SATELLITE IMAGE BASED EVIDENCE OF POSITIVE IMPACT OF FRESHWATER FLOODING IN INDUS DELTA, PAKISTAN

U. Saeed, N. Shahzad, S. R. Ahmad*, W. Yousaf and S. G. M. D. Hashmi

Geographic Information System (GIS) Laboratory, WWF –Pakistan, Lahore
*Institute of Geology, University of the Punjab, Lahore, Pakistan
Corresponding author: wsfyousaf@gmail.com

ABSTRACT: Focusing on the ten year's mangroves cover change analysis of Kharo Chann *taluka*, Indus Delta, this study contributed for understanding the changes in distribution and total area of mangroves. Satellite Remote Sensing (SRS) techniques were used to assess the ecological impact of flooding on mangroves growth/change. Object based image analysis being most recent and advanced classification technique was adopted to quantify the density cover of the mangrove's spread. Multi-temporal (2001 and 2011) images of Terra (ASTER) satellite were used to analyze the extent of mangrove cover, various algorithms were incorporated for hierarchical rule set classification. An increase of 2,568 ha in mangroves, particularly in *Avicenna marina* was observed in this study. Accuracy of the developed forest cover maps was 92.7 % with kappa value of 0.88. Validation of the results was done by ground truthing and an increasing trend in the mangroves from the last 3 to 4 years was seen during analysis. This increase was attributed to plantation activities and natural regeneration as well which was mainly due to the increase in the fresh water flow, downstream from Kotri barrage through floods.

Key word: Mangroves, Indus Delta, Remote sensing, Flood, ASTER.

(Received 14-02-2014 Accepted 29-08-2015).

INTRODUCTION

Mangroves, also known as coastal green gold, thrive in many coastal areas, where slow-moving water allows sediments to settle. This ecosystem dominates the coastal wetlands of tropical and subtropical regions throughout the world. Mangroves are naturally rich with special processes enabling them to take up saline water at different concentrations levels, extracting water molecules, and evacuating the salt through the leaves (Howari *et al.*, 2009). Mangroves provide different economical and ecological services leading to contribute a big role in protection from coastal erosion, filtration of water, providing habitat for fish and shrimp, a source of medicinal ingredients and building materials along with the source of attraction for tourists etc. Such forests grow in wetlands, and marshy areas of saline-brackish water (Rey *et al.*, 1990).

In Pakistan, eight species of mangroves, belonging to 6 genera and 5 families, have been reported so far (Gill *et al*., 2012). Moreover, mangrove trees are one of the most threatening and vulnerable ecosystems of the world and experiencing a tremendous decline during the last five decades. International programs like Kyoto Protocol, and the Ramsar Convention, highlighted the importance of necessary protection measures and conservation activities for the protection of further loss. Forest cover and human or natural alterations of forest cover, play a major role in global-scale patterns of climate and biogeochemistry of any earth ecosystem. This arid climatic region has one of the largest concentrations of mangroves (Giri *et al*., 2007). Fresh water discharge in the delta region is the main cause of the survival of the mangrove forest in this region and these are facing serious problems of over exploitation and progressive sedimentation (Saifullah *et al*., 202). In the past as the World Wide Fund for Nature (WWF) Pakistan report suggest major loss of mangrove forest land has been identified in overall Thatta district (Khan, 2005). There has been global assessment of the changes in physical characteristics of land cover. Satellite Remote sensing technology has been widely used to be the best approach for mapping and monitoring these threatened ecosystems (Everitt *et al*., 2008). It has long been recognized as the most efficient tool for forest monitoring and mapping because it provides spatiotemporal data at different scales. The importance of mapping, quantifying, and monitoring, the changes in physical characteristics of land-cover have been widely recognized in the scientific community as a key element in the study of global change (FAO, 2007).

Globally, mangroves are approximately known to comprise of 70 tree species and shrubs (Duke, 1995). However, Indus delta comprises of four mangrove species, i.e. C*eriops tagal, Avicennia marina, Agiceras corniculatum* and *Rhizophora mucronata*. *Avicennia marina*, is dominating in the investigated area with its characteristic system of hanging roots or pneumatophores. In an era of unpredictable climatic conditions, scientists are working on the monitoring, mitigation and even after effects of floods. Floods are the most destructive of the natural hazards and the cause of large scale damages to lives and property. Each year floods affect about 20,000 lives all over the world. In recent years Pakistan has suffered a series of major floods in 2010 and 2011. The floods of recorded monsoon rainfall have resulted in devastating impacts in the country (Gill *et al.*, 2012). However, unlike northern Pakistan, there are areas where communities welcome the flood as a blessing. This study focuses on the impact of freshwater availability due to floods on mangroves habitat.

Plos One

MATERIALS AND METHODS

The study area was Kharo Chann taluka of Sindh province in Thatta district of Pakistan. It geographically extends from 67° 43' 42.35''E to 67° 29' 58.82''E longitude and 23° 52' 11.14''N to 24° 11' 03.22''N latitude covering about 574 km^2 of area (Figure. 1).

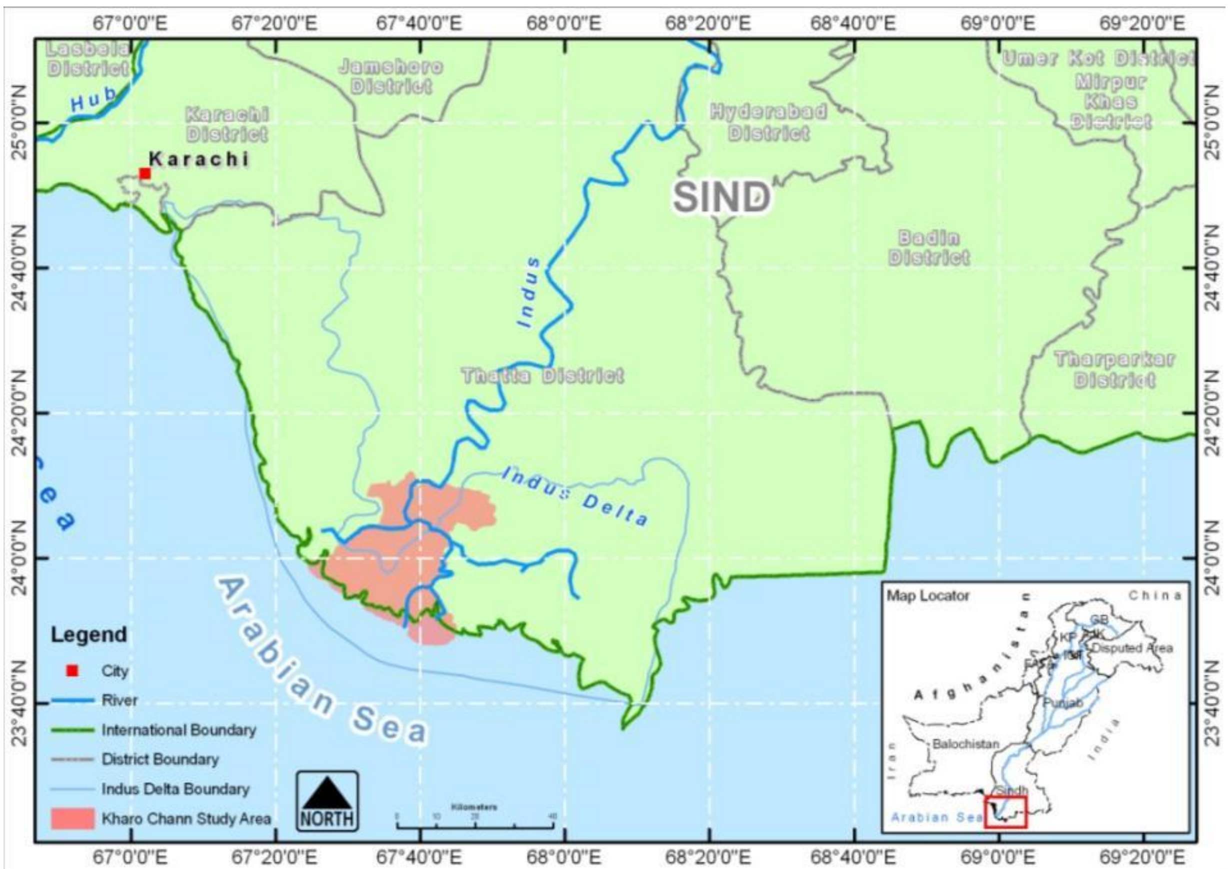

Figure 1. Location map of study area

With the population of about 30,500 the people were mostly dependent on fishing, agriculture and livestock as the major sources of livelihood making them to sustain below the poverty line. The creeks comprised of dense pockets of mangrove forests of the Indus Delta (Saeed *et al.*, 2009).

Kharo Chann taluka of Thatta district was directly affected by the sea water intrusion in the Indus delta region. The people of the area were mostly dependent on the natural resources like forests and fisheries as most of them were fisherman (Saeed *et al.*, 2010). The objective of the study was to Conduct land cover/land use change analysis of the selected sites using multi temporal satellite images and flood impact assessment on mangroves ecosystem.

Following fundamental approaches were adopted for the mapping using Object Based Classification in Definiens Developer®.

Data sets and preprocessing: Assessment and monitoring of the mangrove cover extent in the Kharo Chann taluka, was carried out using medium resolution satellite Terra (ASTER) data sets for the years 2001 and 2011. Historic and current satellite images of Terra

(ASTER) were procured. The characteristics of the procured images are shown in table -

Table 1. Acquired satellite data characteristic.

Study Area	Acquisition Date	Spatial Resolution - VNIR (m)	Spectral Bands	Tide Height (m)
Kharo Chann	December 24, 2001	15	14	1.2
	January 02, 2011	15	14	1.2

The use of remote sensing data, such as satellite images along with various geospatial analysis provided a significant source to map the disastrous areas. Priority was given to Low tide satellite imagery to avoid any chance of misclassification of mangrove cover. Other parameters that controlled image quality such as nadir angle, atmospheric clarity and cloud free data sets were preferred. The procured satellite images were enhanced geometrically and radiometrically, as in doing the change analysis. The images were co-registered and synchronized using the AutoSync tool of ERDAS Imagine.

Land cover land use mapping: For the land cover land use mapping, different conventional and old classification techniques (unsupervised classification, supervised classification, hybrid classification etc.) were being used in the GIS/RS market of the world. In this research study most recent and advanced image classification technique i.e. Object Based Image Analysis was used for the assessment. In this approach, boundaries of the dominant objects were extracted at fine and coarse scales on the basis of hetrogentiy and homogeneity leading to high level accuracy in classifying these extracted objects.

Ground Truthing: For ground truth data collection, a field visit was conducted to Kharo Chann project sites. Garmin 76CSX Global Positioning System (GPS) receiver and digital camera were used to collect eighty-one GPS points.

Preparation of data sets: Satellite images were truncated at the boundary of Kharo Chann taluka. The truncation also provided a high level of confidence at training sites selection, hence enhanced the overall accuracy of the results.

Thematic layer generation: Different parameters/ indices and source data were used for the definition of rule set. To determine the density of green on a patch of land, distinct colors (wavelengths) of visible and near-infrared sunlight reflected by the plants was used during interpretation process. Normalized Difference Vegetation Index (NDVI) (Burgan, 1993 and Ahmad and Lakhan, 2012) and Normalized Difference Water Index (NDWI) were used to enhance and extract water features in satellite image (Grigio *et al.,* 2005).

Particular type of analysis in this study was carried out by incorporating the field data and DN values of the data set. The rule set was developed by considering the spectral behavior of the generated segments with the help of 2D feature space plot and image object information. Moreover, ground survey points, along with the detailed description regarding the forest type, height and age, were used to validate the developed thematic layer.

Accuracy assessment: The accuracy assessment of the forest cover maps was done by using Ground Control Points (GCPs), collected by doing the Fixed Point photography of the area through the field survey.

RESULTS AND DISCUSSIONS

The developed output land cover land use maps consisted of two categories of the vegetation types in Kharo Chann i.e.

1. Deltaic vegetation which comprised of mangrove trees and saltbushes
2. Riparian vegetation which was along the riparian belt of Indus River and its outshoots. This mainly comprised of *Tamarix* spp., *Mesquite* spp., Reeds and sparse trees of *Acacia* spp.

Based on thematic layers statistics generated from ASTER satellite image of the year 2001, the mangrove canopy cover analysis showed that the total mangrove cover in Kharo Chann was about 5,184 ha. Closed canopy mangrove cover was about 1,523 ha (29%), closed to open canopy mangrove cover was about 773 ha (15%), open mangrove cover was about 1,729 ha (33%) and open canopy mangrove cover was about 1,158 ha (22%). Mix class of Saltbush/grasses class covered an area about 3,165 ha (Table 2 and Figures 2 and 3).

In addition closed canopy *Mesquite* spp/*Tamarix* spp/ Bushes cover was about 744 ha and open canopy *Mesquite* spp./*Tamarix* spp/ Bushes cover was about 1,793 ha. From the analysis of Aster image of 2011, it was noted that the total mangrove cover in Kharo Chann was 7,752 ha, out of which closed canopy mangrove cover was about 1,956 ha (25%), closed to open canopy mangrove cover was about 1,197 ha (15%), open canopy mangrove cover was about 2,710 ha (35%) and open canopy (10-30%) mangrove cover was about 1,887 ha (24%). In addition closed canopy Mesquite spp./Tamarix spp/ Bushes spread over 673 ha and open canopy *Mesquite* spp./*Tamarix* spp/ Bushes cover was about 1,491 ha (Table 2 and figure. 2 and Figure 3).

An error matrix was generated (Table 3) to check the accuracy of developed LCLU maps. It was a square array of numbers organized in rows and columns which expressed the number of sample units (i.e. pixels and clusters of pixels) assigned to a particular category relative to the actual category as indicated by reference data (Congalton, 1996; Story, 1986). An accuracy of 92.7% has been achieved with the kappa coefficient of 0.8845 (Table 3).

Table 2. Showing statistical details of historic and current Land cover

Class Name	Area (ha)		Percentage Change
	Historic	Current	
Closed Canopy Mangroves (CCM)	1,523.16	1,956.49	28.45
Closed to Open Canopy Mangroves (COCM)	773.28	1,197.16	54.82
Open Canopy (30-40%) Mangroves (OCM 30-40%)	1,729.44	2,710.96	56.75
Open Canopy (10-30%) Mangroves (OCM 10-30%)	1,158.48	1,887.86	62.96
Mudflats\Wet Soil (MF/W)	37,879.20	43,126.81	13.85
Water (W)	17,058.24	22,642.25	32.73
Saline Area\Sand (SA/S)	24,579.36	7,259.29	-70.47
Salt Bushes\Grasses (SB/G)	3,165.12	3,121.92	-1.36
Agriculture Land (AL)	2,617.56	2,719.35	3.89
Land soil (LS)	1,554.12	5,268.17	238.98
Closed Canopy *Mesquite* spp.*Tamarix* spp.\Bushes (CCMT)	744.84	673.02	-9.64
Open Canopy *Mesquite* spp.*Tamarix* spp.\Bushes (OCMT)	1,793.88	1,491.14	-16.88

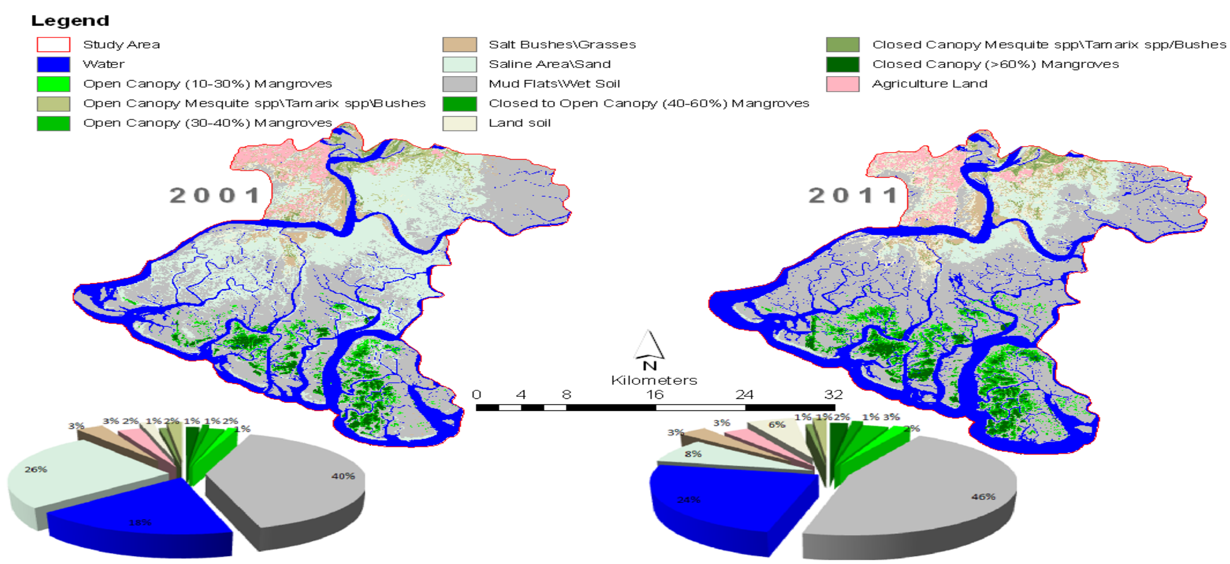

Figure 2: Showing land cover change analysis maps

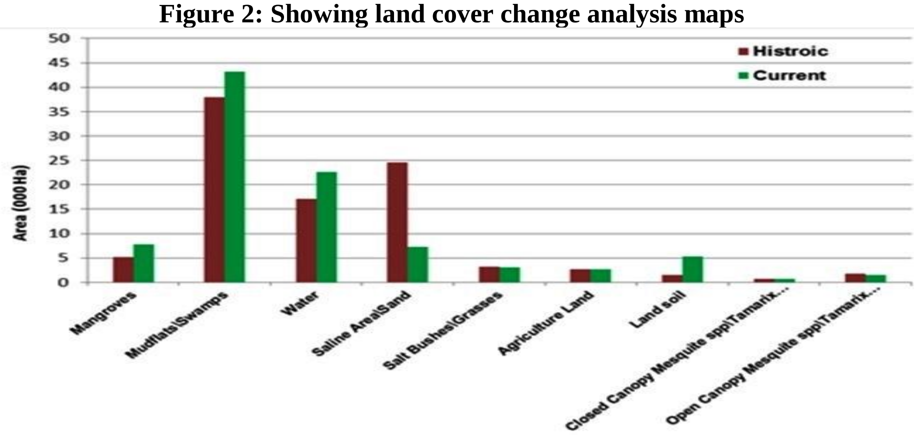

Figure 3: Graphical representation of LCLU classes

Table 3. Showing error matrix – Accuracy Assessment (full name of the land cover classes can be seen in table 2)

Land cover classes	AL	CCM	OCM (30-40%)	CO	OCMT	CCMT.	SB/G	OCM (10-30%)	LS	SA/S	MF	W
AL	**14**	0	0	0	0	0	0	0	0	0	0	0
CCM	0	**10**	0	0	0	0	0	0	0	0	0	0
OCM (30-40%)	0	0	**13**	0	0	0	1	1	0	0	0	0
COCM	0	0	0	**10**	0	0	0	0	0	0	0	0
OCMT	0	0	0	0	**9**	0	1	0	0	0	0	0
CCMT	0	0	0	0	0	**10**	0	0	0	0	0	0
SB/G	1	0	0	0	0	1	**13**	0	0	0	0	0
OCM (10-30%)	0	0	0	0	0	0	0	**5**	0	0	0	0
LS	0	0	0	0	3	0	0	0	**3**	0	0	0
SA/S	0	0	0	0	0	0	0	0	0	**6**	0	0
MF/W	0	0	0	0	0	0	0	2	0	0	**3**	0
W	0	0	0	0	0	0	0	0	0	0	0	**4**

The confusion matrix was developed in order to find out the areas where there has been change or conversion in the land, water or forest (Figure 4).

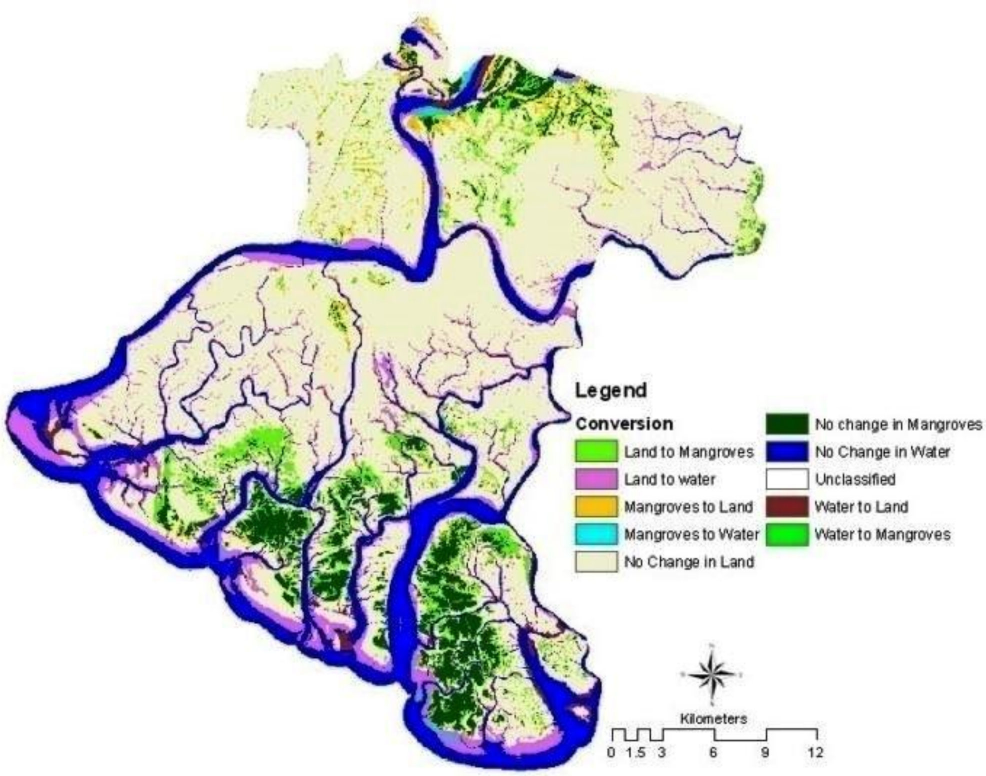

Figure 4. Change Matrix highlighting the conversion of LCLU classes

DISCUSSION

The results revealed significant increase in the forest area in Kharo Chann. The patterns of plantations as well as natural regeneration were observed. The satellite image based slices are shown in the fig. 5, 6 and 7.

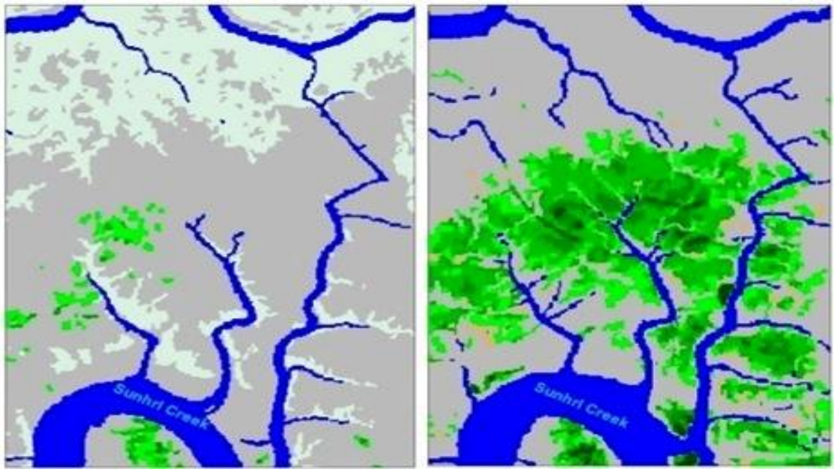

Figure 5. Change slices of Adhiar

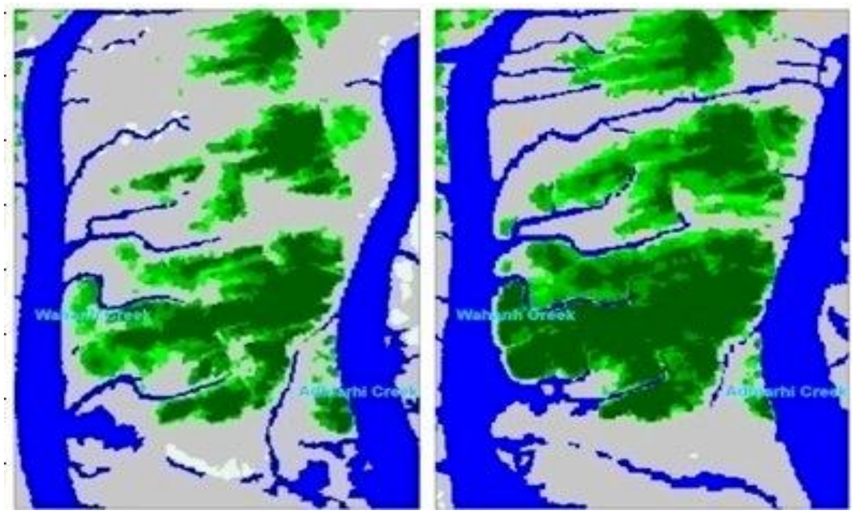

Figure 6. Change slices of Sunheri creek

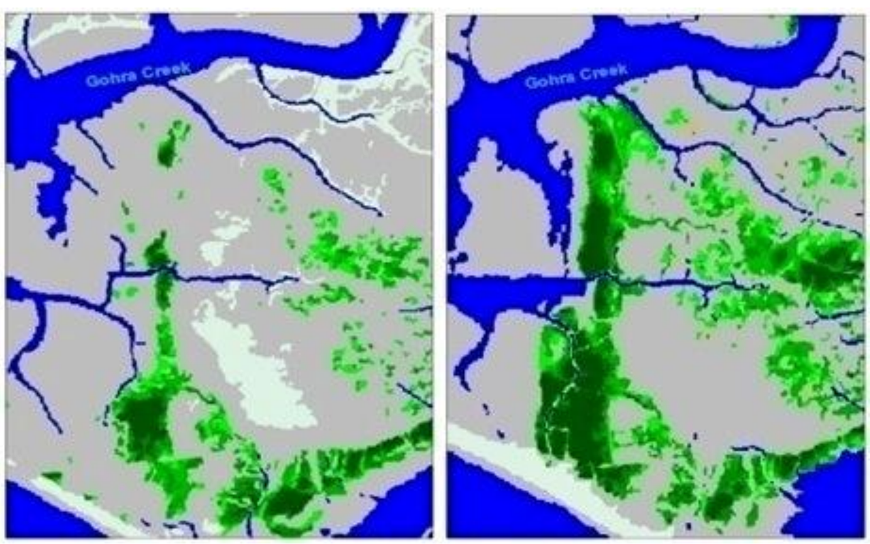

Figure 7. Increase of Mangroves in Gohra creek.

Kharo Chann *taluka* was one of the most sustainable ecosystems of the mangroves. In the area, a significant increase in mangrove forest has been observed (Gill et al., 2012). A huge patch of *Avicinea marina* has been observed in the recent imagery, when the site was surveyed it was seen that this increase in the specie has been attributed to the natural growth of mangrove trees, which might be the after effects of flood 2010 or there might be certain reasons that salinity of the area has been increased during the past half-decade (Rahman and Ahsan, 2001). It was further verified on ground and with the help of Google Earth images. The discussion with the communities and the field survey revealed that there has been an enormous increase in forest cover of the area due to the continuous freshwater flooding in monsoon season since 2010. Moreover, similar trend in the increase in the mangroves has been seen in India which recorded an increase of 23.34 sq km in the mangroves (ISFR, 2011). UNDP in partnership with local volunteer organizations and PDI under WWF-P funding had also planted mangroves in these areas (Mustafa and Reid, 2012). This growth in mangrove cover will help prevent the soil erosion as well as act as a natural barrier against the storms which in recent times have become more frequent (Hamilton, 1983). This impact directly provided benefits to the local communities such as farmers and fishermen. Increase in Mangrove cover was highest near Sohnri and Adhiari creeks at Kharo Chan (Khan and Akbar, 2012). This key finding was a piece of information that must be looked at in conjunction with salinity study, socio economic baseline, vulnerability assessment and other studies before actions can be taken. In this case actions may be to strengthen conservation to ensure the increasing growth trend maintained, or, to examine for replication purposes what conditions was necessary for sustained growth, or, understand which portions of this cover was likely to act as sea barriers and help villagers to organize accordingly.

Conclusion: A very useful key finding of the study is the physical spread as measured in hectares of overall mangrove cover, closed canopy/ closed to open canopy/ open mangrove cover. During the year 2001 to 2011, total mangrove cover in Kharo Chann *taluka* has increased by about 2,568 hectares. The analysis reveals the evidence of the increase in the mangrove patches and according to community all these mangroves are grown in the last 4 to 6 years.

Acknowledgement: We are thankful to World Wide Fund for Nature (WWF) Pakistan for sharing the satellite data and field support for the study. We are also grateful and thankful to Mr. Rab Nawaz (Regional Director, Sindh) and Dr. Uzma Khan (Director, Biodiversity) for their suggestions and support.

REFERENCES

Ahmad, S.R. and V.C Lakhan (2012). GIS-Based Analysis and Modeling of Coastline Advance and Retreat Along the Coast of Guyana. J. Mar Geod. 35 (1): 1-15

Burgan, R. E. and R. A. Hartford (1993). Monitoring vegetation greenness with satellite data. US Department of Agriculture, Forest Service, Intermountain Research Station; Ogden (USA).

Congalton, R. G. (1996). Accuracy assessment: a critical component of land cover mapping. Gap analysis: a landscape approach to biodiversity planning. 119-131

Duke, N. C. (1995). Genetic diversity, distributional barriers and rafting continents—more thoughts on the evolution of mangroves. Hydrobiologia, 295(1-3): 167-181

Everitt, J.H., C. Yang, S. Sriharan, F.W. Judd (2008). Using high resolution satellite imagery to map black mangrove on the Texas Gulf Coast. J. Coast. Res. 24: 1582-1586

FAO. The World’s Mangroves 1980–2005; FAO Forestry Paper 153. FAO; Rome, Italy. Available online: ftp://ftp.fao.org/docrep/fao/010/a1427e/a1427e00.pdf (accessed on 30 October 2009).

Gill, K., N. Shahzad, I. Ashraf, U. Saeed, and F. Laghari (2012). Impact of floods 2010 in coastal area of Pakistan – a case study of Kharo Chann, Thatta District. Rec Zool. Surv. Pakistan 21: 29-34

Giri, C., B. Pengra, Z. Zhu, A. Singh, and L.L. Tieszen (2007). Monitoring Mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. Estuar. Coast. Shelf Sci. 73(1): 91-100

Grigio, A.M., V.E. Amaro, H. Vital, and M.A. Diodato (2005). A method for coastline evolution analysis using GIS and remote sensing–A case study from the Guamare City, Northeast Brazil. J. Coastal Res. 42: 412–421

Hamilton, L.S. and P.N. King (1983) Tropical Forested Watersheds: Hydrologic and Soils Response to Major Uses or Conversions. Westview Press, Boulder.

Howari, M.F., R.B. Jordan, N. Bouhouche and E.S Wyllie (2009). Field and Remote Sensing Assessment of Mangrove Forests and Seagrass Beds in the Northwestern Part of the United Arab Emirates. J. Coastal Res. 25(1): 48- 56

ISFR (2011), Forest survey of India, Ministry of environment and forest. India.36-37

Khan, M. Z. and G. Akbar (2012). In the Indus delta it is no more the mighty Indus. River Conservation and Management. 69-78

Khan, Z. (2005). Current status of international important wetlands in Pakistan. J. Basic Appl. Sci.. 2 (1).

Mustafa, D. and L. E. Reid (2012). Negotiating Known Unknowns: "Better" Climate Adaptation Practices from the Indian Ocean Basin. World Wide Fund for Nature – Pakistan.

Rahman, M. M. and M. Ahsan (2001). Salinity constraints and agricultural productivity in coastal saline area of Bangladesh. Soil Resources in Bangladesh: Assessment and Utilization. 1-14

Rey, J.R., R.A. Crossman, and T.T. Kain (1990). Vegetation dynamics in impounded marshes along the Indian River Lagoon. Environmental Management Florida, USA. 14(3): 397-409

Saeed, U., H. Gilani, N. Shahzad, U. Khan, G. Akbar and R. Nawaz 2010. Integrating in situ-aerial and space borne data for monitoring coastal change trends in Keti Bunder – a fifty five years comparison. In ISNET/NARSS seminar on bridging the gap through Satellite technology. Cairo, Egypt.

Saeed, U., H. Gilani, N. Shahzad, K. Gill (2009). Remote sensing based forest change trend analysis – a case study of mangrove forest of Keti Bunder. Indus Delta. In 2nd Pakistan Botanic Garden Conference on Botanic Garden held on Feb 02-04. A vehicle to promote Public/Private/NGOs Partnership, GC University, Lahore, Pakistan.

Saifullah S.M. and F. Rasool (2002). Mangroves of Miani hor lagoon on the north Arabian Sea coast of Pakistan. Pak J. Bot. 34 (3): 303-310

Story, M. and R. G. Congalton, (1986). Accuracy assessment-A user\'s perspective. Photogramm Eng Remote Sensing. *52*(3): 397-399.