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Mapping Change in Spatial Extent and Density of Mangrove Forest at Karachi Coast Using Object Based Image Analysis

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Abstract: Karachi shoreline is more than 135 Km long significant for marine fishery breeding and spawning. During 2005 to 2018 the mangrove forest areas in Karachi increased in extent but declined in density. The main cause of mangrove cover change in this region are coastal region development (port building, industrial area and waterfront project). This study aims to monitor both extent and density changes of mangrove forest at Karachi coast. For this purpose, the Landsat imagery was used of the years 2005 and 2018 covering a span of 14 years. The imageries were processed through Normalized Difference Vegetation Index (NDVI) analysis. Simultaneously, random sample locations were identified for mapping and validation of mangrove forest extent and density during 2005 to 2018. The sample locations were categorized as dense, normal and sparse classes. In the next step, sample locations were plotted on NDVI images to determine mean, minimum and maximum values for each class of mangrove forest. In the final step, the accuracy assessment was done using Kappa statistics. Results show that overall accuracy of 2018 imagery is better than 2005 Landsat imagery. The overall extent of mangrove forest increased in the past years.

Keywords: Mangrove forest, Karachi, mangroves area, object-based Image analysis.

Introduction

Mangroves are the woody plants that live throughout the world in the tropical and subtropical coastal areas. These are the main elements of the marine and terrestrial ecosystems and offer a variety of advantages in terms of healthy environment, biodiversity, food, fuel and feed etc. Despite the fact that mangroves are significant substance and play a crucial role in marine food webs, which are significantly affected by various anthropogenic activities including marine pollution (Saifullah, 1997). Mangrove forests are salt-tolerant woody plants that shape inter-tidal and fragile coastal ecosystems at a land-water intersection (Alongi and Daniel, 2002; Warne, 2007). Satellite Remote sensing is frequently used to evaluate mangrove extensions and dynamics as well as to detect alterations (Sulaiman *et al.,* 2013). In the early stages of digital mangrove mapping using remote sensing data, the supervised Maximum Likelihood Classifier (MLC) is the most common method of classification of mangrove size and composition based on satellite images (Gao, 1998; Green et al., 1998b; Rasolofoharinoro et al., 1998; Gao, 1999). A number of new techniques have been introduced with the modern technology to monitor changes in land cover / land use which mainly include image difference, ratio, main component analysis (Jensen and Toll, 1982; Singh 1989; Chavez and Mackinnon, 1994 Chavez and Kwarteng, 1989). In Pakistan, mangroves cover an area of around 600,000 hectares and is ranked third in the world (Khan and Aziz, 2001). The forest of mangroves in Sindh extends from Korangi to the Indian border Sir Creek. This forest possess Sindh and Baluchistan’s particular plant community and significant biological system (Ali and Qaiser,1986; Khan and Aziz, 2001; Nasir *et.al.*, 1995; Peoples, 1997). *Avicennia marina* (95%) with few species of *Aegiceras corniculatum*, Ceriops tagal, and Rhizophora mucronate almost entirely govern the display mangrove forest (Saifullah *et al.*, 1994). The Indus delta is regarded one of the biggest endangered deltas in the world because of the upstream freshwater extraction that irrigates 180,000 square kilometers of agriculture(Spalding, 2010).

Remote sensing technology allows us to collect data cost-effectively, accurately by covering broad regions for research. This often happens particularly if we compare remote sensing with traditional techniques of field survey (Kokalj and Oštir, 2007). Remotely sensed data is widely used for the identification of change, land use /land cover, mapping, modelling of the surroundings and management of earth's resources. Remote sensing techniques and methods have been shown to be effective for all of these reasons (Downie *et al.*,1999; El-Raey*et al.*, 2007; Kushwaha *et al.*, 1996). Change detection is the method of defining variations in the status of an object or phenomenon by observing it at specific times (Singh, 1989). A number of methods for change detection were created and many were summarized and evaluated (Coppin and Bauer, 1996; Deer, 1995; Lyon *et al.*,, 1998; Mouat*et al.*, 1993; Serpico and Bruzzone, 1999; Singh, 1989).

The main objective of the study was to assess the nature, significance, and mangroves change during 2005-2018 and find out the areas of rapid change, extent of change and evaluate the past and present condition of mangrove-cover to understand the elements and trend of change.

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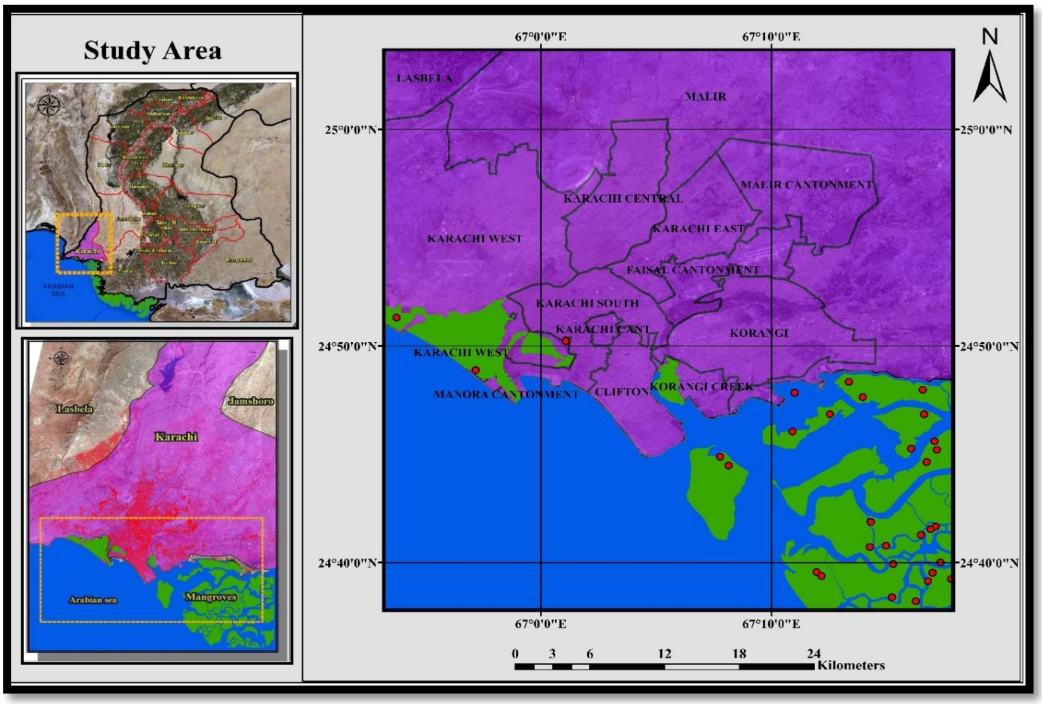

Fig. 1 Location map of the study area.

Table 1 Specification of satellite imagery used in this study.

S. No.	Date of images	Satellites	Sensors	Resolution (m)	Bands
1.	22-03-2005	LANDSAT-7	ETM+	30 m	07
2.	13- 01-2018	LANDSAT_8	OLI/TIRS	30 m	11

Study Area

Pakistan's coastline stretches approximately 1050 km, where Karachi is situated on the Arabian Sea northern boundary (Fig. 1). It is about 135 km long and one of the most affected areas along Pakistan's shoreline (Khan and Aziz, 2001). Karachi coast latitude is 24°45” to 25°15” N and longitude is 66° 37” to 67° 37” E. Karachi, the provincial capital of Sindh, is also the largest city in Pakistan, with an area of 3,527 km^2. (Ali and Qaiser, 1986, Khan and Aziz, 2001; Pernetta, 1993). In the present study area, most dominant mangrove tree species, such as *Avicennia marina*, *Rhizophora mucronata*, *Aegiceras corniculatum*, *Ceriops tagal*, are evergreens. Karachi is the most populated city and the largest industrial centre in Pakistan. Karachi is fed with three major river basins, Hab, Lyari and Malir. Due to shortage of proper drainage system, Karachi uses two rivers for the sewerage discharge in the Arabian sea. Most of the rivers and their tributaries are sources of fresh water in the river drainage areas, resulting in brackish water supply that is suitable for growth mangrove forests at rivers discharges (Ali *et al.*,2012; Tariq*et al.*, 2016). Karachi is situated just above the tropical zone, 24° N. It is located on the Arabian sea coast. Both of these factors affect Karachi's climate. Summer is warm in June, with an average monthly temperature of 31.4 °Celsius while winter is mild in January, and that is 18.1 ° Celsius is the minimum mean (monthly) temperature. (Nichol and Wong, 2005; Lo and Faber, 1997). The climate of the study area is subtropical maritime desert. The city's average annual rainfall is approximately 208 mm. The city receives summer monsoon's tail end which is the city's main source of rainfall from June through September.

Materials and Methods

In this study, Landsat scenes, acquired from United States Geological Survey (USGS) were downloaded to measure temporal changes of mangrove cover and density at the coastal areas of Karachi (Table 1).

The objective of study is pragmatic application of integrated technology of Remote sensing and GIS to coastal area of Karachi. Manual Digitization, Raster to Vector Conversions, Landsat Image Processing, and NDVI based mangrove density mapping are the predominant GIS and Remote Sensing techniques, used in this study.

In addition, for mapping and validation of images, the high-resolution Google earth data available in the same time period were used as a reference. In the first phase, sample locations were identified using random sampling techniques for both mapping and validation. A simple random sample is intended to represent a group on an impartial basis. Figure 2 shows the location of sample points collected for validation and

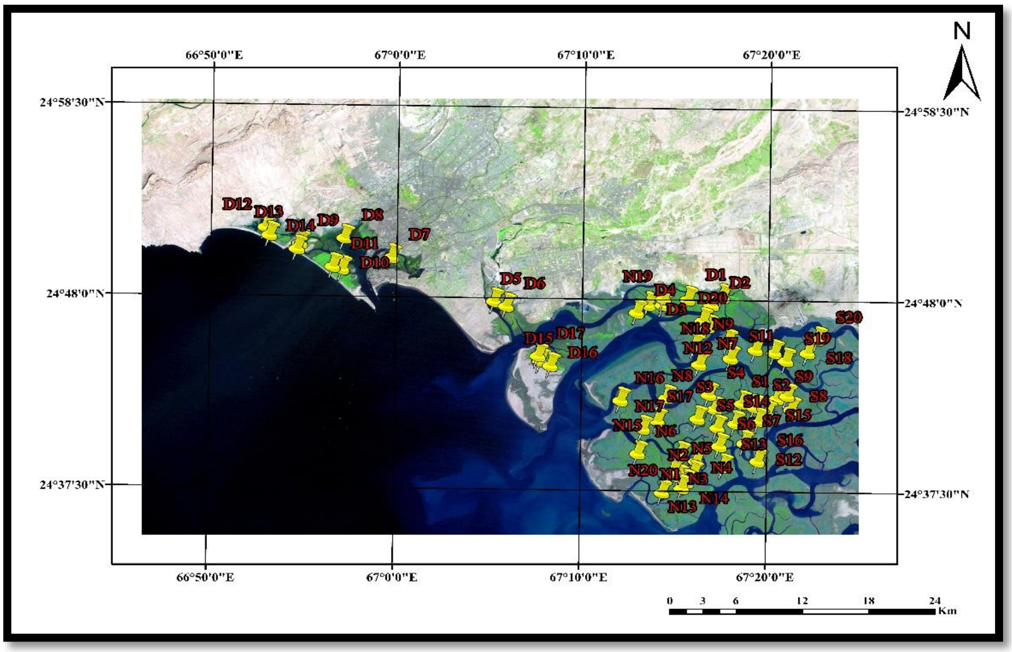

Fig. 2 Random sampling plots

mapping. The sample locations extracted in the year 2018 were categorized in dense, normal and sparse Mangroves classes using visual interpretation. This classification of sample data was revised for the year 2005. Sixty percent of the sample locations were used as training datasets for NDVI based classification. The normalized difference vegetation index (NDVI) is a vital parameter for vegetation identification and has a clear signature of vegetation cover (Vicente et al., 2016). Rest 40% of the sample locations were used for validation of the results. In first step of NDVI based mangrove density mapping, NDVI images of the 2018 and 2005 imageries were extracted. The identified sample locations were overlaid on these NDVI images to extract NDVI values of dense, sparse and normal mangrove forests. The values extracted were averaged out and a mean, maximum and minimum values were extracted for each type of mangrove forest. These values were used to map extent and density of mangrove forests.

In the second phase the mapped imagery of 2005 and 2018 were examined for accuracy. Kappa statistics and correlation coefficient were used for the estimation of accuracy of the images. Table 2 and Table 3 showing the minimum and maximum values of each class i-e, dense normal and sparse mangroves in 2005 and 2018 are given in Table 2, 3.

Results and Discussion

Interpretation and analysis of remotely sensed image include identifying the target that may be an object or characteristic on the surface of the earth. The high-resolution imageries of Google earth depict that the mangrove forest is increasing both in extent and density in major areas of Karachi coast. This could be

Table 2 Classification of mangroves density 2005

Dense	Values	Difference	Normal	Values	Difference	Sparse	Values	Difference
Minimum	0	0	Minimum	0	0	Minimum	-0.1028	-0.1028
Q1	0.013441	0.013441	Q1	0.117647	0.117647	Q1	-0.05533	0.047472
Mean	0.231315	0.217874	Mean	0.147174	0.029527	Mean	0	0.055332
Q3	0.392311	0.160996	Q3	0.187806	0.040632	Q3	0.061108	0.061108
Maximum	0.496063	0.103752	Maximum	0.236364	0.048559	Maximum	0.117647	0.056539

Table 3. Classification of mangroves density 2018

Dense	Values	Difference	Normal	Values	Difference	Sparse	Values	Difference
Minimum	0.151247	0.151247	Minimum	0.110403	0.110403	Minimum	0.136985	0.136985
Q1	0.197	0.045753	Q1	0.153199	0.042796	Q1	0.139077	0.002092
Mean	0.217334	0.020334	Mean	0.163455	0.010256	Mean	0.155384	0.016307
Q3	0.229113	0.011779	Q3	0.163455	0	Q3	0.165257	0.009873
Maximum	0.268439	0.039326	Maximum	0.231399	0.067944	Maximum	0.170859	0.005603

due to sewerage discharge at the coastal areas from Malir and Lyari rivers. In addition, other probable reason may be the availability of alternate energy source to the coastal communities through the utilization of mangrove forests.

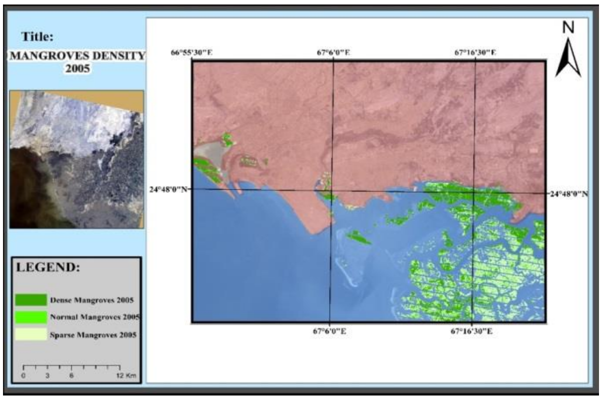

Fig. 3 Map showing mangroves density in 2005

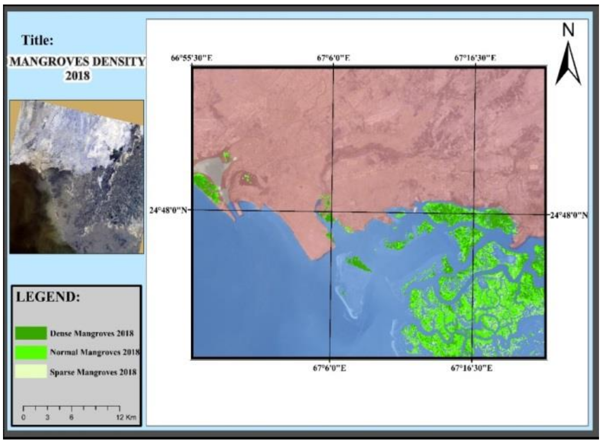

Fig. 4 Map showing mangroves density in 2018

The index used in this research is an index based on a ratio called the Normalized Difference Vegetation Index (NDVI). The NDVI has been and is still widely used for green vegetation cover monitoring (Chen and Brutsaert, 2002; Hielkema *et al.,* 1986; Tucker and Sellers, 1986) all over the world. Figures 4, 5 show the maps of mangrove forest extent and density in the years 2005 and 2018, respectively. The present study shows increase in the mangrove extent over the last thirteen years' period. The density of mangroves reduced as the dense mangroves were converted in normal mangroves.

Accuracy evaluation in this study showed that it was useful to use Landsat data to estimate mangrove coverage in other areas. The precision of the individual classes showed that the maximum likelihood algorithm was efficient in separating mangroves from non-mangrove classes and in distinguishing mangroves from other classes of Land use / Landcover (LU/LC). Landsat L-8 OLI classified pictures provided greater general precision and Kappa values (96 % and 0.96) than ETM+ classified images (87 %and 0.82). The area calculated in 2005 the area was 6,344.82 Ha dense, 4,344.21 Ha normal and 7,119.81 Ha sparse mangroves while in 2018 was 5,786.01 Ha dense, 1,0264.41 Ha normal, and 2,922.57 Ha sparse.

It has been reveled from this study that spatial extent of the mangroves could be examined through successive Landsat Imageries. Furthermore, their by-products such as Classified and NDVI Images provided more accurate results to judge the distribution of mangrove species at the Karachi Coast. Moreover, it also provides future opportunities of such studies through more Remote Sensing Platforms and Sensors to evaluate the Mangrove Eco-system, the backbone of ecological life at this important coastal system.

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