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Application of Satellite Remote Sensing Data for Assessment of Land Use and Land Cover Changes in Krishna District, Andhra Pradesh

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ABSTRACT
The applicability of temporal remote sensing digital data supported by conventional data in the impact assessment of cyclones and storm surges on an ecologically and economically significant fertile delta area in terms of changes in land use /land cover has been attempted. The changes in land use/land cover classes in the cyclone prone delta area of river Krishna in the state of Andhra Pradesh, India during the period 1990-2000 were mapped and were studied through digital interpretation of IRS-1A and IRS-1C images. Digital image classification using supervised classification technique with maximum likelihood algorithm with the help of principal component analysis has been implemented on multi-dated digital data to study the changes in the study area. Aquaculture and agricultural land show increasing trend, where as, the areas under fallow land, water logged marshy and water bodies have shown a declining trend. Degraded forest, forest plantation, sandy area and mud flats show minor changes. A notable increase is observed in aquaculture and agriculture lands. The aqua area has increased to about 6.57% in total geographical area (TGA) and 51.91% in total aqua farm area. It was observed that fallow land, water bodies and waterlogged areas have been converted into aquaculture and other agriculture uses. The declining trend in forest plantations, degraded forest and plantations and increase of aquaculture farms lead to environmental degradation in this area. It is concluded that the importance of remote sensing data in combination with other relevant data to help in more detailed understanding of the land use / land cover and its changes in different time periods.

INTRODUCTION

Land use and land cover of the earth are changing rapidly because of the human induced and natural activities. Land use / land cover change may result in environmental, social, and economic impacts of greater damage than benefit to the area (Mohsen 1999). In Krishna delta, irregular farming operations, rapid industrialization, increasing population, occurrence of natural and man-made disasters, and the events of ecological and socioeconomic importance resulting in frequent land use/land cover changes. The changes in land use and land cover, characterizing the most of the fertile delta areas, necessitate proper utilization of available land through scientific land use planning. Hence, it is considered important to study the land use/land cover change in order to make a sustainable land use plan in this area. The utility of remotely sensed imagery for detecting and monitoring changes in land cover (Price, Pike & Mendes 1992, Ram & Kolarkar 1993), vegetation dynamics and urban expansion, has become very widely recognized, because of repeated broad-scale coverage of the satellites.

Temporal data on land use/land cover changes and spatial distribution is prerequisites for planning and development. Conventional ground methods of land use mapping are labor intensive, time consuming and hence are done relatively infrequently, and these maps soon become outdated with passage of time, particularly in a rapidly changing environment. The satellite-borne data offer a quick and efficient approach for mapping and evaluation of land use/land cover pattern over space and time. In the present paper, land use/land cover change detection analysis was carried out using Indian Remote Sensing satellite imagery obtained in the year 1990 and 2000, and the

results were compared qualitatively and quantitatively; of different land use and land cover classes in the study area.

The classification techniques are post classification change detection (Hurd et al., 1992), multi-date classification change detection, cross-correlation analysis (Hurd et al., 2001), multi-date principal components analysis and RGB-NDVI color composite change detection (Hoffhine 2000). In the present study post classification change detection analysis was carried out. Studies on land use/land cover changes using satellite data, have gained lot of importance for the last two decades. Research on land use/land cover mapping and change, using visual interpretation and onscreen digitization to identify landscape features, was carried out by the Applied Research Institute (ARI 1997) to map the West Bank using remotely sensed digital data. Temporal changes in land use/land cover between two dates in Chiang Mai area using Landsat TM, were measured by performing change matrix (Somporn 1995). Many investigations were done with Remote Sensing & GIS inputs for studying various land features and the changes (Lo 1981, Ragahav Swamy et al., 1992, Civco 1993, Rao et al., 1996, Murthy & Venkateswara Rao 1997, Weicheng Wu et al., 2002 and Gerhard Kemper et al., 2004).

STUDY AREA

In the present research area, the changes in land cover occur in two forms, inter-category changes, i.e., forest land to agriculture, and intra-category changes i.e. changes in aerial extent of any feature. Digital classification techniques through stratification approach for larger areas, with limited ground truth, has been used for mapping broad categories of land use/land cover features and for change detection research. Delta areas are among the most fertile areas because of the soil consisting of deposited silt and rich and adequate water source, so they are agriculturally and industrially well developed and hence are densely populated. These factors contribute to their environmental importance. Therefore, the present investigation concentrates on one of the cyclone-prone and ecologically fertile delta regions undergoing frequent land use/ land cover changes owing to the storm surges originating in the sea.

The study area is the Krishna District which includes delta of the river Krishna, lying between 15°43' -17°10' North latitudes and 80° 00'- 81°33' East longitudes (Fig.1) covers 8030 km^2. The delta is under intensive irrigation with paddy crop cultivated twice a year. The upland in the delta region has an undulating topography consisting of low ranges of

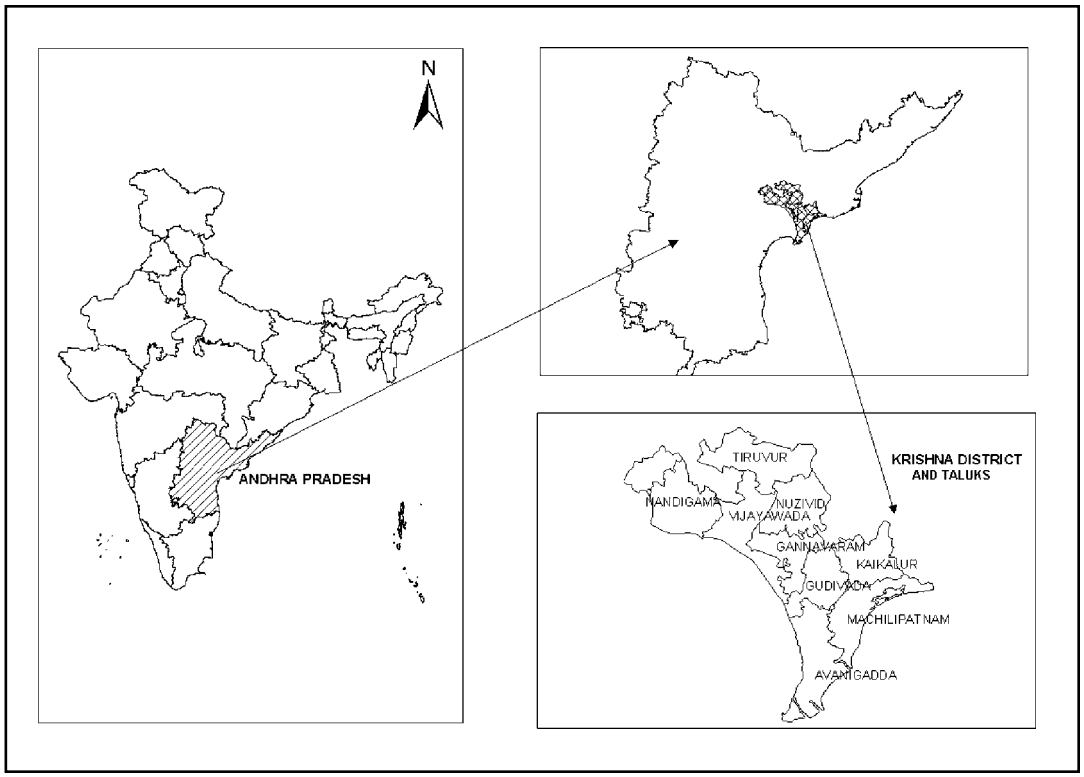

Figure 1. Location Map of the Study Area

Eastern Ghat hills. Forest types are mixed deciduous in highland and the extreme south (near river mouth) has a thick mangrove forest with wildlife habitat. The population of the district was 3,625,728 in 1990 and is increased to 4,218,416 in 2000 (14.05% growth). The coastal *taluks* (a *taluk* is an administrative unit in a district) have extensive cultivation and industrial development and hence are densely populated. The area experiences tropical maritime climate, characterized by an oppressive summer and good seasonal rainfall mainly because of South-West monsoon from June to September. The study area is affected frequently by tropical cyclones created by low-pressure systems in the Bay of Bengal, during the post monsoon period (October - November). The severe depressions lead to disastrous cyclonic storms associated with gale winds, heavy rainfall and storm surge causing huge losses and marked land use/land cover changes.

Table-1. Details of the Satellite data used

Satellite/ Sensor	Path	Row	No.of Scan lines/Pixels	Date of Pass
IRS –1A	23	57	2500/2520	21-01-1990
LISS – I	23	56	2500/2520	21-01-1990
IRS – 1C	102	61	6003/6480	23-10-2000
LISS-III	102	62	6003/6480	23-10-2000
	103	61	6003/6480	23-10-2000

DATA USED AND METHODOLOGY

Both spatial and non-spatial data are used for the study. Multi-temporal digital data of IRS 1A, LISS-I (1990) and IRS 1C, LISS-III (2000) pertaining to the study are used. The details of the digital datasets used in the present study are shown in Table 1. The relevant Survey of India (SOI) topographical maps on 1:50,000 scales, the base maps surveyed in 1972 are used in geo-referencing the satellite data. The Census and Statistical Handbook of the Krishna District (1991, 2001) are referred to for socioeconomic assessment.

The first step in processing satellite imageries was to geo-reference the multi-temporal scenes to make them spatially comparable. The IRS-1A and IRS-1C digital data was geo-referenced to geographic latitude and longitudes, using Ground Control Points derived from the Survey of India toposheets and mosaics are created in ERDAS Imagine 8.6. First order polynomial geometric model has been used and nearest neighborhood resampling technique was opted in order to preserve the original pixel values. The boundary of the study area obtained from the village and town directory of the district census data (1991) handbook and is digitized using Arc/Info software, and overlaid on the SOI topographic map to transfer the control points from the topographic map. This digitized vector boundary is geo-referenced to real world geographic coordinate system using first order polynomial geometric model, spheroid as Everest. The district boundary is taken as AOI for sub setting image data from the images mosaic.

CLASSIFICATION RESULTS AND DISCUSSION

Supervised classification technique has been implemented using the maximum likelihood algorithm and classifications procedure was applied on each scene separately using spectral reflectance and field knowledge. All the pixels of image mosaics of the year 1990 and the year 2000 have been classified to different land use/land cover classes. Before classifying the images using supervised classification technique, unsupervised classification was done to attain spectral signature of real land use and land cover. The maximum likelihood algorithm was used for different class segments with separate training data set. About twelve land use/land cover classes are demarcated. In the case of LISS-III high-resolution data (23m) classification, two or more classes are obtained for each of the land use category. They are integrated into a specific land use category obtained in the case of LISS-I data (73m) of low resolution, for comparison. The digital image and corresponding classified image are shown in figures 2 and 3 respectively. To assess the accuracy of the classified image, ground truth surveys have been carried out, and pure signatures were collected using ground truth points obtained from the field.

The land use/land cover classification system with 24 categories (up to Level-2) under 6 main categories (Level-1) is used for generation of classified out-put. The total area is classified into thirteen classes viz, agricultural land, fallow land, settlements & others, aquaculture, water bodies, water logged marshy land, plantation, degraded forest, mangroves, forest plantation (open/dense scrub), sandy area mud flats. The land use/land cover statistics derived from a direct comparison of the two classified images data are represented in the Table. 2. Fig.4 shows the bar diagram of the changes that occurred from 1990 to 2000 in the study area. The land use/ land cover features identified from the IRS-IA and IRS- IC images of 1990 and 2000 substantiated by field observations.

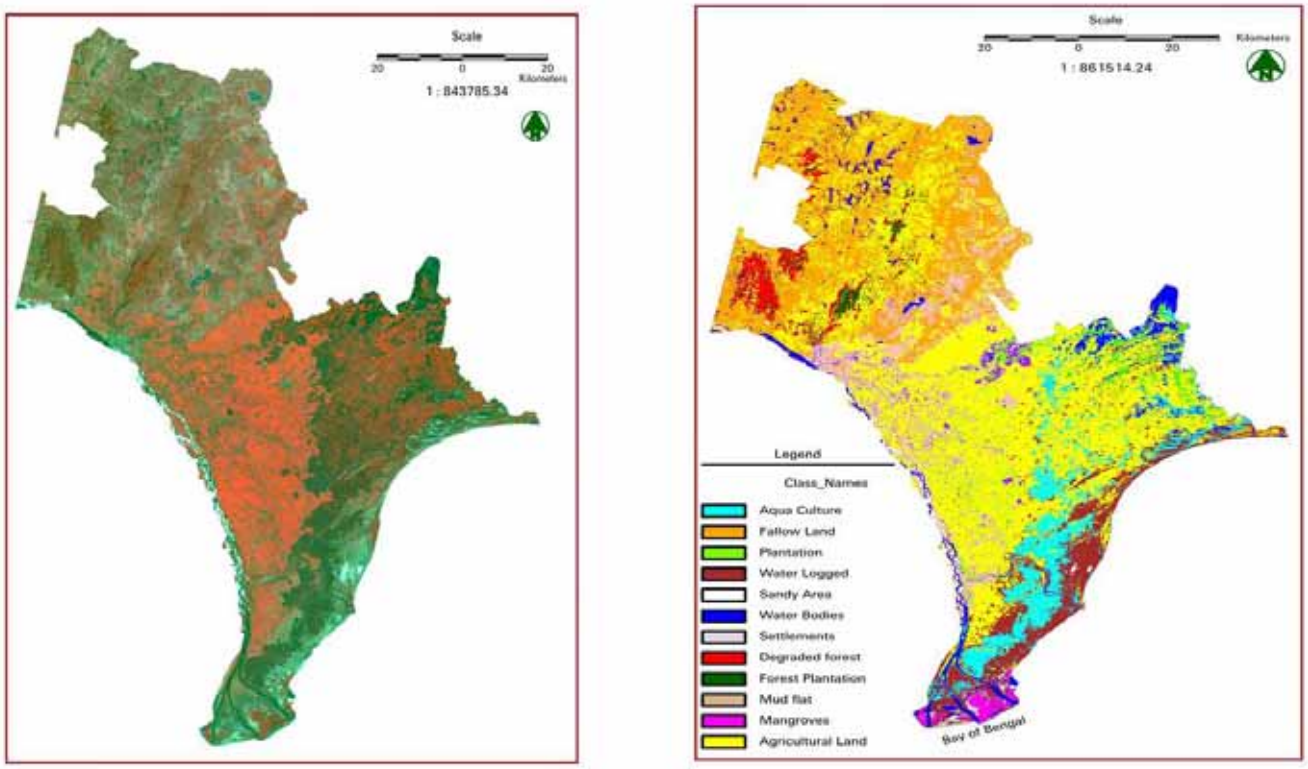

Figure 2. Digital False Colour Composite of IRS 1A (1990) and classified map

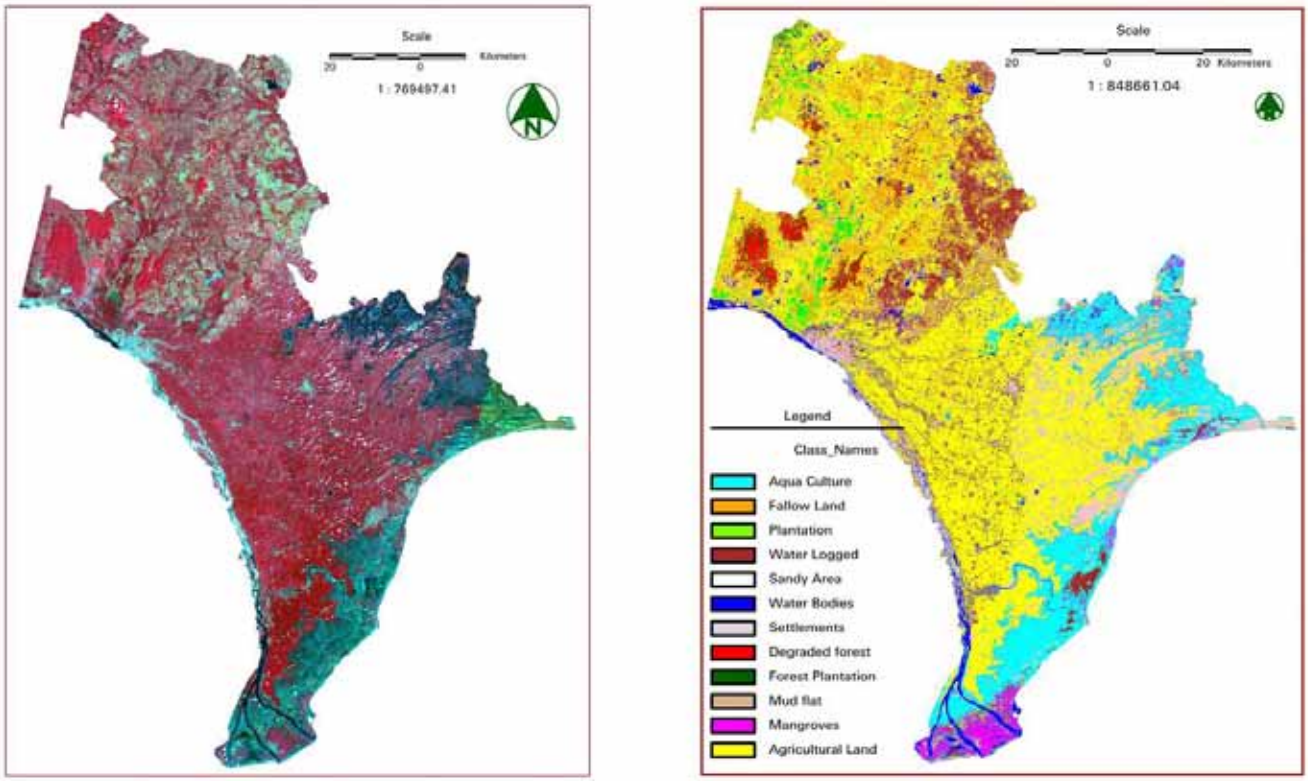

Figure 3. Digital False Colour Composite of IRC 1C (2000) and classified map

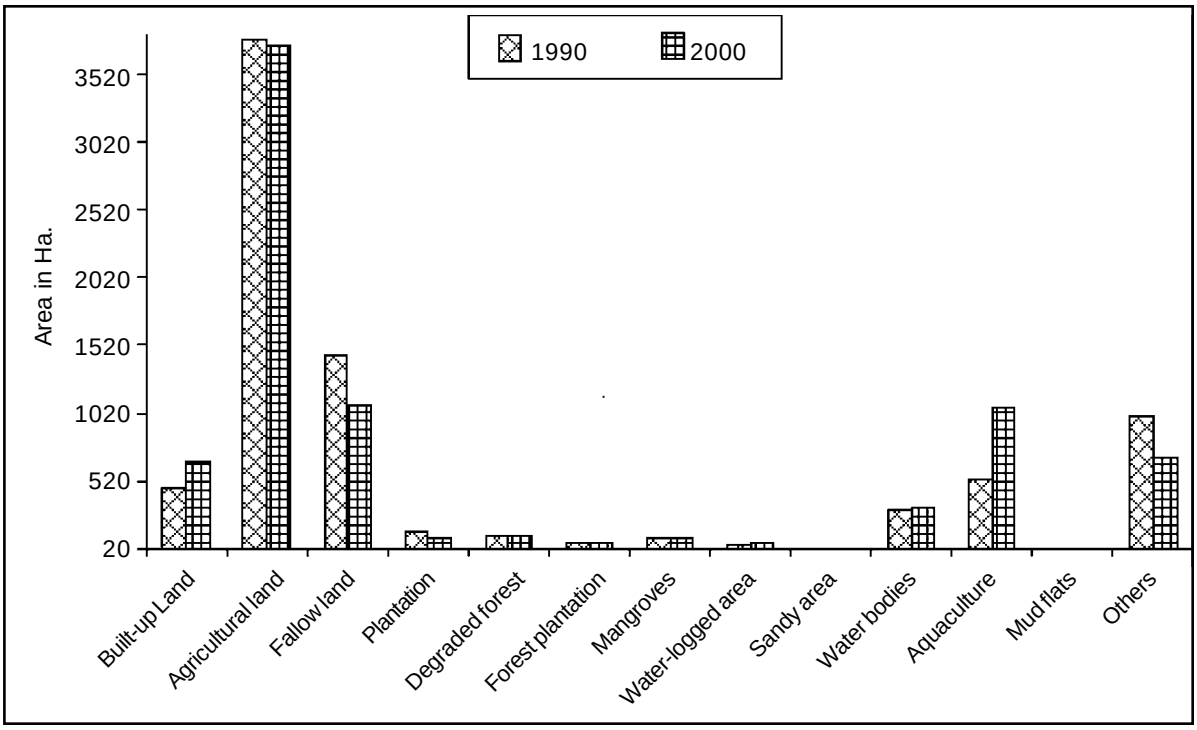

Figure 4. Plot on Land use change from 1990-2000

Table 2. Land use/Land cover changes from 1990 to 2000

Land use/Land cover Feature	Area (Sq.km) in 1990	% TGA in Study Area	Area (Sq.km) in 2000	% TGA in Study Area	Change in Area (sq.km)	% Change
Agriculture Land	3409.25	42.45	3792.75	47.23	+383.50	+11.25
Fallow Land	1452.50	18.09	1076.44	13.40	-376.06	-25.89
Settlements/Others	1260.75	15.70	1262.35	15.72	+1.60	+0.13
Aquaculture	488.73	6.09	1016.45	12.66	+527.72	107.98
Water Logged Marsh Land	331.31	4.13	84.70	1.05	-246.61	-74.43
Water Bodies	374.99	4.67	174.33	2.17	-200.66	-53.51
Plantation	185.49	2.31	146.88	1.83	-38.61	-20.82
Degraded Forest	166.00	2.07	155.23	1.93	-10.77	-6.49
Mangroves	152.25	1.90	157.44	1.96	+5.19	+3.41
Forest Plantation	93.40	1.16	61.56	0.77	-31.84	-34.09
Sandy Area	86.88	1.08	69.55	0.87	-17.33	-19.95
Mudflats	27.61	0.34	34.93	0.43	+7.32	+26.51
	8029.16	99.98	8032.61	100.02		

Agriculture land

Agriculture land occupies a major portion of the study area, except a few isolated patches along the coast because of dense network of canal irrigation, fertile soils and the favorable climate conditions. The agriculture land in the area at the time of satellite pass can be divided into two classes, the land with standing crop considered as the cropland and the land already harvested or under preparation for sowing and transplantation considered as the current fallow. The remote sensing technique has made a mark in identifying traditional agricultural lands and crop growth rate since a decade because of its repetitive coverage and high resolution. The red tone of the cropland demarcates it from other associated land use classes. The total agricultural area (TAA) in 1990 was 3409.25 km2 constituting 42.45% of total geographic area (TGA). It has increased by 383.5 km^2 to a total agricultural area of 3792.75 km^2 in the year 2000 accounting for 47.23% in total geographic area.

Fallow land

Fallow land is a dominant feature next to agriculture land. The wasteland and harvested areas of the agriculture land without vegetation are discernible in the satellite imagery with grayish tinge and square pattern. Field observation and enquiries revealed that paddy is the dominant crop. Land use of LISS-1data sensor (October 1990) and LISS-III data (January 2000), both belong to cropped season only. Commonly the periods October and January have a continuous crop season. The classified image shows that fallow land covered 1,452.5 km^2 in 1990 has come down to 1,076.44 km^2 in 2000. The decrease of 376.06 km^2 accounting for a reduction of 25.89% in the fallow land, is attributable to approximately equal areas of increase in agricultural land (383.5 km^2) from 1990 to 2000.

Settlements/Others

Human settlements and roads come under this classification. However, much change in built-up area and others has been not observed during the past ten years. The built-up area and others have been estimated at 1260.75 km^2 in 1990 and it is 1262.35 km^2 in 2000. It constitutes 15.70% of TGA of the district. This amounts to an increase of +0.13% in the TGA of the district.

Aquaculture

Aquaculture is the most dominant type in the southern part of the study area. The satellite image of the study area presents a mottled appearance with a number of rectangular or square shaped tanks spread over a considerable extent. The farms are concentrated more in the lagoon plain, which has a clayey substratum with brackish water areas along the coastline in the delta. The farms are spread all along the tidal inlets and the swale portions in between the beach ridge areas. The encroachment of aqua-farms into the protected mangrove forest is observed near the river mouth. The transformation of agriculture area into aqua-farms reduces cropland area and affects groundwater quality and the physical and chemical composition of the soil to a great extent. Aquaculture recorded the highest increase of 108%, probably attributable to the conversion of water bodies; water logged land and a part of fallow land. The area was 488.73 km^2 (6.09% in TGA) in 1990 and 1016.45 km^2 (12.66%) in the year 2000 accounting for an increase of about 6.57% in its share in TGA and 51.91% in total aqua-farm area.

The water-spread area in this district is large because of the river *Krishna* and the famous *Kolleru* lake. The area covered under water bodies is 374.99 km^2 (4.67% in TGA). The decrease in this class is about 200.66 km^2. The major ecological danger evident from the present study is the conversion of *Kolleru* Lake almost completely into aqua ponds and it is manifested in the form of rectangular bunds and paths in the image.

Waterlogged marshy area

The part of the southern area is covered by water throughout the year, is a waterlogged area, characterized by specific vegetation, free floating rooted hydrophytes and amphibian hydrophytes**.** The land is ecologically significant as it can harbor only a specific vegetation and eco-system, as qualitatively the available water is unsuitable for other plant species. The waterlogged area of about 331.31 km^2 in 1990 has come down to 84.7 km^2 in a decade recording a decrease of 246.61 km^2 (74.43% in total water logged area).

Plantations and degraded forest

Plantation area covers the erstwhile wasteland or in a few cases agricultural cropped land whereas degraded

forest area probably had a forest cover earlier, which has now become degraded because of anthropogenic activities or natural calamities. The belt of unconsolidated coastal sands constituting beach ridge with crescent shape parallel to the coast is very prominent landform suitable for plantation like casuarina, cashew and mango. In the satellite image, the linear patches with dark brownish red color and fine texture are the casuarina plantations and the shades of light red color are cashew and mango. The area under plantation class shows a decrease of 20.82% (2.31% in TGA) from 185.49 km^2 in 1990 to 146.88 km^2 (1.83% in TGA) in 2000.

The FCC shows the degraded forest in light gray to greenish white tone, fine to medium texture, irregular in shape and varying in size mostly associated with the forest, showing degradation characteristics. The degradation characteristics of a forest are very sparse dry deciduous vegetation showing stunted growth, leaves with little chlorophyll, frequent defoliation and effected with deceases. This feature covers an area of 166 km^2 in hills in 1990; it is 155.23 km^2 in 2000.

Mangroves

Mangrove forests form an integral component of the dynamic coastal ecosystem. Termed as "*Coastal Woodlands*" or "*Tidal Forests*" mangroves, are composed of salt tolerant inter-tidal halophytic vegetation, which form a locale specific unique community with specific ecological role. Ecologically mangroves form the buffer zone along the coast and act as "s*helter belts*" preventing soil erosion and protecting the land from high tidal surges of cyclonic storms. Generally degradation of mangrove area has been recorded in many studies because of illegal felling for fuel wood timber, tannin, bark, construction materials, and development of prawn culture in the past decade. Mangroves vegetation is identified because of its brick red colour in the FCC image near the mouth of the Krishna River. During classification it is mixed with plantations and irrigated land, hence this part was separated by sub-setting the digital data and classified separately. No remarkable change was observed in mangroves from 1990 (152.25 km^2) to 2000 (157.44 km^2).

Forest plantation

Forest plantation area was a degraded forest area or a wasteland present in the forest, which has been covered recently for ecological conservation and/or economic benefits. Forests that include both evergreen and deciduous trees covering an area of 93.4 km^2 in 1990 have decreased to 31.84 km^2 (34.09% of the total plantation area) by 2000. As forest plantation and agricultural area are contiguous to each other, extension of agricultural land might have resulted in the reduction of the forest plantation.

Sandy Area and mud flats

Sandy area found along all the river channels and beaches along the shoreline and in the site of dead river courses and beach ridges was 86.88 km^2 has decreased marginally to 69.55 km^2. The change is probably due to plantations and aqua-farms. The land originally covered by mud flats showed a little increase. Unaltered mud flats are in the extreme south of the study area near the river mouth. The change in the mud flat area is negligible.

Accuracy assessment

The classification accuracy was assessed using the data collected from the field. Field data was used to get a better idea of the land use present with in the study area in terms of location and heterogeneity. The classification accuracy has been assessed with the use of an error matrix (confusion matrix) calculated for the LISS-III data of 2000. An error matrix of numbers are shown (Table 3) in rows and columns, representing the sample pixels of each category relative to the actual category as confirmed on the ground. The rows in the matrix represent classified land use map, while the columns represent the reference data obtained from the field.

The accuracy of the classification has been assessed in terms of over all accuracy, average producer accuracy (interpretation accuracy) and average user accuracy (target accuracy). The overall accuracy of 87.97%, an average producer accuracy of 86.05% and average user accuracy of 86.41 were achieved with a Kappa coefficient of 0.8711. Kappa coefficient is widely used because all elements in the classification error matrix, including diagonal and off diagonal values in its calculation and makes them useful for testing the statistical significance of the differences in various error matrices (Congalton 1991).

CONCLUSIONS

Supervised classification alone is not sufficient to arrive at a meaningful classification because of the same reflectance characteristics of two different land use classes (i.e. mangroves and agriculture). Hence the method of sub-setting is adapted to the satellite data

Table 3. Accuracy Assessment confusion Matrix –LISS-III 2000 data

Feature	Aqua culture	Fallow	Planta-tion	Water logged	Sandy area	Water body	Settle-ments	Degraded forest	Forest Plantation	Mud Flat	Man-groves	Agricul-ture land	Total of Row	User Accuracy
Aquaculture	148	0	0	11	0	16	0	0	0	0	0	0	169	87.6
Fallow	0	225	0	0	0	0	10	32	0	0	0	0	253	88.9
Plantation	0	0	125	0	0	0	0	0	19	0	13	0	171	73.1
Water logged	19	0	0	40	0	0	0	0	0	10	0	0	60	66.7
Sandy area	0	0	0	0	23	0	0	0	0	0	0	0	25	92.0
Water body	10	0	0	0	0	68	0	0	0	0	0	0	78	87.2
Settlements	0	0	0	0	0	0	52	0	0	0	0	0	52	100.0
Degraded forest	0	16	0	0	0	0	0	224	0	0	0	0	240	93.3
Forest Plantation	0	0	12	0	0	0	0	0	160	0	0	0	172	93.0
Mud Flat	0	0	0	8	0	0	0	0	0	48	0	0	56	85.7
Mangroves	0	0	5	0	0	0	0	0	6	0	66	18	95	69.5
Agriculture land	0	0	0	0	0	0	0	0	0	0	0	321	321	100.0
Total of Column	177	241	142	59	23	84	62	256	185	58	79	339	1692	Av. User accuracy: 86.41
Producer Accuracy	83.6	93.4	88.0	67.8	100.0	81.0	83.9	87.5	86.5	82.8	83.5	94.7	Average Producer Accuracy: 86.05% Overall accuracy = 87.97	

and they are mosaiced after performing supervised classification. This approach is carried out for aquaculture, fallow land, mangroves and agriculture. It has yielded a better-classified image of the study area. Further the classification of IRS-1A, LISS-1 is encountered with similar problems in classifying some classes in the image due to low resolution. The low spatial resolution (LISS-I, 73m) did not give proper signature to distinguish the fallow land and the settlements and wetlands and water bodies. But the high spatial resolution of LISS-III (23m) data gave identifiable signatures for the above classes. The classification of IRS-1C, LISS-III data having high resolution made the classification easy and more meaningful. Based on this classification, suitable changes are made in the classification map prepared from IRS-1A data. The accuracy of the results in terms of change in land use/land cover from 1990 to 2000 is evident as the total increase in the percentage of area of various features (agricultural land, aquaculture, mud flats and mangroves) is 11.49% which is exactly equal to the total percentage of decrease in area of other features (fallow land, water logged, water bodies and forest plantations). It is significant to note that the increase in the class aquaculture is double (107.98%) in the total aqua culture area of the district). The decrease in fallow land, water bodies and water-logged area has probably contributed to the increase in the area of aquaculture farms. Only five major changes have been considered meaningful from the classified map of the study area. A major increase (+383 km^2) was also noticed in agriculture land, which may be the result of decrease in fallow land to the tune of –376 km^2. The total increase in area of various features is 925.33 km^2 comparable to total decrease in area of 921.33 km^2 of the other features. A difference of 4.33 km^2 in the comparison with an area of 8030 km^2 is presumably negligible. The Kolleru lake which was known to be an haven for continental bird migration, a home for many plant and minor species, and demonstration of a sound ecological interaction of its environmental friendly habitat has almost been vanished today.

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