A Study of Forest Land Cover Changes Using Satellite Remote Sensing in Thatta District Pakistan

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***ABSTRACT*:** *For the past few decades, Remote sensing and GIS tool has been used all over the Pakistan for Land cover and Land use mapping. Related tools and techniques have been used in this research for Land use mapping in Thatta district, Sindh province. Supervised classification, which is one of the beneficial technique of remote sensing is used for three decades study. In this study nine different Landsat images, comprising of temporal window of about three decade, along with survey points, has been used for accurate land use estimation. The study focused on change detection of seven major land use consisting on Mangroves forest, Riverine Forest, Agricultural lands, Bushes, Saccharum spp. /Typha spp., Algal mats and Soil. Based on the results obtained, the classified land cover data showed an overall depletion of Mangrove forest cover when compared the results from 1990 to 2014. Depletion has also been observed for Riverine forest cover, while changes in other land covers observed e.g., Saccharum spp., Typha spp., Terrestrial vegetation and Algal mats have been found more or less seasonal in nature. The conclusions of this study is that rate of deforestation increase in Thatta District. Both riverine and mangrove forests are deeply affected due to anthropogenic activities. Reduction in forest is a main loss in ecosystem which also increase the flood risk in coastal areas.*

Keywords: Remote Sensing, Forest, Pakistan, Land cover, Landsat.

1. INTRODUCTION

Mapping of land cover is one of the earliest applications of remote sensing [1]. The process of change detection can be done by using dataset obtained on different dates. It is premised on the capability to determine temporal effects [2].

Change detection can be done through the analysis of multi date satellite and aerial images [2]. It is divided into two categories [3] i.e.

Change mask development which usually cannot identify what type of land use change have taken place between them commonly called Image differencing and Image ratio-ing

Categorical change extraction which can be performed by comparing two different time images commonly called Post classification comparison

With the launch of satellites it is possible to monitor land cover and land use change on regional and global scale [4]. Alvarez et al., (2003) classified land covers of Mexico using three decades satellite images [5]. Two different data sets, real multi temporal data set and a synthetic dataset were used in that study. Real time multi temporal data set consist of two multi spectral image of the year 1995 and 2002 obtained from ETM+ sensor and in a synthetic data consist of China Brazil Earth Remote Sensing Satellite-1 multi spectral images and three synthetic change images [6].

This study aims is to examine three decades temporal change in Thatta district using Maximum Likelihood Classification (MLC), which is one approach of supervised classification. The main objective of this research is to estimate deforestation level in Thatta District.

Forests are divided into following broader groups in Pakistan

Alpine forest
Temperate forest
Sub-Tropical forest
Coastal forest
Dry tropical forest
Juniper forest
Riverine forest
Irrigated forest

Forests are the most valuable resources of ecosystem. They are precious resource which provide climatic stability, environmental stability, and rainfall pattern and also contribute significantly to the economy [7].

Table 1: Forestry Sector Master Plan Estimate of Forest Cover Area 100Ha [6].

Forest Cover and Landuse Class	Area(100 Ha)
Riverine forest	
Dense	85
Sparce	27
Sub-total	112
Mangroves	
Dense	85
Sparce	120
Sub-total	205
Irrigated Plantation	
Dense	7
Sparce	16

Sub-total	23
Farmland trees	54
Misc. planting	5
Total area	399

Sader et al., (2008) used Landsat TM/ETM+ data for forest mapping [8]. They used eight Landsat TM and ETM+ images for WRS path 12 and row 28. Their study focused on forest inventory, wild life habitat modeling and biomass of carbon stock estimation and also regeneration spatial pattern in updating forest maps. Change detection technique was applied on eight Landsat images and obtained a time series of harvest maps. Then the map was merged with 2004 forest type map and also with Geological survey's Gap analysis program of 1993 land cover map. Applying post classification techniques they obtained update land cover map of Gap analysis program of 2004 [9].

Pakistan has an alarming rate of deforestation. The report published in 2009 by the United Nation (UN), Food and Agriculture Organization (FAO) on the state of the World forests shows that Pakistan has only 2.5 % of its area under forest cover. The annual rate of deforestation in Pakistan is 2.1%; no Asian country has the forest degradation rate higher than this [6].

Depression in forests means not only damage of trees but also it is a big loss to environment and ecosystem. Every year, there is a big change in natural land covers and extensive areas of agriculture and forestlands are ruined and slowly turned into waste land due to human activities or natural causes. There are several causes of deforestation such as urban development, forest fires, agricultural expansion and construction of dams etc. Today, depletion in the forest cover is an important issue for the world [10].

2. Study Area

Figure 1: Study Area Map.

Area wise Sindh is the 3rd largest province of Pakistan which is further divided into 23 districts. Its total area is about 140,915 km² [11]. Table 1 shows different types of forest of Sindh with their areas in 100 Ha. The study area is Thatta district which is located in the Southern part of Sindh province as shown in figure 1. Its population is about 1.1 million, majority of which are rural [12].

It is situated from 23°43' to 25°26' north latitudes and 67°05' to 68°45' east longitude. It is located 98 kilometer east of the provincial capital of Sindh, Karachi. The total area of district Thatta is 17,361 square kilometers [13] Thatta is sub classified administratively into nine Talukas (Tehsils) as shown in table 4.

Table 4: Wise Distribution of Population of Thatta District [14].

Town/Taluka	Population
Ghora Bari	105,482
Jati	123,957
Keti Bander	25700
Kharo Chan	25666
Mirpur Bathoro	151951
Mirpur Sakro	198852
Shah Bandar	100575
Sujawal	127,299
Thatta	237,048
Total	1,096,494

The soil of this area is very fertile. The underlying rocks of Indus delta are mostly of highly folded, marine origin, fissured and faulted everywhere. It mainly consists of clay and limestone. The deltaic land mass is furrowed into a large number of coastal islands separated by a large number of creeks spreading over about 5,200km² and varying in width from few meters to many hundred meters [15].

The annual rainfall in Sindh is app. 150 mm. The climate is mainly governed by rainfall and temperature. The climate varies from extremely hot in the north to moderate in lower Sindh districts. The temperature in lower Sindh reaches generally 40 degree Celsius in peak summer months of May and June but in winter it remains 17 to 19 degree Celsius [16].

The vegetation that is mainly found in the Thatta is Mangroves, Riverine Forest, Algae, Salt bushes, Saccharum spp. and Typha spp., Mesquite, Bushes and Grasses.

Mangroves exist mainly in five distinct sites, which include Jiwani, Kalmat khor, Sonmiani, Sandspit and Indus Delta. In the past following species were reported in the coastal areas of Pakistan.

Rhizophoraceae:
Bruguiera conjugate
Rhizophora apiculata
Rhizophora mucronata
Ceriops tagal
Ceriops roxburghiana
Avicenniaceaemysinaceae
Avicennia marina
Myrsinaceae
Aegiceras corniculata
Sonneratia
Sonneratia caseolaris

But in present time only four species Avicennia marina (95% of the mangroves), Ceriops tagal and Aegiceras corniculata and Rhizophora mucronata found in the delta [17].

The Bela forests or Riverine forests are grown in the narrow belt along the banks of Indus. The existence of riverine forest depends on natural annual flooding of the Indus basin. These forests act as a barrier between river and embankments and the countryside and protect us from severity of floods.

The main productive forests in the province of Sindh are:

Acacia nilotica
Tamarix dioca
Populus euphratica
Prosopis specigera [10]

3. Methodology

Figure 2: Flow Chart of Methodology.

Different types of datasets were used for land cover mapping of Thatta district. These data included Satellites Data (Landsat Satellite Images, Google Earth Imagery and ASTER Images), Vector Data, Ground Truth Data and Local Area Information etc. For change detection of district Thatta, temporal Landsat satellite images of Thematic Mapper (TM) sensor were downloaded from the official websites of USGS (United States Geological Survey) and GLCF (Global Land Cover Facility). Study area covers three different path/row of Landsat archive. Satellite images of suitable dates by considering tide height values and cloud cover percentage was downloaded.

The images were already Geo-referenced by the EROS (Earth Resources Observation Satellite) Data Center registered to UTM (Universal Transverse Mercator) coordinates, with Spheroid and Datum WGS (World Geographic System) 84, zone 43 north. All the individual layers (bands) were stacked together to obtain multispectral (colored) image. Sixth band of Landsat is thermal band (10.4-12.5 um) of relatively low resolution (120 meter) and hence it was not used for classification. The characteristic details of the satellite images are given in table 5 table 6 and table 7.

Table 5: Dataset used for the year 1990.

Sr. No.	Date DD/MM/YY	Sensor	WRS2	Satellite Reference	Tide height (meter)
1.	27/04/1992	TM	152/43	Landsat GLCF	1.2
2.	21/10/1989	TM	151/43	Landsat USGS	1.1
3.	18/09/1992	TM	152/42	Landsat USGS	1.3

Table 6: Dataset used for the year 2010.

Sr. No.	Date DD/MM/YY	Sensor	WRS2	Satellite Reference	Tide Height (meter)
1.	29/04/2010	TM	152/43	Landsat USGS	1.1
2.	29/04/2010	TM	151/43	Landsat USGS	1.1
3.	29/04/2010	TM	152/42	Landsat USGS	1.1

Table 7: Dataset used for the year 2014.

Sr. No.	Date DD/MM/YY	Sensor	WRS2	Satellite Reference	Tide height (meter)
1.	08/04/2014	TM	152/43	Landsat USGS	1.0
2.	11/01/2014	TM	151/43	Landsat USGS	0.5
3.	18/01/2014	TM	152/42	Landsat USGS	2.4

A subset of the study area of Thatta district boundary was generated from the images to separate out the area of Thatta district. This process is performed using subset utility of the ERDAS Imagine 9.1®. Various algorithms were used to enhance low contrast image to high contrast image so that image can be easily handled for interpretation and processing. To improve enhancement, brightness control utilities were also applied. This technique was used to improve the image quality for better interpretation.

To classify Landsat image of Thatta district supervised classification technique was prepared, because an extensive ground survey data of Thatta district was available. In post classification method we can get the change through the comparison of three different classified images acquired on different dates [3]. Maximum likelihood classification is one of the best techniques because it gives us more accurate result but this method is good only when limited no. of cover types is present [18].

4. Visual Image Interpretation

Figure 3: Visual Image Interpretation.

The basic elements of visual image interpretation are Tone, Texture, Shape, Size, Pattern, Shadow, Association etc. Different False Color Composite band combinations such as (TM bands: 4, 3, 2; 5, 4, 2; 7, 4, 3) were also tested for visual interpretation. Tonal variation of some land covers of Thatta district inLandsat TM band 4, 3, 2 was described below:

A) The bright red tone in the satellite image as shown in the thumbnail represents the dense mangrove whereas the dark tone of same pattern represents medium and sparse mangroves,

B) Irregular pattern along river bed represents dense riverine forest whereas the same pattern in darkest tone represents sparse riverine forest,

C) Bright red tone along lakes represents saccharum and typha. These patches have been detected along Keenjhar lake and fish pounds,

D) The reddish tone with regular pattern of rectangular shape in the image presents agricultural lands.

E) Whitish color and smooth texture represents bare land soil and the darkish tone of same pattern represents wet soil,

F) Variation in blue tone represents the sedimentation, depth and turbidity in water class,

G) Light reddish tone mixed with soil represents bushes and grasses,

H) Light gray tone along the river in the satellite image represents river bed.

Spectral Signatures are basically spectral response pattern. Experience has shown that many features on the earth surface can be mapped, studied and identified on the basis of their spectral characteristics. It is the measurement of percentage of solar reflectance as the function of their wavelength. Many features on the earth surface can be mapped, studied and identified on the basis of their spectral characteristics [2].

Landsat TM consists of 7 bands, ranging from visible to near infrared and one thermal band. On the basis of the properties of these bands and the behavior of different land covers in these bands, different spectral signature of desired area was obtained. For example, in the range from about 0.7-1.3µm, leaf of the plant reflects 40 to 50% of its total incident energy, thus fourth band is helpful to determine the leaf structure [2].

Feature space images were also created from all available bands of Landsat TM. It provides information about the combinations of pixel values that occur within the image. Intensity value of cluster is related to number of pixel with that specific value. Different land cover classes were separated on the basis of their position in different feature space. If the classes do not have separate clusters in feature space than our results must not be accurate or there must be mixing between the classes. Specific part of the feature space correspond the definite class. Distance in feature space is expressed as Euclidean distance. Once the classes had been defined in the feature space, then after applying classification technique each pixel of the image assigned the matched class [19].

For accurate and better results, it was beneficial to recode to layer so that all of the best classes have highest value [20]. For supervised classification, maximum numbers of variations were picked and at last similar classes were re-coded and combined together. Land cover of Thatta district was re-coded into 10 major classes such as Agricultural Land, Riverine Forest, Bushes/Grasses, Saccharum spp. /Typha spp., Sand/River Bed/Saline Area, Soil/Rocks, Water, Algal Mat, Dense Mangrove Forest and Sparse Mangrove Forest.

It is the process of piecing together images side by side to form a larger image. Once images were classified by using supervised maximum likelihood classifier, all images of Thatta district were mosaiced. It was better to mosaic images after classification because in all images solar angle and reflectance values of same land cover varies, for accurate result images were mosaiced after classification.

5. Results and Discussions

Following changes were observed using Satellite images and output land cover map. The results obtained after applying the classification technique are listed in table 8

Table 8: Comparison Statistics of the years 1990, 2010 and 2014.

Sr. No.	Class Names	Area(Ha) 1990	Area(Ha) 2010	Area(Ha) 2014
1	Dense Mangrove Forest	15,227	12,513	8872
2	Sparse Mangrove Forest	92,407	80,361	67463
3	Riverine Forest	45,128	36,432	25888
4	Agriculture Land	131,589	174,201	186349
5	Mesquite/Grasses/Bushes	189,009	129,336	216359
6	Saccharum spp./Typha spp.	34,550	26,438	11894
7	Soil/Wet Soil/Mudflats/Rocks	251786	274362	100908
8	Algal Mat	34,401	7,611	24665
9	Sand/River Bed/Saline Area	19,508	7,978	10217
10	Water	233,354	230,460	243143

Conversion of Riverine Forest into Agricultural Land

With the increase in population in Pakistan, large area is converted into agricultural land. Riverine forest of Sindh was deeply affected due to anthropogenic activities or natural causes. Due to anthropogenic activities such as constructions of dams or barrages on the on the upper reaches of Indus river about 100,000 acre of forest disappeared. Large area of agricultural forest is now utilized in form of agricultural lands [10]. In this research a large portion of riverine forest was observed which were converted into agricultural land.

Cutting of Riverine Forest

Depletion in forest cover has an important impact on both ecological balance and socio-economic development. There are several causes of increase in deforestation level in Pakistan such as urban development, expansion in agricultural area, illegal cutting, grazing of animal, increase in the demand of wood for fuel etc [10]. In Thatta District these changes were also observed.

Changes in Mangrove Forest Extent

Globally, mangroves are relatively rare forest type Table 2 shows the mangroves area in different regions of the world. They are found in 123 countries globally and cover total area of 152,000 square kilometers Country wise distribution of mangroves is shown in table 5. Mangroves forests are valuable economic resources. But due to different anthropogenic activities such as construction of dams reduce the flow of water level, grazing of camels, cutting of mangroves for wood decrease the total extent of mangroves.

Changes in Saccharum spp./Typha spp.

Spread of exotic vegetation such as Prosipis spp. is the main reason for decrease in Tamarix spp. and this spread increase due to over cutting of Tamarix for woods etc. A lot of change has been observed between Typha spp., Saccharum spp., Tamarix spp. and Prosipis spp., Saccharum spp. and Typha spp. are mostly seasonal dependent and both of them vary inversely to the water level [21] and are observed in this study as well.

Figure 4: Land cover & Pie chart of the year 1990.

Fish Pounds:

Water level increased from 1990 to 2014. Formation of fish pounds and annual flooding in that area is the main case of it. Regular patches of pounds and water bodies can be easily observed in both the satellite images and Land cover maps.

Figure 5: Land cover & Pie chart of the year 2010.

Figure 6: Land cover Pie chart of the year 2014.

Figure 7: Comparison Statistics of Landsat Classified Images of the years 1990, 2010 and 2014.

6. Conclusions and Limitations

6.1 Conclusions

In this research, three decades land cover change was detected in the Thatta district using supervised classification technique. Three land cover maps were produced as shown in Figure 4, figure 5 and figure 6, and the statistics of each class was calculated as in Figure 7. As shown in the statistic it was evident that deforestation level increased in the past years in the Thatta district, especially in the riverine forest and the deltaic region.

Riverine Forest

Area of riverine forest in the Thatta district calculated in 1990 is 45,128 hectares while the area obtained in 2010 is 36,432 hectares and in 2014 the area further decreased to 25888. The riverine forest was deeply affected due to anthropogenic activities. A large portion of riverine forests was converted into agricultural land. Depletion in forest area with the increase of agricultural land is a major loss of natural ecosystem. Every year extensive area of forests land is turned into waste land or agricultural land due to natural causes or human activities.

Mangrove Forest

Outcome of classified maps shows the depletion in area of both the dense and sparse mangroves from 1990s to 2014. Dense mangroves were about 15,227 ha in 1990s, 12,513 ha in 2010 and only about 8872 ha left in 2014. Similarly loss in the area of sparse mangroves was about 92,407 ha to 80,316 ha then 67463 ha. Mangroves forests are also badly affected during these two decades. This decrease was due to the increase in the settlements in the coastal region and several other reasons such as camel grazing and illegal cuttings may also be the cause of this depletion.

Agricultural Land

Agricultural land observed from 1990s to 2014 is increased. Rate of increase of agricultural Lands from 1990s to 2014 is about 7.3 to 21%. Total area in 1990 was 131,589 hectares which has been increased to 174,201 hectares in 2010 and in 2014 value increased to 186349. Reason for this increase is obviously linked with an increase in the population.

Algal Mats

The outcomes of classified maps show 34,401 hectares in 1990, 7,611 hectares in 2010 and 24665 hectares in 2014. Algal mats are totally depending upon season. The Landsat images used for the study were of the month of April, September and October which were the month of heavy rain fall. So the total area of Algal mats in that month must be greater.

Saccharum spp. and Typha spp.

The output results show the depletion in this class. Both Saccharum spp. and Typha spp. depend upon season. Their content changes with respect to the seasonal change. Due to heavy deforestation and wood cutting this class also disturbed.

6.2 Limitations

Limitations of the study are as followed:

Dataset available for three decade study was only of Landsat satellite, which was a medium resolution satellite images. The pixel size of Landsat TM is 30 by 30m. So there must be some mixing between sparse bushes/grasses and soil due to large pixel size.

Dataset available of 1990s were of different date and different months, because images of similar dates were flooded region or have clouds cover more than 70 %.

The image which covers the major portion of Thatta district was of the month of April, which was the

month of harvesting of Agricultural Lands in Pakistan, due to which a lot of mixing occurred during classification between Agricultural, Cultivated and Grassy Land.

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