ha, the area under Mudflats changed to Crop Land is 219.75 ha, the area under Scrub Land changed to Crop Land is 1072.23 ha, the area under Open Land changed to Crop Land is 318.53 ha, the area under Plantation changed to Crop Land is 105.00 ha, the area under Sandy area changed to Crop Land is 182.42 ha, the area under Water Bodies changed to Crop Land is 12760.24 ha. from 1998 to 2010.

Changes Related to Fallow Lands

From the analysis it is observed that the Unchanged Fallow Land is 30463.41 ha, the area under Mangrove changed to Fallow Land is 76.15 ha, the area under Aquaculture changed to Fallow Land is 725.65 ha, the area under Crop Lands which changed to Fallow Land is 25079.26 ha, the area under Degraded Mangrove changed to Fallow Land is 138.82 ha the area under Built-up land changed to Fallow Land is 51.76 ha, the area under Mudflats changed to Fallow Land is 183.86 ha, the area under Scrub Land changed to Fallow Land is 1491.28 ha, the area under Open Land changed to Fallow Land is 1065.44 ha, the area under Plantation changed to Fallow Land is 545.19ha, the area under Sandy area changed to Fallow Land is 1070.62 ha, the area under Water Bodies changed to Fallow Land is 4165.38 ha. From 1998 to 2010.

Changes Related to Mudflats

From the analysis it is observed that the Unchanged Mudflats is 2019.75 ha, the area under Mangrove changed to Mudflats is 702.55 ha, the area under Aquaculture changed to Mudflats is 175.28 ha, the area under Crop Lands which changed to Mudflats is 352.63 ha, the area under Fallow Land changed to Mudflats is 198.66 ha the area under Built-up land changed to Mudflats is 45.22 ha, the area under Degraded Mangrove Changed to Mudflats is 521.57 ha, the area under Scrub Land changed to Mudflats is 51.38 ha, the area under Open Land changed to Mudflats is 502.68 ha, the area under Plantation changed to Mudflats is 1047.23 ha, the area under Sandy area changed to Mudflats is 288.75 ha, the area under Water Bodies changed to Mudflats is 362.71 ha. from 1998 to 2010.

Changes Related to Built-up Lands

From the analysis it is observed that the Unchanged Built-up land is 2008.66 ha, the area under Mangrove changed to Built-up is 17.28 ha, the area under Aquaculture changed to Built-up is 56.62 ha, the area under Crop Lands which changed to Built-up is 3386.97 ha, the area under Fallow Land changed to Built-up is 3877.03 ha the area under Degraded Mangrove land changed to Built-up is 29.03 ha, the area under Mudflats changed to Built-up is 21.08 ha, the area under Scrub Land changed to Built-up is 309.03ha, the area under Open Land changed to Built-up is 1947.16 ha, the area under Plantation changed to Built-up is 10.43 ha, the area under Sandy area changed to Built-up is 136.23ha, the area under Water Bodies changed to Built-up is 401.30 ha. from 1998 to 2010.

Changes Related to Scrub Lands

From the analysis it is observed that the Unchanged Scrub Land is 411.27 ha, the area under Mangrove changed to Scrub Land is 59.67 ha, the area under Aquaculture changed to Scrub Land is 52.99 ha, the area under Crop Lands which changed to Scrub Land is 2599.80 ha, the area under Fallow Land changed to Scrub Land is 2035.66 ha the area under Built-up land changed to Scrub Land is 64.80 ha, the area under Mudflats changed to Scrub Land is 58.69 ha, the area under Degraded Mangrove changed to Scrub Land is 41.47 ha, the area under Open Land changed to Scrub Land is 233.17 ha, the area under Plantation changed to Scrub Land is 45.45 ha, the area under Sandy area changed to Scrub Land is 144.46 ha, the area under Water Bodies changed to Scrub Land is 314.21 ha. from 1998 to 2010.

Changes Related to Plantation

From the analysis it is observed that the Unchanged Plantation is 356.84 ha, the area under Mangrove changed to Plantation is 34.33 ha, the area under Aquaculture changed to Plantation is 0.75 ha, the area under Crop Lands which changed to Plantation is 1118.95 ha, the area under Fallow Land changed to Plantation is 205.46 ha the area under Built-up land changed to Plantation is 8.64 ha, the area under Mudflats changed to Plantation is 76.84 ha, the area under Scrub Land changed to Plantation is 6.80 ha, the area under Open Land changed to Plantation is 16.13 ha, the area under Degraded Mangrove changed to Plantation is 20.04 ha, the area under Sandy area changed to Plantation is 7.20 ha, the area under Water Bodies changed to Plantation is 46.48 ha. from 1998 to 2010.

Changes Related to Sandy Area

From the analysis it is observed that the Unchanged Sandy area is 568.40 ha, the area under Mangrove changed to Sandy area is 39.80 ha, the area under Aquaculture changed to Sandy area is 5.64 ha, the area under Crop Lands which changed to Sandy area is 937.62 ha, the area under Fallow Land changed to Sandy area is 4463.92 ha the area under Built-up land changed to Sandy area is 169.23 ha, the area under Mudflats changed to Sandy area is 33.70 ha, the area under Scrub Land changed to Sandy area is 245.09 ha, the area under Open Land changed to Sandy area is 775.65 ha, the area under Plantation changed to Sandy area is 28.97 ha, the area under Degraded Mangrove changed to Sandy area is 32.08 ha, the area under Water Bodies changed to Sandy area is 1152.93 ha. from 1998 to 2010.

Changes Related to Open Lands

From the analysis it is observed that the Unchanged Open Land is 2472.04 ha, the area under Mangrove changed to Open Land is 136.40 ha, the area under Aquaculture changed to

Table 4. Changes Related to Waterbodies from the year of 1998 to 2005

Classes 1998/ 2005	Water bodies	Mangr-ove	Degra-ded Mangr-ove	Crop land	Fallow land	Open land	Sandy area	Scrub land	Aquac-ulture	Built-up land	Mudf-lat	Planta-tion
Water bodies	27406.27	310.58	361.47	1488.00	10823.03	1139.03	771.28	1283.89	1049.31	1985.08	145.11	16.88
Mangrove	387.98	13500.21	1000.37	109.76	104.83	182.47	51.74	71.12	369.40	25.05	224.47	45.59
Degraded Mangrove	587.16	2906.16	1442.17	59.73	133.59	176.87	59.73	71.86	353.06	78.07	169.86	129.82
Crop land	1059.06	180.40	255.73	63383.42	22659.53	438.57	140.54	1935.84	1935.53	1822.48	276.33	303.82
Fallow land	11075.77	79.47	255.79	21607.54	79571.67	3414.03	599.89	6843.66	4252.59	10475.39	771.88	317.04
Open land	1304.49	61.25	39.86	158.28	1053.09	2268.97	1392.38	179.97	235.56	221.24	47.29	229.83
Sandy area	758.78	38.21	8.29	131.34	1054.80	700.03	771.46	112.57	20.42	203.56	10.06	94.77
Scrub land	110.19	12.86	5.00	893.29	1979.41	215.81	91.54	560.77	26.51	261.15	5.49	19.81
Aquaculture	712.40	15.72	77.52	61.37	491.47	164.68	21.09	193.44	5116.99	734.83	46.08	0.67
Built-up land	97.39	2.68	12.25	9.82	61.70	129.69	72.40	158.77	67.59	5876.23	3.84	40.65
Mudflat	2025.18	379.45	586.24	90.51	210.75	416.81	129.75	125.73	774.32	49.73	462.34	275.29
Plantation	53.57	25.72	43.76	65.27	281.69	160.17	126.10	63.14	5.67	4.63	140.85	1711.37

Table 5. NDVI Classified Image of 2010

NDVI Class	Area in Hectares
Very Low Density Vegetation	54972.15
Low Density Vegetation	88815.37
Moderate Density Vegetation	61735.97
High Density Vegetation	79684.80
Very High Density Vegetation	49724.06
Total	334932.35

Figure 6. NDVI Classified image

NDVI Class	Area in Hectares
Very Low Density Vegetation	54972.15
Low Density Vegetation	88815.37
Moderate Density Vegetation	61735.97
High Density Vegetation	79684.80
Very High Density Vegetation	49724.06
Total	334932.35

Figure 7. NDVI Classified Image of 2005

NDVI Class	Area in Hectares
Very Low Density Vegetation	26148.89
Low Density Vegetation	34224.15
Moderate Density Vegetation	54037.67
High Density Vegetation	100498.68
Very High Density Vegetation	117124.22
Total	332033.61

Figure 8. NDVI Classified Image

NDVI Class	Area in Hectares
Very Low Density Vegetation	54972.15
Low Density Vegetation	88815.37
Moderate Density Vegetation	61735.97
High Density Vegetation	79684.80
Very High Density Vegetation	49724.06
Total	334932.35

Open Land is 184.55 ha, the area under Crop Lands which changed to Open Land is 655.21 ha, the area under Fallow Land changed to Open Land is 2064.11 ha the area under Built-up land changed to Open Land is 18.46 ha, the area under Mudflats changed to Open Land is 361.04 ha, the area under Scrub Land changed to Open Land is 276.66 ha. The area under Degraded Mangrove changed to Open Land is 197.86 ha, the area under Plantation changed to Open Land is 205.69 ha, the area under Sandy area changed to Open Land is 562.35 ha, the area under Water Bodies changed to Open Land is 1370.32 ha. from 1998 to 2010.

Changes Related to Water Bodies

From the analysis it is observed that the Unchanged Water Bodies is 23222.97 ha, the area under Mangrove changed to Water Bodies is 595.24 ha, the area under Aquaculture changed to Water Bodies is 206.27 ha, the area under Crop Lands which changed to Water Bodies is 618.69 ha, the area under Fallow Land changed to Water Bodies is 2080.41 ha the area under Built-up land changed to Water Bodies is 51.45 ha, the area under Mudflats changed to Water Bodies is 1365.82 ha, the area under Scrub Land changed to Water Bodies is

134.21 ha, the area under Degraded Mangrove changed to Water Bodies is 444.16 ha, the area under Plantation changed to Water Bodies is 10.08 ha, the area under Sandy area changed to Water Bodies is 690.28 ha, the area under Open Land changed to Water Bodies is 892.58ha. from 1998 to 2010.

NDVI Classified Image of 1998

Vegetation density mapping is carried with helps vegetation indices such as NDVI. Vegetation indices widely employed for determination of density of vegetation, water stress, and crop health monitoring. Vegetation density mapping was carried out for Godavari River Region in East Godavari District. Common classification techniques employed for NDVI derived IRS images and classification was carried out based on assigned land use classes. Results displayed in the form of maps, table and chart.

Conclusion

In conclusion, this study has demonstrated the usefulness of multi-temporal IRS LISS III images in detecting land-cover change, in identifying areas for rehabilitation, and in evaluating rehabilitation strategies for Coastal Regions. Change detection techniques using temporal remote sensing data provide detailed information for detecting and assessing land cover and land use dynamics. Different change detection techniques were applied to monitor the changes. The change analysis spanning over a period of twelve years using classification techniques shows that the Mangroves is the dominant class in the study area and there is slight increase in the total area covered by crop land from 22227.21 hectares to 23101.26 hectares between 1998 to 2005 and a sharp decrease from 23101.26 hectares to 22800.02 hectares 2005 to 2010, for Godavari river region. The Godavari mangroves and the coastline have undergone drastic changes within a short period of about 12 years due to both natural and anthropogenic causes. On the other hand, the mangroves facing the sea have vanished due to coastal erosion. The overall change in the mangrove area is not very much, since the area of accreted and restored mangroves is almost equal to the area of degradation, land use conversion and erosion.

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