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Application of Comparative Remote Sensing Techniques for Monitoring Mangroves in Indus Delta, Sindh, Pakistan

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ABSTRACT: The Pakistan coastline has five noteworthy sites that are blessed with mangroves in which, Indus Delta contains the most extensive mangroves area and rank as the largest arid climate mangrove in the world. Due to an urgent demand for conservation and restoration purposes, retrieving up-to-date information about the extent and condition of mangrove ecosystem is essential for management and decision making process.

This study aimed to assess the present extent of mangrove forest and their distribution along the Indus Delta and provide the up-to date mangroves forest cover assessment, and detecting the changes in between 2009 and 2014. Landsat 5 Thematic Mapper (TM) and 8 Operational Land Imager (OLI) data were used for mangroves mapping as well as a comparison of pixel based Supervised classification and on screen digitization techniques for delineation of land cover.

The supervised classification and onscreen digitization results showed that total area of mangrove cover was 946.52 km^2, 960.83km^2 and 1010.11km^2, 1082.71km^2 in 2009 and 2014 respectively. The study indicates that during the year of 2009 to 2014 area of mangrove has increased. Most of the re-growth took place around the southern part of the Indus Delta. The comparative analysis indicates that the overall trend in land cover classes of both approaches is same.

Keywords: Mangrove, pixel based supervised classification, onscreen digitization, Land cover.

INTRODUCTION

Mangroves are evergreen forests that are found along the coast of tropics and subtropics intertidal regions (Tomlinson, 1986; Hamilton and Snedaker, 1984; Chapman, 1976; Dahdouh-Guebas, 2002). Mangroves provide important ecological and socio-economic functions to coastal communities. The present extent has been estimated about 137,760 km^2 in 118 countries and territories of the world (Giri *et al.,* 2010). They provide important forest products such as wood, medicines, fuel-wood and fodder (Lee and Yeh, 2009).These forests also serve several important functions, such as the maintenance of coastal water quality, reduction in severity of storm, wave and flood damage, protect shorelines from erosion, and provide nursery and feeding areas for many species of fish and crustaceans (Kuenzer *et al.,* 2011). Pakistan has 1050 km long coastline, 350 km of Sindh and 700 km of Balochistan. The arid subtropical coastline has five different sites of mangrove include Mianihor, Kalmatkhor, Gawatar bay, sandspit and Indus Delta. Indus Delta has seventeen major creeks and numerous minor creeks and host to the most extensive area of mangroves forest (about 97%) and mudflats from Korangi Creek to Sir Creek **(**Amjadand Jusoff, 2007). Mangrove occupies area approximately157000 ha in 2005 (FAO, 2007). Previously the region have eight species of mangroves (Hasan *et al.,* 1983) but now only four species exist (*Avicennia marina, Rhizophora mucronata, Ceriops tagal and Aegiceras corniculatum*) 95% mangroves in Indus Delta are *Avicennia marina*. Very small patches of *Ceriops tagal* and *Aegiceras corniculatum* are found near the mouth of the Indus at Keti Bunder. *Rhizophora mucronata* and *Ceriops tagal* are present due to some replantation work. In 1957 the two large areas within the Delta were declared as protected forest and are currently managed by the Forest Department **(**FAO, 2007).

The Indus Delta comes under the control of different agencies includes Port Qasim Authority and Karachi Port Trust, Sindh Forest and Wildlife Department, Sindh Board of Revenue, and Sindh coastal Development Authority. In the past and current, mangrove plantation along the entire coast have been attempt for rehabilitation purposes with the collaboration of different department and organization like SFD (Sindh Forest Department), IUCN (International Union for the conservation of nature) and WWF (world wildlife fund) etc.

Optical Remote Sensing technique has effective tool for the estimation of mangrove forest area, productivity, and species distribution and discrimination (Green *et al.*,1998; Wang *et al.*, 2004; Lee and Yeh, 2009). Remote Sensing plays a vital role for mapping mangrove due to the inaccessibility of this ecosystem and difficulty in field activity because of the nature of mangrove environment (Kamal and Phinn, 2011).

Remote Sensing and GIS based technologies are used to map forest cover since the last three decades in Pakistan. Estimates of mangroves area in Pakistan vary greatly (FAO, 2007; IUCN, 2005; Giri *et al.*, 2014) but generally the most recent estimates of mangrove area is 98,014 ha in 2010 (Giri *et al.*, 2014). Present study used two processing technique; on screen digitization and pixel based classification. On-screen digitizing is a way to tracing features from images. This is one of the most accurate techniques for characterizing landcover (Ruelland *et al.*, 2011).

It is indicate that various studies have used pixel based approach for landcover monitoring (Fatoyinbo *et al.*, 2008; Muttitanon and Tripathi, 2005). The objectives of this study are; comparison of two main processing techniques (on screen digitization and pixel based classification) in a single study area on the basis of two date imageries; and to map the spatial distribution and current extent of mangrove forest using remote sensing and GIS.

A. Study Area

The study area is located between 67° 12’15” to 68° 13’00” E and 23° 39’00” to 24° 51’13” N (Fig. 1). Pakistan coastal climate is an arid subtropical climate with a mean annual rainfall of 100-200 mm. Study area comprises intertidal mudflats, mangroves, creeks, Saltflats, marshes etc. *Avicennia marina* is the dominant species in Indus Delta, which comprises approximately 95% of the whole community (Fig. 2). The Indus delta is an important stop for migratory birds from Siberia. The mangrove of Indus Delta provide an important ecosystem services like nursery and breeding ground for migratory birds and marine life, protect coastline from erosion, provide fuel wood and fodder for local communities, and physical barrier from cyclones and typhoons (Giri *et al.*, 2014).

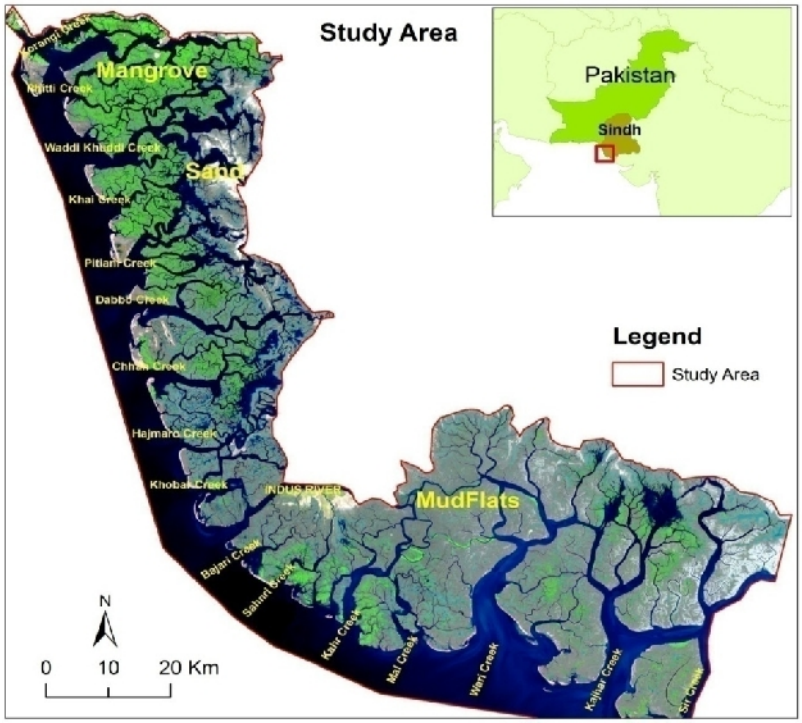

Fig. 1. The Study Area.

Fig. 2. Some Field photographs of *Avicennia marina*.

DATA AND METHOD

A. Image Data

Landsat thematic mapper (TM) images are the most commonly used data source for mapping large areas. Two satellite images obtained are dated 2009, and 2014 as described in following (Table 1). In this study, cloud free Landsat images of the study area were freely downloaded from open source. All bands were used for image analysis except for thermal bands.

A Band combination used for visual interpretation is band 4, 3 and 2 as red, green and blue for Landsat 5 whereas, band 5, 4, 3 as red, green, and blue for Landsat 8. A subset was extracted from the entire scene and used as a study site. Two different techniques were employed to develop land cover maps which are Pixel based technique and On-screen digitization. Google earth software has been used for filtering final map (Fig. 3).

Table 1: Acquisition dates of Landsat imagery.

Image Acquisition Date	Satellite	Spatial Resolution (Meters)
6-12-2009	Landsat Thematic Mapper (TM)	30
18-1-2014	Landsat 8 Operational Land Imager (OLI)	30

B. Ground truthing

Ground truthing is the process of sending researcher to gather data in the field that either complements or disputes remote sensing data collected by satellite images. In this research study the collection of ground-truth data enables calibration of remote-sensing data, and aids in the interpretation and analysis of what is being sensed.

C. On-screen digitization

On-screen digitizing is way to get vector (point, line or polygon) information from images. This technique is used to extract new data from imagery and for comparing and detecting changes over time. Six land cover classes were extracted from on screen Digitization of satellite data and mangrove habitat maps of 2009 and 2014 were prepared in ArcMap 10.1.For digitizing purpose scale 1:20,000 used. A Band combination used for visual interpretation is R4, G3, B2 and R5, G4. B3 for Landsat TM and OLI. The area of land cover was also computed.

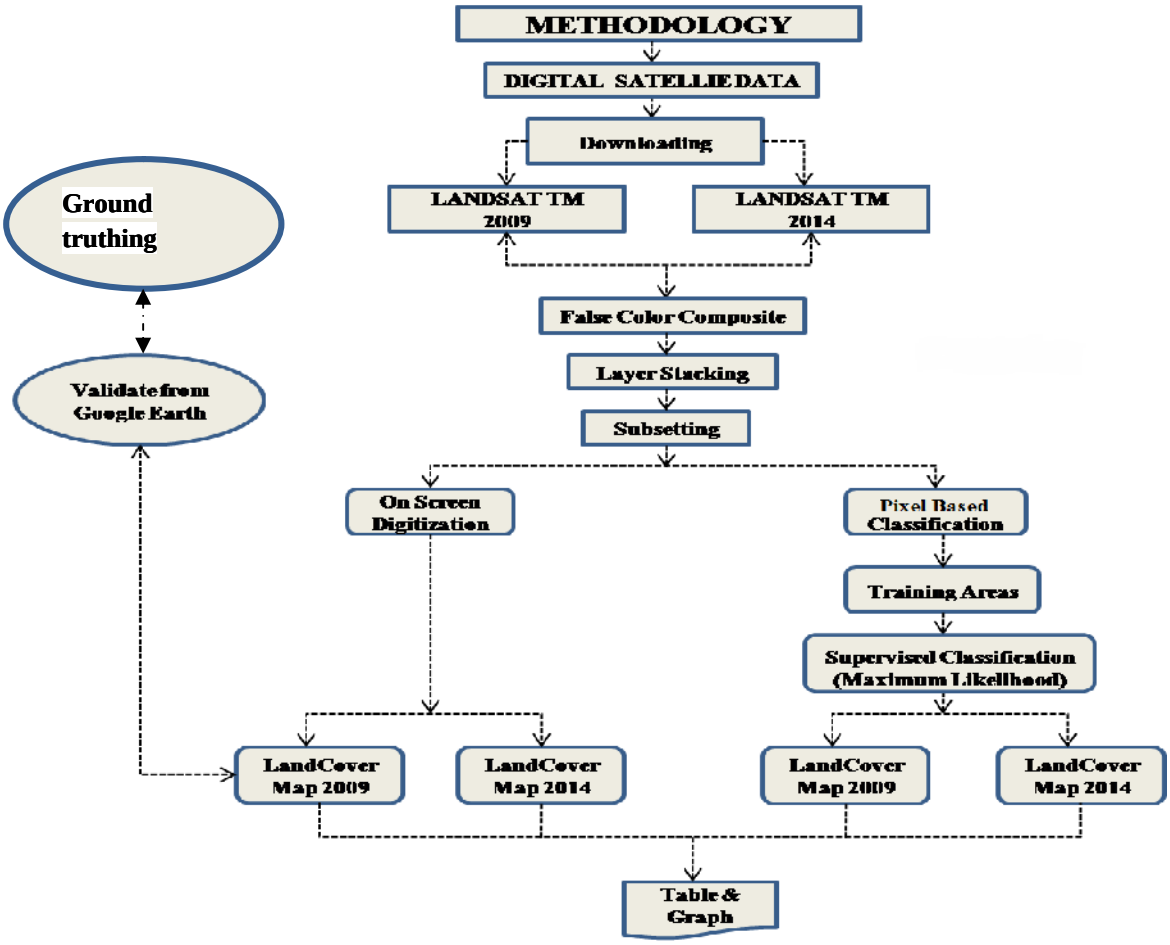

Fig. 3. Flow diagram of Methodology.

D. Pixel based technique

The second technique used in this study is pixel based supervised classification. The Supervised classification is semi-automated technique, and this is used to extract numerical data from the image in the form of Training sets. The training area is used to classify the image. This technique was done to locate specific areas within the image that show homogenous categories of the land cover types. For this purpose, Maximum Likelihood classification Algorithm was used and training areas were developed for images using area of interest (AOI) tool in ERDAS Imagine 9.2 software. Maximum likelihood classification (MLC) is the most robust methods in the field of Remote Sensing **(**Wang *et al.*, 2004). Several AOI were drawn for each cover type then group for a single category to create signature file. Six classes were generated for each image like, Mangrove, Sand, Mud Flats, Vegetation/crops, Algae and Water body of Indus Delta. The areas of each land cover type of 2009-2014 were also computed and then compared with digitized images. The area was calculated in square kilometer.

RESULTS AND DISCUSSION

Present study assesses the current status and spatial distribution of Mangroves along the Indus delta. Land cover maps of study site were developed using Pixel based and onscreen digitization techniques. Description and statistics of each land cover map is discussed in the following sub-section.

A. Comparison between classification Approaches

This study used two mapping technique for different land cover classes. The overall trends in land cover from 2009 to 2014 are the same (Fig. 4) for the both approaches test (on-screen digitization, pixel based).This study shows that there is overall 1.16% increase of mangrove area from 2009 to 2014 in onscreen method. In 2009, mangrove area was 16.34% of the total covered area, which was further increased in 17.50% in year 2014 of the total area.

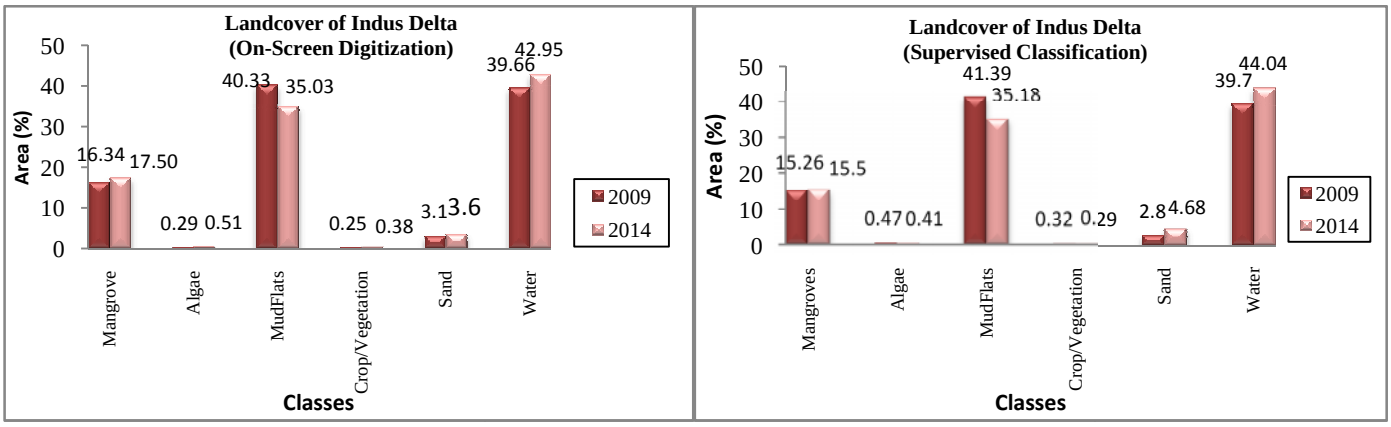

Fig. 4. The Land Cover Classes of Indus Delta.

In Pixel based technique, the covered area of mangrove was 15.25 % in year 2009 to 15.50% in year 2014. The percentages of mudflats and water are of pixel based approach and on screen Digitization are closer to each other. Fig. 5 shows the comparative analysis of Pixel-based and on-screen Digitization.

The visual comparison of resultant classified images shows the pixel based classification contains group of pixels or individual pixels whereas onscreen digitization map have a smooth appearance.

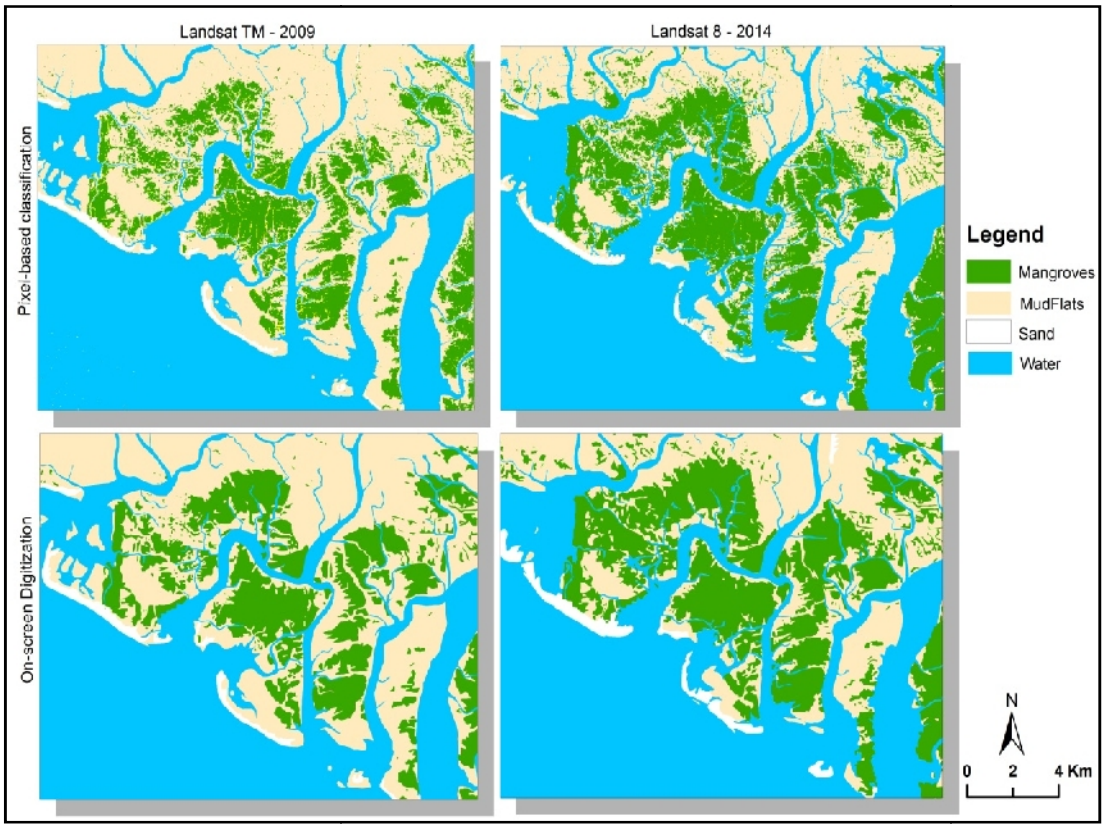

Fig. 5. Comparison of pixel based classification and on screen Digitization.

B. Analysis of land covers (2009-2014)

The result of classified image shows that mudflats dominate this area, approximately 35% of the total land is mudflats and 44% of the total area is water. Decrease in mudflats area and increase in water area of 2009 to 2014 in both techniques is due to the change in images acquisition months.

From the analysis of 2009 classified image, the total area of mangrove cover around Indus Delta was about 946.52km² from Korangi creek to Sir Creek. In Landsat image of 2009, algae have also been classified with an area of about 29.17km². The result of mangrove cover using on screen method is 1010.11 km², which is more than value comes after classification. Other land cover statistic is given in Table 2. Landsat image of 2014 analysis show that the total cover of mangrove area in the Indus Delta was about 960.83km² whereas, mangrove extent in digitized map is 1082.58km². The final classification maps shown in Fig. 6**.**

Both approaches represent an increasing trend in mangrove area. The changes in the expansion of mangrove were observed in 2014. Most of expansion can be seen in southern part of delta whereas Northwest part of Indus Delta mangroves has not changed.

It is observed that the increase in mangrove in the said year is because of natural regrowth along southern portion of Delta. Human efforts of mangrove plantation or in other words human efforts is a contributing factor in increasing that specific land cover. Therefore, the Mangrove plantation map is also developed from Google earth (Fig. 7). By observing the texture and pattern (Fig. 8 and 9) it is found that mangrove plantation can be seen at ketibunder and shah bunder area. The vast area of mudflats can be used to select potential rehabilitation sites therefore some plantation efforts can be seen in barren areas of mudflats along chhan creek, hajmaro creek and khobar creek after 2009 (Fig. 8 and 9).

Table 2: Land cover Statistics of Indus Delta.

Land cover Classes	On-Screen Digitization (2009)		On-Screen Digitization (2014)		Net change	Pixel Based Classification (2009)		Pixel Based Classification (2014)		Net change
	Area (km²)	Percentage%	Area (km²)	Percentage%		Area (km²)	Percentage%	Area (km²)	Percentage%	
Mangroves	1010.11	16.34	1082.58	17.50	72.6	946.52	15.3	960.83	15.5	14.31
Algae	18.35	0.29	29.09	0.51	10.74	29.17	0.47	25.63	0.41	-3.54
Mud Flats	2494.15	40.33	2166.83	35.03	-327.32	2566.21	41.4	2179.74	35.18	-386.47
Crop/Vegetation	16.04	0.25	23.68	0.38	7.64	20.13	0.32	10.86	0.29	-9.27
Sand	192.16	3.1	225.75	3.6	33.59	174.09	2.8	290.05	4.68	115.96
Water	2453.04	39.66	2655.92	42.95	202.75	2462.88	39.7	2731.89	44.06	269.01
Total	**6183.85**	**100**	**6183.85**	**100**		**6199**	**100**	**6199**	**100**	

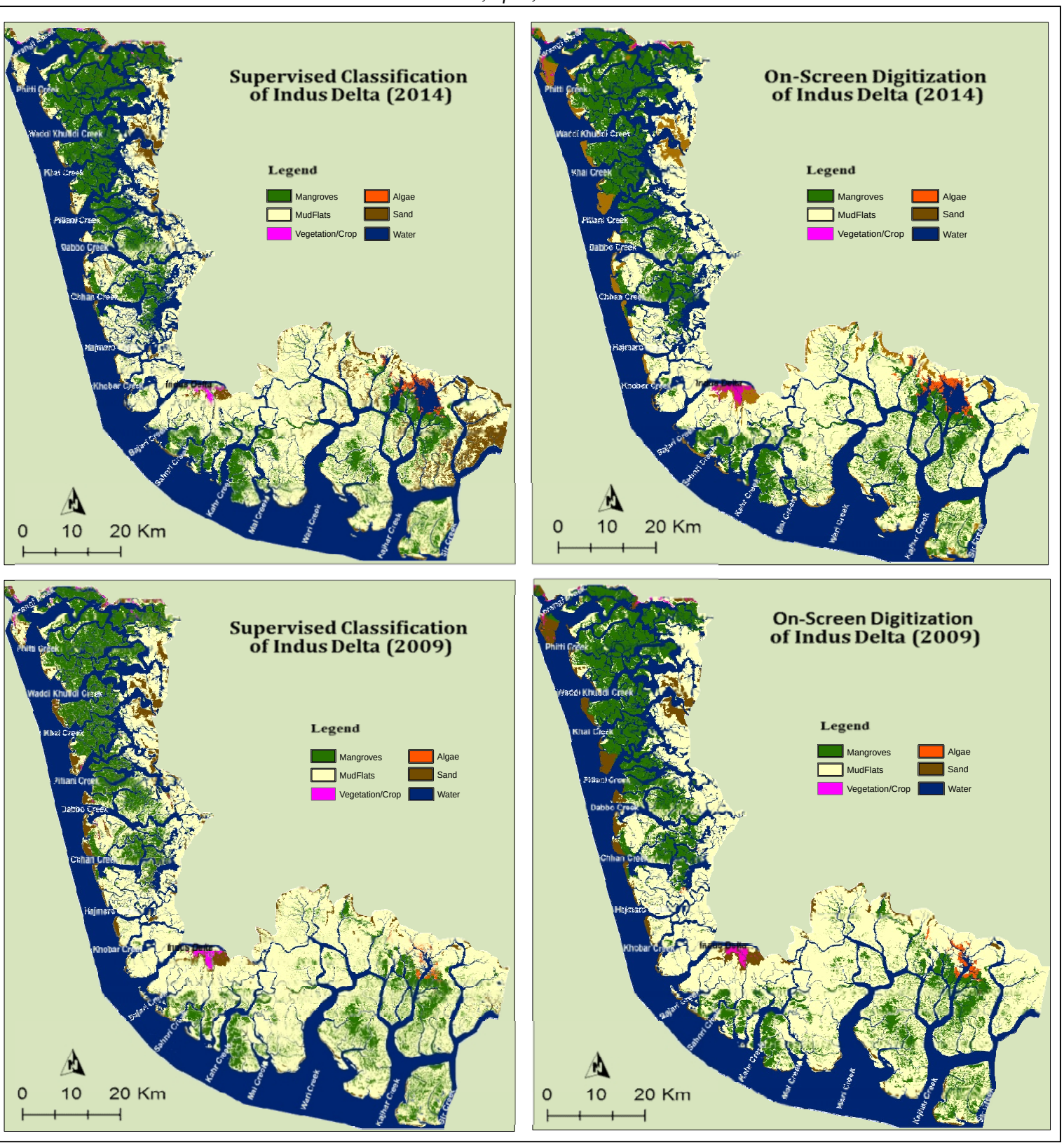

Fig. 6. Land cover of Indus Delta 2009-2014 (Pixel based classification, onscreen Digitization).

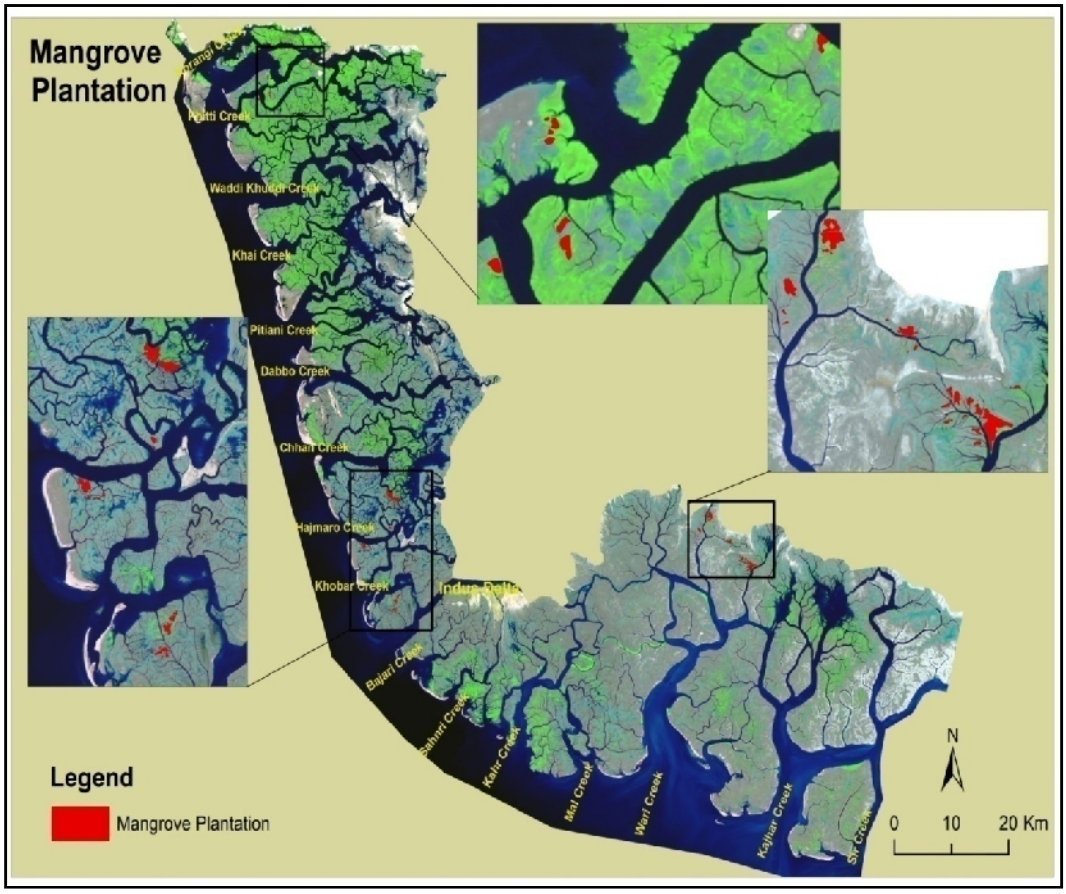

Fig. 7. Mangrove plantation in Indus Delta.

Fig. 8. Mangrove plantation identified on Google Earth.

a: Muchak Island b: Shah bunder

Fig. 9. Mangroves Plantation (Source: IUCN).

CONCLUSION

This study assess the spatio-temporal distribution of mangrove forest of Indus Delta and also compared the pixel based and on screen digitization techniques. On screen Digitizationis dependent on the operator knowledge about the area. It is obviously a very time-consuming and laborious work when compared to the automated approach, particularly for classifications at a broader scale. However this technique shows difficulties when applied to time series images to reproduce an equivalent level of detail between different types of cover. Using Landsat data for on screen digitization it was found that small area/ scattered mangroves was not digitized properly although on screen digitization requires good spatial resolution in order to get the appropriate result. The maps generated from on-screen interpretation have a smooth appearance whereas the maps derived from pixel based approach have some salt and pepper' appearance. Supervised classification depends on the prior knowledge, and skill of the individual processing the image. This study indicates an overall 1.16% increase in mangrove areas during five years and this is due to some plantation work along ketibunder and shah bunder area by the Sind forest department, coastal development authorities, Asian Development Bank, IUCN etc. whereas, some natural increase can be seen along sahnri creek, Kahr creek and mal creek area. The areas of Mangrove, Mudflats, and water classes are relatively similar in both approaches. The net change of mudflat area is approximately -327.32 Km^2 and -386.47 Km^2 in pixel based and onscreen digitization and this negative trend is due to the tidal effects on the mudflats area in 2014.The area of algae in onscreen digitization shows the positive net change (10.74) between five years while the Pixel based classification shows the negative net change (- 3.54) between 2009 and 2014.

The difference in both classification results is due to some misclassification of algae with mangrove in Pixel based classification. The sand class appears in pixel based classification was under-represented in 2009 whereas over-represented in 2014 however, the overall result of this study indicate that the result will follow the same trend either we will adopt any of the methods for analyzing land cover.

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