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USING SATELLITE DATA TO DETECT AND MONITOR COASTAL LAND USE CHANGE IN BANGLADESH

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Abstract : The main aim of the present study is to evaluate the applicability of remote sensing techniques for land use pattern recognition as well as land use change detection of the Hatiya Island. In this research using Landsat ETM, TM and MSS images land use features have been identified and analyzed. The Maximum likelihood supervised classification technique has been used to extract information from satellite data. Considering the nature and diversity of land uses eight major land use categories have been identified which are marshy land, mud, mud with small grass, agricultural land, bare soil, medium forest, forest and settlement. After the classification of the images, areas under different land use types have been calculated in acres for all the images and subsequently comparing the results land use changes have been detected. Accuracy of the classification has been assessed using kappa coefficient. The overall accuracy of classified maps, generated from Landsat images, is ranged from 86% to 94%. The study has quantified the patterns of land use change for the 22 years for Hatiya Island that forms valuable resources for planners and decision makers to devise sustainable land use planning.

Key words: Land use, Change Detection, Image Classification, Landsat

Introduction

Land is the most important natural resource on which all activities are based. Human intervention and natural phenomenon cause changes in land use on a regular basis. Land use change analysis is an important tool to assess global change at various spatial–temporal scales (Lambin, 1997). Moreover, it reflects the dimension of human activities on a given environment (López et al., 2001). Availability of accurate land use information is essential for various applications such as natural resource management, planning and monitoring programs (Kasetkasem et al., 2005) and also important

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information for a number of applications like agriculture, hydrology, forestry and ecology.

Change detection analysis becomes extremely important in order to understand the interactions and relationships between natural phenomena and human, through the accurately change detection of earth's surface features (Lu et al., 2004). This provides an accurate assessment of the extent and health of the world's forest, grassland, and agricultural resources that has become an important priority. For studying land use changes some of the information sources are field survey, existing maps, statistical data, existing documents or available literature and remote sensing images. Even though most of the developed countries are well equipped and updated with detailed land use information, developing countries are facing lack of and/or restricted access to geospatial database. For developing countries like Bangladesh, aerial photograph, for instance, absolutely classified for public (Dewan & Yamaguchi, 2009). Still now traditional methods are considered to be one of the important methods for land use mapping which are time consuming, expensive and limited to field surveys. Satellite remote sensing methods can in principle be used to monitor very large areas in a reasonably short period of time (Rees et al., 2003) and it has been also widely applied and accepted as a powerful and an effective tool for detecting land use changes (Ehlers et al., 1990; Harris & Ventura, 1995; Irish, 1990; Treitz et al., 1992; Welch et al., 1988). Remote sensing data, such as aerial photographs and satellite imageries, are undoubtedly the most ideal data for understanding the spatial and temporal dynamics of land use as well as for extracting land use change information (Hathout, 2002; Herold et al., 2003; Lambin et. al., 2003; Serra et al., 2008). Remotely sensed data can provide valuable multi-temporal data on the processes and patterns of land use change, and GIS is useful for mapping and analyzing those patterns (Zhang et al.,). In addition, retrospective and consistent synoptic coverage from satellites is particularly useful in areas where changes have been occurred rapidly (Blodget et al., 1991). Furthermore, digital documentation of remotely sensed data have been provided the opportunity to study historical land use changes and creating the opportunity to understand the geographic pattern of such changes in relation to other environmental and human factors.

Remote sensing proved its effectiveness to provide accurate information illustrating land use dynamics but unfortunately, no such application is available for Hatiya Island for land use change assessment. It is necessary to mention that the island does not have any official statistics on land use pattern which is very important for sustainable environmental management of the island. Although recent and accurate data on land use is a requirement for sustainably managing and planning the coastal island such as Hatiya, data scarcity and lack of current information on land use exist. In the absence of such information, sustainable development cannot be achieved and may lead to the mismanagement of scarce resources. So, in this case space-borne remotely sensed data is considered to be predominantly important for coastal island like Hatiya, because not only this is required for comprehend the past and present condition of the land but also used to achieve sustainable development and to derive sound environmental planning (Dewan & Yamaguchi, 2009).

In this study an attempt has been made to identify the status of land use of Hatiya Island, Bangladesh and to understand change detection using different remote sensing data of twenty two years and detecting the trend of changes. There are many advanced techniques available like object-based image analysis, fuzzy approach, tree decision analysis, artificial neural network, maximum likelihood classifier etc. to extract land use information from satellite data (Rogan & Chen, 2004). The approach used in this study is to classify satellite images and detect changes based on the maximum likelihood classifier approach. Although the maximum likelihood classifier technique is a conventional one in respect to other mentioned techniques, it has the ability to classify image with promising accuracy. And still now the vast majority of land-use monitoring approaches have used this image classification algorithm (Rogan & Chen, 2004). In this research Hatiya Island are selected from the coastal region to detect the changing features and determine the trend and rate of the change

Study Area

The study area is Hatiya Island of Noakhali district of Bangladesh. Geographically, it is located between 22°03´N to 22°25´ N latitude and 90°58´ E to 91° 12´ E longitudes (LGED, 1994). Total area covered by the Hatiya Island is about 115353 acres (Dwip Unnayan, 2008) and the average elevation of the Island is about 2.4 meters from the mean sea-level. The north the Island is bounded by river Meghna and Noakhali main land; Shahabajpur River, Monpura and Tajumuddin thana of Bhola district to the west, in the east Meghna River and Sandwip thana of Chittagong district and the Bay of Bengal on the south. The study area is a part of an active delta of the three mighty river systems the Ganges (Padma), Brahmaputra (Jamuna) and the Meghna.

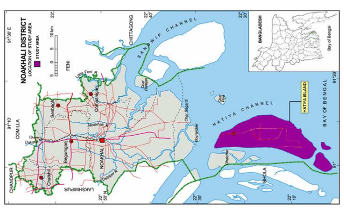

Figure 1: Location of the study area
Source: Banglapedia CD-ROM edition (version 1)

Materials and Methods

In this study four Landsat data included of MSS (21 January 1977), TM (03 February 1989; 08 February 1997) and ETM (12 January 1999) were obtained and employed to monitor land use. Idrisi 32 software was used to derive land use classification in a multi-temporal approach processing and Arcview 3.2, Arc Info and Cartalinx were used for analysis and integration of spatial data. As unsystematic errors remain in commercially available remote sensing data, geometric correction was therefore needed to reduce the error (Dewan & Yamaguchi, 2009). The images used in this study were geometrically corrected using a Landsat TM image of 1999 as a reference. At least 21 well distributed ground control points were used in the rectification process. Registration of images were carried out using twenty one ground control points and the root mean square error (RMSE) varied from 0.002047- 0.002547 pixels. Finally, a first-order polynomial fit was applied and all the images were re-sampled to a 30 meter pixel size using the nearest neighbor resampling method. The latlong system was used as the coordinate system. In addition, a number of geospatial data which includes union boundaries, road networks and geomorphic units were constructed as GIS layers from diverse sources.

In this study a number of reference datasets were constructed. To develop reference data for training area selection and accuracy assessment of land use maps the study relied on a variety of sources due its retrospective nature. Reference data for the 1977 Landsat MSS image were obtained from the topographic maps of the study area (scale 1:50,000) published by SOB in 1974. The LGED map of 1989 was used to develop reference data for the image of 1989. The reference data were used both for training area selection and evaluation of the result. The reference data for images of 1997 and 1999 were acquired from ground truth data. These reference data were used for developing training samples on the image and to evaluate the map accuracy. The 42 reference points were collected in the field using a handheld GPS. This information was then brought into GIS for overlaying with the images for the selection of training areas and subsequent accuracy assessment. To do so, reference points were used to train pixels and GPS data were used for classification accuracy.

Modified version of the Anderson Scheme Level I (Anderson, 1976) was adopted to study the land use change. Though the scheme was originally developed for the USA, it is the widely used land use classification system across the world (Mundia & Aniya, 2006; Shalaby & Tateishi, 2007; Yuan et al., 2005). The system proposed multilevel land use classification of which level I classes can be mapped from Landsat data or from high-altitude airphoto/ imagery, whereas the extraction of information at levels II, III, and IV requires the use of high, medium, and low-altitude photographs, respectively. All the satellite data were thoroughly studied using spectral and spatial profiles to ascertain the digital numbers (DNs) of different land use types prior to classification. Training samples were selected through reference data.

The supervised maximum likelihood classification scheme was used to classify and extract land use patterns. The maximum likelihood classifier was applied over Normalized Difference Vegetation Index (NDVI) images. To create NDVI image, following equation was used.

$$\text{NDVI}=\frac{\text{Near IR band - red band}}{\text{Near IR band + red band}}$$

Besides NDVI, false colour composite (FCC) images were also used to clarify some land use types, which had appeared hazy in NDVI images. After the classification of the NDVI images, areas under different land use types were calculated in acres for all the images and subsequently comparing the results land use change were detected. Classified land use maps from satellite data were further used for validation using ground truth data obtained from a variety of sources. Accuracy of the classification was assessed using kappa coefficient. To assess the accuracy of the classified map of 1977 and 1989 topographical map of 1974 and LGED map of 1989 were used respectively. Moreover, available ground truth data were used for derive accuracy for the classified images of 1997 and 1999. Producer's and User's accuracy for each class were calculated along with the overall accuracy and kappa coefficient.

Result and Discussion

Land use pattern of the study area has been recognized for the time periods of 1977 to 1999.Considering the nature and diversity of land uses eight major land use categories have been identified in the study area in all the study years (1977, 1989, 1997, and 1999), which are: marshy land, mud, mud with small grass, agricultural land, bare soil, medium forest/vegetation, forest and settlement. The results have been presented in form of maps, diagrams and statistical tables. The land use pattern of study area has been shown in table 3 and figure 2 and 3. The major proportion of the land use is the agricultural land. Assessed overall accuracy and kappa coefficient index for all classified image are shown in table 1. Producer's and User's accuracy also calculated which are shown in table 2. The results indicate overall accuracy of 86%, 90%, 92% and 94% and kappa index 0.83, 0.89, 0.89 and 0.92 for the images of 1977, 1989, 1997 and 1999 respectively (Table 1). Table 3 shows the land cover changes that have taken place between 1977 and 1999.

Table 1: The Kappa Coefficient and Overall Classification Accuracy for the Images of Landsat MSS 1977, TM 1989 and 1997 and ETM 1999

Land use map	Kappa coefficient	Overall classification accuracy (%)
1977	0.83	86
1989	0.89	90
1997	0.89	92
1999	0.92	94

Table 2: User's and Producer's Accuracies (%) for each class for the Images of Landsat MSS 1977, TM 1989 and 1997 and ETM 1999

Land use class	1977		1989		1997		1999	
	User's	Producer's	User's	Producer's	User's	Producer's	User's	Producer's
Marshy Land	95	92	97	92	93	79	96	92
Mud	84	86	82	90	83	81	74	83
Mud with small grass	79	79	80	77	69	70	77	76
Agricultural land	64	82	92	89	80	90	97	96
Bare soil	75	72	77	80	86	81	83	78
Medium forest	83	92	83	94	97	97	95	97
Forest	94	82	96	97	96	97	92	93
Settlement	96	77	100	84	100	91	99	71

Table 3: Land use pattern analysis of Hatiya Island, Bangladesh (1977-1999)

Land use category	Area in acres				Area in percentage (%)			
	1977	1989	1997	1999	1977	1989	1997	1999
Marshy land	17133.21	17686.63	6057.22	2572.32	15.10	15.78	6.13	2.46
Mud	17612.03	12915.49	10893.61	9543.56	15.52	11.52	11.02	9.12
Mud with small grass	14289.97	9389.62	8247.26	7990.90	12.59	8.38	8.34	7.63
Agricultural land	34875.77	36525.86	39112.90	43762.00	30.73	32.59	39.57	41.80
Bare soil	11136.12	10446.25	4295.42	8469.93	9.81	9.32	4.35	8.09
Medium forest	15565.30	19865.03	21851.90	22602.89	13.72	17.73	22.11	21.59
Forest	1705.78	3525.05	6573.51	7901.33	1.50	3.15	6.65	7.55
Settlement	1162.02	1719.46	1816.61	1849.67	1.03	1.53	1.84	1.77
Total	113480.2	112073.39	98848.43	104692.6	100	100	100	100

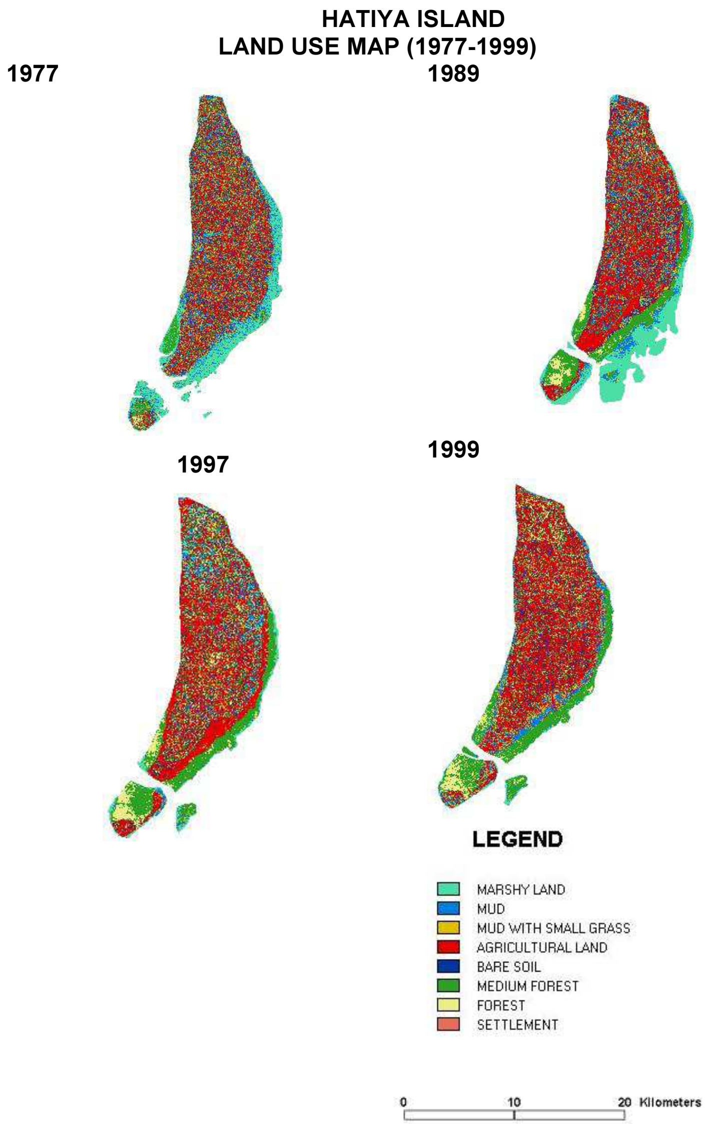

Figure 2: Land use details of Hatiya Island

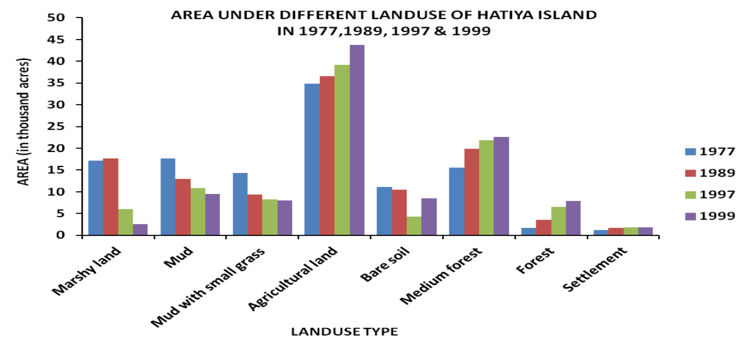

Figure 3: Land use features of the Hatiya Island in 1977-1999

Analysis of Land use Changes

Hatiya Island is in lower Meghna estuary and consists of quaternary alluvial deposits of silt, sand and clay. During the period of 1977 to 1999 it is found that a significant change have taken place in the island due to massive erosion than that of accretion (Table 4). So, during that period (1977-1999) erosion was predominate which also affect the land use of Hatiya Island. In the present research both the physical and cultural factors affecting the land use changes in the study area have been considered.

Table 4: Total area of Hatiya Island, Bangladesh and its Changing Rate in Different Years (1977-1999)

Year	Area in acres	Change in area from 1977	Change rate (in %)	Remarks
1977	113480	-	-	Base map
1989	112073	1407	1.24	Erosion in reference to 1977
1997	98848	14632	12.89	Erosion in reference to 1977 and 1989
1999	104693	8788	7.74	Erosion in reference to 1977 but Accretion in reference to 1997

Source: Classified Images of 1977, 1989, 1997 and 1999

Analysis of land use change for the Hatiya Island shows that, following the spatial change, the land use patterns have been remarkably changed in between 1977 and 1989 and 1989 and 1997, but the change was not much significant between 1997 and 1999 (Figure 4).

Marshy land has decreased by 84.99% in 1999 with reference to 1977. It has been converted into the mud and medium forest/ vegetation. Mud, mud with small grass and bare soil has also decreased by about 45.81%, 44.08% and 23.94% respectively during this time period while agricultural land, medium forest/vegetation and forest has increased by about 25.48%, 45.21% and 363.21% respectively.

Mud converted into mud with small grass, medium forest/vegetation and agricultural land. Mainly, south-eastern and south-western part of Hatiya Island and northern part of Nijhum dwip are the main regions where this change has been occurred. The remarkable changes in mud land have been occurred in Harni union. Erosion plays an active role to bring this change. Mud with small grass is also changed into medium forest/vegetation, agricultural land and bare soil. It has decreased by about 95.51% in the Harni union. On the other hand least amount of change has been occurred in Jahajmara union (3.23%). Jahajmara is the only union where it has been increased. Similarly, Mud, mud with small grass and bare soil mainly converted into agricultural land. This land use change process has been affected remarkably in Harni union (89.68%) and least amount of change has been occurred in Nalchira union (2.63%). Sonadia, Tamaruddin, Jahajmara, Burirchar, Char Ishwar and Char king are the unions where the agricultural land has been increased in the mentioned period. On the other hand Harni, Sukchar and Nalchira are the unions where the agricultural land has been decreased.

Table 5: Analysis of Land Use Changes of Hatiya Island

Land use category	Change in Area (in acres)				Percentage of Change			
	1977 to 1989	1989 to 1997	1997 to 1999	1977 to 1999	1977 to 1989	1989 to 1997	1997 to 1999	1977 to 1999
Marshy land	+553.42	-11629.41	-3484.9	-14560.89	+3.23	-65.75	-57.53	-84.99
Mud	-4696.54	-2021.88	-1350.05	-8068.47	-26.67	-15.65	-12.39	-45.81
Mud with small grass	-4900.35	-1142.36	-256.36	-6299.07	-34.29	-12.17	-3.11	-44.08
Agricultural land	+1650.09	+2587.04	+4659.10	+8886.23	+4.73	+7.08	+11.91	+25.48
Bare soil	-689.87	-6150.83	-4174.51	-2666.19	-6.19	-58.88	-97.18	-23.94
Medium forest	+4299.73	+1986.87	+750.99	+7037.59	+27.62	+10.00	+3.44	+45.21
Forest	+1819.27	+3048.46	+1327.82	+6195.55	+106.65	+86.48	+20.20	+363.21
Settlement	+557.44	+97.15	+33.06	+687.65	+47.97	+5.65	+1.82	+59.18

Note: (-) sign represents percentage of decreasing rate and (+) sign represents percentage of increasing rate.

Table 6: Union wise Analysis of Land Use Changes of Hatiya Island (1977-1999)

Union	**Percentage of Change**							
	Marshy land	**Mud**	**Mud with small grass**	**Agricultural land**	**Bare soil**	**Medium forest**	**Forest**	**Settlement**
Harni	-78.90	-97.02	-95.51	-89.68	-96.43	-100	-100	-100
Sukchar	+53.69	-69.09	-60.64	-5.91	-51.62	-49.94	+183.32	-18.99
Nalchira	-40.89	-81.87	-62.47	-2.63	-38.60	-18.10	+319.94	-09.97
Charking	-5.09	-54.60	-47.09	+19.74	-18.45	-15.85	+296.66	+28.05
Char Ishwar	-83.95	-25.96	-43.39	+28.10	-16.97	+41.10	+363.46	+190.09
Tamaruddin	-63.55	-66.82	-53.42	+29.01	-01.68	-2.76	+120.51	+121.70
Sonadia	-71.20	-56.11	- 57.94	+31.86	-4.16	-17.41	+207.47	+154.55
Burirchar	-92.73	-49.61	-44.75	+54.41	-2.05	+102.34	+377.33	+232.89
Jahajmara	-86.94	-13.42	+3.23	+53.95	-40.97	+158.45	+725.99	+129.19

Note: (-) sign represents percentage of decreasing rate and (+) sign represents percentage of increasing rate.

The highest and lowest amount of change of bare soil has taken place respectively in Harni (96.43%) and Tamaruddin (1.68%) unions. The highest

amount of change in medium forest/vegetation has been occurred in Jahajmara union (158.45%). Mainly mud, marshy land and mud with small grass has moved into medium forest and medium forest to forest. Forest has been increased by about 363.21% during the study period from 1977 to 1999. Harni is the only union where the forest has been decreased. In case of settlement the highest amount of change has occurred in Burirchar union (232.89%) and least amount of change has taken place in Nalchira union (9.97%).

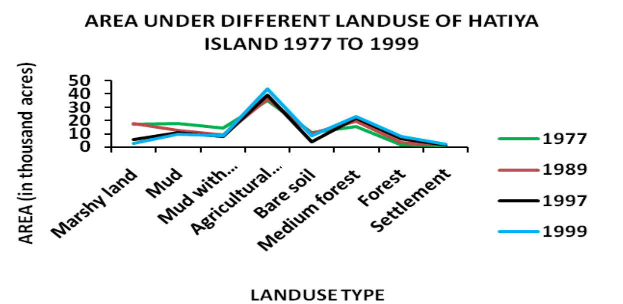

Figure 4: Changing pattern of land use of Hatiya Island1977 to 1999

Hatiya Island is an erosion and accretion prone region which greatly influenced the land use pattern. In recent time (1977 to 1999) channel migration of Meghna Old River is very rapid causing severe erosion of Hatiya Island. Remote sensing data also indicates this trends and it is evident that significant changes has taken place in the island where erosion and accretion have taken active role to bring the change. But erosion process is dominant in the study area than accretion. Major erosion took place in the northern part of the Island and accretion took place southern part of the Island. Similarly, by following these morphological process land use pattern have been changed drastically in these erosion and accretion prone area Agricultural land and settlement have increased in all the unions of the Hatiya Island except nalchira, sukhchar and harni union where erosion process plays an active role to oppose such kind of change. On the other hand in the southern part of the island where accretion process is dominant than erosion medium forest/vegetation and forest have increased due to afforestation program of Bangladesh Forest Department, and mud, mud with small grass and marshy land have decreased due to land reclamation policy of Bangladesh Government. To evaluate the efficacy of image classification User's and Producer's accuracy have been calculated for each of the eight classes for all the images. Overall accuracy, the percentage of pixels classified as correct among those sampled, have been highest (94 percent) for the classified image of 1999 followed by the 1997 image (92 percent), 1989 image (90 percent) and 1977 image (86 percent) . Thus, the classified image of 1999 resulted in the highest Kappa coefficient value (0.92), followed by the classified images of 1997 and 1989 (0.89) and classified image of 1977 (0.83). In this study all the classified images have the overall accuracy of more than 85 percent, which meets the level (85 percent) that the U.S Geological Survey has recommended for acceptability of classification results (Anderson, 1976).

Conclusion

The coastal region of Bangladesh is a part of the world's largest delta and is characterized by unstable hydro-morphological and meteorological conditions, accompanied by catastrophic disasters, such as cyclones, storm surges, etc. The coastal morphology of Bangladesh is very complicated and dynamic in nature. As a result, coastal landforms and land use have changed continuously through history. Erosion, accretion and land-use changes are regular phenomena of the coastal areas of Bangladesh. Hatiya Island is no exception in this regard. Remote sensing techniques provide the most effective way to monitor the gradual changes in land use in different years, and it also offers a quick and relatively cheap means of generating spatial data for optimal land use planning. In this research, remote sensing techniques were used for land use pattern recognition and land use change detection Results show that significant changes in land use occurred during the study period in Hatiya Island. The highest amount of land use changes were observed in the northern and southern parts of the island, where major morphological change had occurred due to erosion and accretion. During the study period, marshy land, mud, mud with small grass and bare soil classes had decreased by 85.0%, 45.8%, 44.1% and 45.2% respectively. On the contrary, agricultural land, medium forest, forest and settlement classes had increased. While remote sensing has the capability of monitoring land use and its changes, accuracy of extracting land use information from satellite data relies on effective image classification algorithm. The classification technique (maximum likelihood) used in this research produces an overall accuracy of 86 to 94% that fulfills the recommended accuracy level (85 %) set by U.S Geological Survey (Anderson, 1976) . So, the efficacy of maximum likelihood technique for monitoring land use change is acceptable. It gives a fairly good understanding of land use changes for a period of two decades, which in turn will be very helpful for local administrative bodies, decision makers, regional planners and Stakeholders. With the help of this study it proves that this technology has the capability to provide the necessary input and intelligence for preparation of base maps, formulation of planning proposals and as a monitoring tool during the implementation phase, as the result of this study also show efficient effect of this tool in analyzing Land Use change detection.

For the sustainability of the coastal environment, better understanding of the complicated coastal dynamics of offshore islands like Hatiya is very important. Remote sensing can plan an important role here through providing recent or near real time information on a continuous basis.

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