Temporal Mapping and Prediction of Coastal Biomass for Keti Bunder.

Muhammad A. Sohl[1*]; Anser Mehmood[1];
Muhammad H. Mazher[1]; Najam[1];
Urooj Saeed[2]; and Hafiz M. Rafique[3]

[1]Department of Space Science, University of the Punjab, Lahore, Pakistan.
[2]Geographical Information System Laboratory, World Wide Fund for Nature, Lahore, Pakistan.
[3]Department of Physics, University of the Punjab, Lahore, Pakistan.

[*]E-mail: imabdullah@gmail.com

ABSTRACT

This study deals with mapping, monitoring, and prediction of the mangrove forest of the Keti Bunder area which lies in the Indus Delta and covers about 14% of the deltaic region. For mapping purposes satellite images of Landsat, Terra, and SPOT were used. After preprocessing of these satellite images, close and open canopy polygons were delineated by onscreen digitization. To further analyze the mangrove change status in detail, the study area was divided in four quarters (i.e., upper left, upper right, lower left and lower right). On the basis of forest cover of 1978, 1989, 1992, 2001, 2006, and 2007 years, the future state of the forest was predicted for both the study area and quarters. Accuracy assessment was performed on 2006 and 2007 data sets by comparing the calculated area (from satellite images) and predicted areas (by using Matlab® software) of close and open forest canopy. The overall accuracy was calculated to be more than 94%.

(Keywords: mangrove, mapping, Indus Delta, GIS, satellite images, Matlab®, prediction)

INTRODUCTION

The Indus River Delta is the 5th largest delta in the world. It covers an area of about 600,000 hectares [1]. The study area which is Keti Bunder, is a part of Indus Delta and covers 14% of the deltaic region [2]. It expands from 67º 16'E to 67º 32'E longitude and from 24º 21'N to 24º 0'N parallels and covers an area of 60,969 ha [3]. As shown in Figure 1, study area contains tidal lagoons, intertidal mudflats and mangrove swamps [1].

Mangrove forests are an integral part of intertidal zone of the coastal environment extending throughout the tropics and subtropics of the world [5]. Mangrove forests are one of the most productive forests on this fragile earth and also a habitat of many vital fish species. They play a major role in land structure as they stabilize and colonize newly deposited sediments.

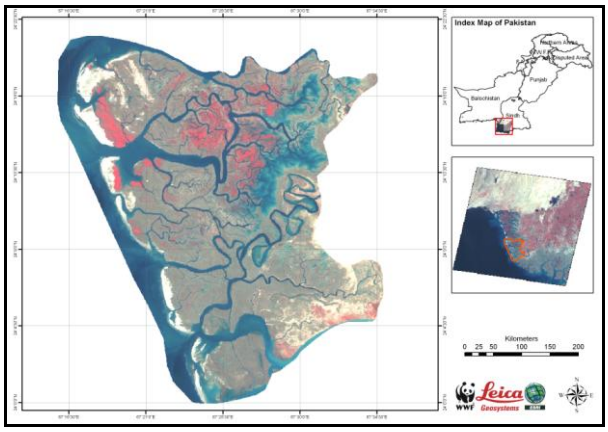

Figure 1: Location Map of Study Area
(Satellite Image taken from Reference [4]).

In general, mangrove ecosystems do not require a great deal of supervision until and unless natural processes are disrupted. Although mangroves are of great importance, barely any consideration has been given to their management in Pakistan [6]. The survival of the mangrove forests of Keti Bunder heavily depends upon perennial freshwater supplies from the Indus River [7].

Mangroves are becoming extinct at an alarming rate and the root causes of such a speedy decline are lack of awareness amongst policy makers, authorities and public at large [6]. The devastation of mangrove communities in Keti Bunder will lead

to destabilization of established sediments, erosion of soil, and reduction in diversity of flora and fauna, as well as the loss of more typical woodland resources [8].

PURPOSE OF STUDY

The main objective of this study is to map the current extent of mangroves forest, perform temporal change analysis of past 30 years and predict the mangrove status for the years 2012 and 2017.

MATERIALS AND METHODS

Four Landsat (1978, 1989, 1992, 2001), one Terra (2006), and one SPOT (2007) satellite images were used to identify mangroves status in Keti Bunder. After applying the initial image processing, all satellite images were digitized.

Two mangrove density classes were developed on the basis of sparseness and closeness of the canopies. Dense and medium mangroves were placed in close canopy. While sparse and very sparse mangroves were categorized as open canopy. For uniformity in visual interpretation, all the satellite images were interpreted and analyzed at a scale of 1:25,000 except Landsat 1978 data which was delineated at a scale of 1:50,000 to accommodate the lower spatial resolution. The density allocations of polygons, as shown in Table 1, were done by using the criteria defined by foresters.

Table 1: Density Allocation Criteria.

Mangroves Density Classes	Percentage Tree Cover
Close Canopy	>60%
Open Canopy	≤60%

Digital photographs and videos of the area were acquired from World Wide Fund for Nature, Pakistan (WWF-P) to get an idea about the forest and land situation. Moreover Ground Control Points (GCPs) of various vegetation classes were also used to increase the accuracy.

For accurate area estimation of mangrove extent, all the delineated polygons were re-projected into Universal Transverse Mercator (UTM) projection with Spheroid and Datum as WGS 84. ESRI ArcGIS® 9.3 was used to calculate the area of delineated polygons. To further analyze the mangrove status in detail, study area was divided into four quarters i.e. upper left, upper right, lower left and lower right. In Matlab® Inverse Square Weighted Distance (ISWD) Interpolation was used for future prediction of mangrove extent

ANALYSIS AND RESULTS

Temporal Change Analysis of Study Area

Analysis, as seen from Table 2, reveals that from 1978 to 1989, there was a positive increase of 11% in mangrove forest cover. Afterwards there has been constant fluctuation in the forest area. One of the surprising results was the decrease of 749 ha of forest cover from 2006 to 2007. During this one year close canopy was increased by 117 ha and open canopy was decreased by 866 ha. This may be due to the fact that 2007 image was acquired during very high tide value i.e. 3.2 m. High water spread over the creeks and mudflats area reduced the details within the satellite image and hence resulted in decreased open canopy area.

Table 2: Mangrove Temporal Change Status

Satellite	Acquisition Date	Close Canopy (ha)	Open Canopy (ha)	Total
Landsat	11-10-1978	3,507	3,298	6,805
Landsat	28-10-1989	3,362	4,209	7,571
Landsat	27-04-1992	3,207	4,354	7,561
Landsat	06-11-2001	2,955	4,877	7,832
Terra	12-02-2006	2,799	5,192	7,991
SPOT	30-04-2007	2,916	4,326	7,242

Prediction of Mangrove Extent in Study Area for Years 2012 And 2017

Statistical values of the mangrove extent from 1978 to 2007 were used to make prediction for years 2012 and 2017. The total predicted area of close and open canopy for year 2012 and 2017 are shown in Table 3 and Figure 2.

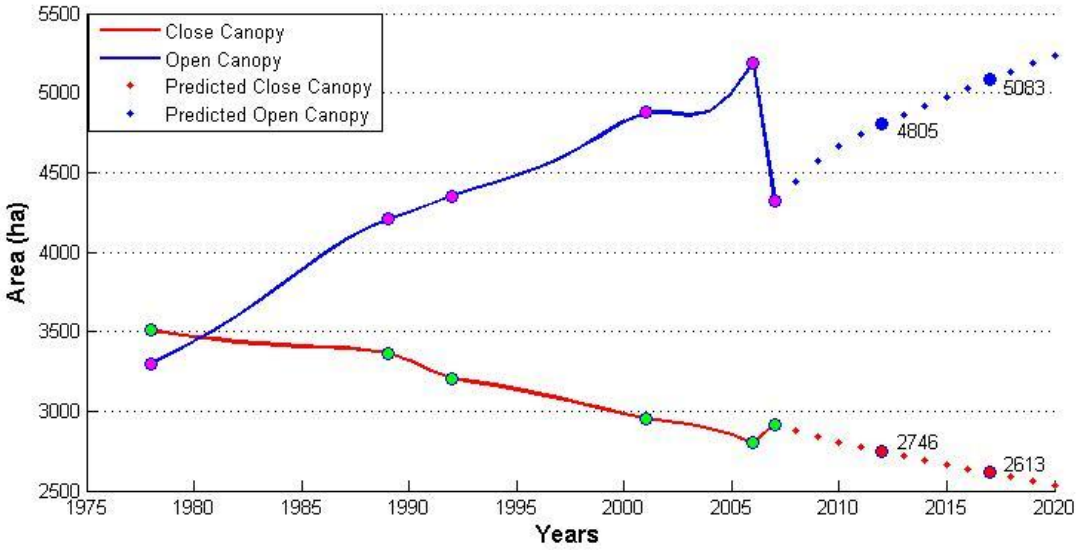

Figure 2: Graphical Representation of Mangrove Extent.

Table 3: Predicted Area of Close and Open Canopy

Year	Close Canopy (ha)	Open Canopy (ha)
2012	2,746	4,805
2017	2,613	5,083

Our predictive graph shows that in next 10 year period there will be decrease in close mangrove canopy and increase in open mangrove canopy. This can be illustrated with a statement that in near future, large close forest canopy patches will be converted into open canopy.

Temporal Change Analysis and Prediction of Mangrove Extent for Each Quarter Area

As for detailed analysis, study area was divided into four parts i.e. upper left quarter, upper right quarter, lower left quarter and lower right quarter. Figure 3 and Table 4 define the forest change in each quarter.

The upper left quarter has maximum contribution of mangroves in the study area. Figure 3 (a) and Table 4 highlight the fact that there will be conversion of dense forest patches into sparse forest if proper attention is not given by the management authorities.

A positive future trend in mangroves extent has been observed in upper right quarter. As Figure 3 (b) and Table 4 highlight that there would be a significant increase in open and close canopies. This increase in both open and close canopies would results in an overall increased in forest extent. This quarter covers large area which is managed by the Sindh Forest Department and proper look after can result in more healthy growth of the forest.

Table 4: Predicted Area of Close and Open Canopy for each quarter

Quarter	Year	Close Canopy (ha)	Open Canopy (ha)
Upper Left	2012	1,588	2,348
	2017	1,431	2,513
Upper Right	2012	1,113	2,237
	2017	1,142	2,346
Lower Left	2012	5	165
	2017	0	163
Lower Right	2012	41	55
	2017	43	61

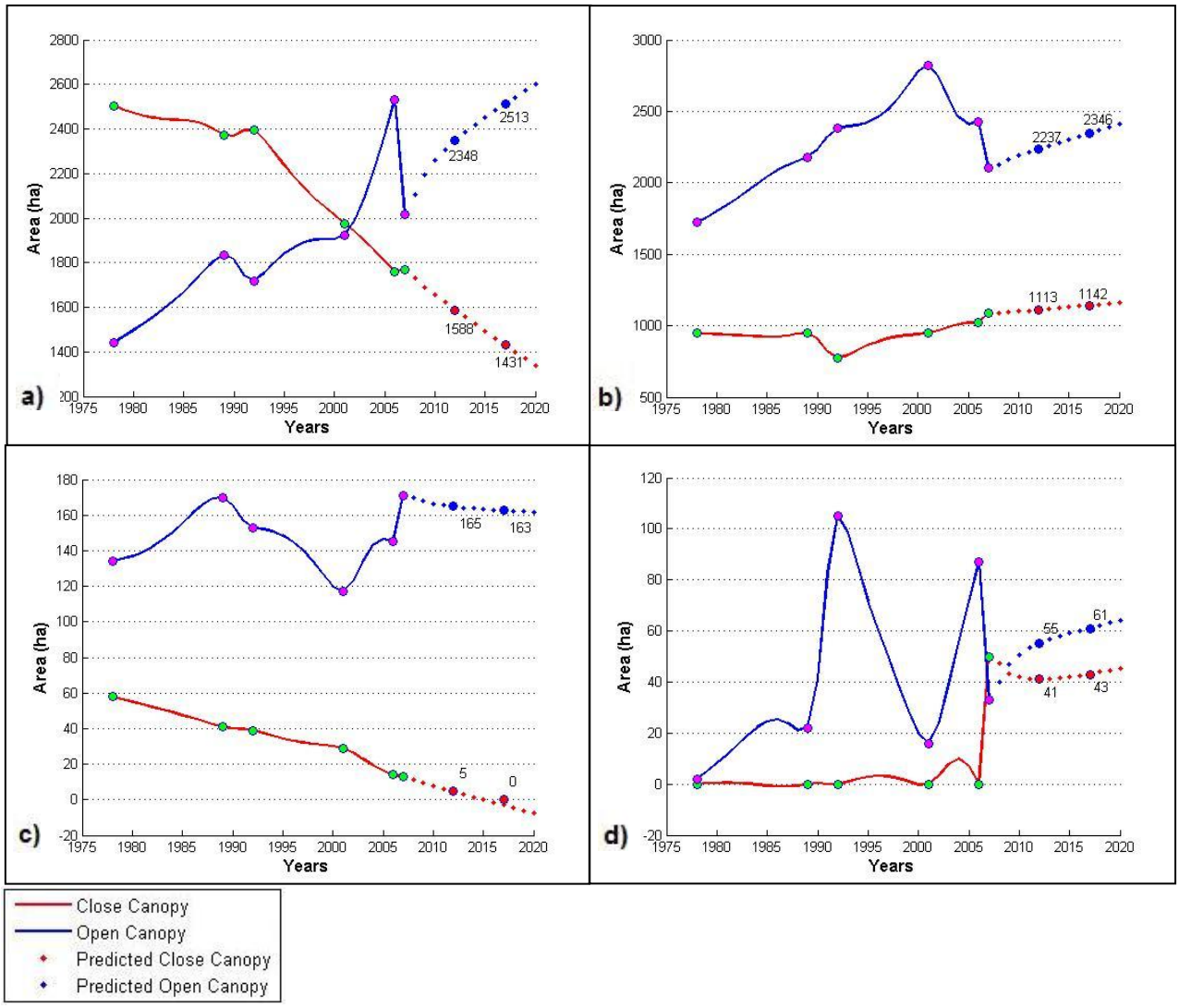

Figure 3: Graphical Representation of Mangrove Extent in Quarters; a) Upper Left, b) Upper Right, c) Lower Left, and d) Lower Right.

Analysis provides an alarming predictive fact about the lower left quarter (i.e., close forest patches in this area will be totally vanished in 2017 if proper attention is not given).

Lower right quarter has minimum forested land as compared to other quarters which appears to be due to more number of communities living in and around this area. Open canopy shows an increasing trend in 2012 and 2017. On the other hand there will be a decreasing trend of close canopy in 2012 and a small increase of close canopy in 2017.

Accuracy Assessment of the Predicted Values

In this study, mangrove extent was calculated by using images of years 1978, 1989, 1992, 2001, 2006 and 2007. To check the accuracy of predicted values for the years 2012 and 2017, Inverse Square Weighted Distance (ISWD) Interpolation was applied on the years 2006 and 2007 in Matlab® Software. This interpolation provided an idea about the level of accuracy of the mangrove extent. Actual forest extent (calculated from satellite imagery) values were incorporated of years 1978, 1989, 1992 and 2001.

Predicted values for close and open canopy of year 2006 were 2,818 ha and 5,194 ha, respectively. These values were compared with actual close and open mangrove extent of year 2006 (i.e., 2,799 ha and 5,192 ha, respectively). The comparison between actual area and predicted areas showed that the prediction was 99% accurate for both close canopy and open canopy.

Similarly, the predicted values for close and open canopy of year 2007 are 2,792 ha and 5259 ha respectively. These values were compared with actual close and open mangrove extent of year 2007 i.e. 2916 ha and 4326 ha respectively. This comparison showed that the prediction was 96 % accurate for close canopy and 82% for the open canopy.

CONCLUSION AND RECOMMENDATIONS

This study results, from 1978 to 1989, reveal an increasing trend (11%) of mangroves. Afterwards there was constant fluctuation in the mangrove extent. But from 2006 to 2007, an unexpected decrease of mangrove forest area was observed. The major decrease occurred in open canopy class which is due to the 2007 satellite image limitation of high tide value.

Our predictive graphs disclose that in the future 10 year period there will be a decrease in close mangrove canopy and an increase in open mangrove canopy. This can be summarized with a statement that in near future, large close forest canopy patches will be converted into open canopy. Though illegal cutting of mangroves and grazing are also contributing to the depleting mangrove cover, the reduced flow of freshwater is the major reason behind their destruction.

The predicted values are based on the previous data collected from space technology. In case of any natural disaster or any management interventions, these values can vary. Satellites data of same spatial resolution with equal time interval was not available. Moreover precipitation and temperature data for the image acquisition dates were also not available. This restricted to study the temporal variation of algal mats in correlation with climatic data.

It is recommended to map the mangrove forest at species level by using hyper-spectral data. This will help to study the mangrove species at micro-level details. It is also recommended to develop a predictive model by using the satellite data of same spatial resolution (if possible) data. Aerial photographs and Keyhole/KFA data can also be used to do fifty years change analysis. This would help to study new creek formation process; shift in agriculture land etc. The developed model will predict the mangrove area in detail with greater level of accurately. It is also recommended to use the predictive results for the future planning and management of mangroves. The results can be significantly used to divert the community awareness programs and plantation activities to the pressure areas.

REFERENCES

1. Khan, M.Z. 2005. “Wetlands of Sindh with Reference to Ramsar Sites in 2005”. *J. Nat. Hist. Wildl*. 4(2):141-145.

2. Qureshi, T.M. 2007. “Working Plan of Mangrove Forests (Coastal Forests) from 1985-86 to 2004-05.” Sindh Forest Department, Government of Sindh.

3. WWF – Pakistan. 2004. “Study on Knowledge, Attitude & Practices of Fisherfolk Communities about Fisheries and Mangrove Resources – Keti Bunder Report.” *Tackling Poverty in Pakistan’s Coastal Communities through the Sustainable Coastal Livelihood Project*.

4. WWF – Pakistan, Lahore Office, GIS Lab. 2008.

5. Giri, C.P. and Delsol, J.P. “Mangrove Forest cover mapping in Phangnga Bay, Thailand; Using SPOT, HRV, and JERS -1 Data in Conjunction with GIS.” Presented at International Seminar for Remote Sensing on Coastal Zone and Coral Reef Applications at Asian Institute of Technology, Bangkok; 1st November 1993 - 25th October 1993.

6. Saifullah, S.M. 1997. “Management of the Indus Delta Mangroves”. In: B.U. Haq et al. (eds.). Coastal Zone Management Imperative for Maritime Developing Nations. Kluwer Academic Publishers: Amsterdam, Netherlands. 333-346.

7. Qureshi, T.M. and Khan, D. 1988. “Experimental Plantation for Asia and the Pacific (RAS/86/002)”. Sindh Forest Department, Government of Sindh: Karach,i Pakistan. *Rehabilitation of Mangrove Forest in Pakistan*. First Report UNDP/UNESCO Reg. Proj. for Res. and Training Prog. On Mangrove.

8. Mehdi, F.S. and Saifullah, S.M. 1992. “Occurrence of Fungi on Mangrove of Karachi. Status of Plant Pathology in Pakistan”. 177-82.

ABOUT THE AUTHORS

Mr. Muhammad Abdullah Sohl, has a B.Sc. (Hons) degree in Space Science from University of the Punjab, Pakistan. The B.Sc. (hons) degree is equivalent to the ordinary Masters degree (M.Sc.) per the Pakistan Higher Education Commission (HEC) and represents 16 years of education. His fields of interest are photogrammetry, remote sensing, and geoinformatics. Currently he is doing Masters coursework and research in photogrammetry and geoinformatics from Stuttgart University of Applied Sciences, Germany.

Mr. Anser Mehmood, has a B.Sc. (Hons) degree in Space Science from University of the Punjab, Pakistan. The B.Sc. (Hons) degree is equivalent to the ordinary Masters degree (M.Sc.) per the Pakistan Higher Education Commission (HEC) and represents 16 years of education. His fields of interest are remote sensing and geomatics. Currently he is doing Masters course work and research in photogrammetry and geoinformatics from Stuttgart University of Applied Sciences, Germany.

Mr. Muhammad Haris Mazher, has a B.Sc. (Hons) degree in Space Science from University of the Punjab, Pakistan. The B.Sc. (Hons) degree is equivalent to the ordinary Masters degree (M.Sc.) per the Pakistan Higher Education Commission (HEC) and represents 16 years of education. His fields of interest are remote sensing and Geographical Information Systems (GIS). Currently he is doing Masters course work and research in GIS from National University of Sciences and Technology (NUST), Pakistan.

Mr. Najam, has a B.Sc. (Hons) degree in Space Science from University of the Punjab, Pakistan. The B.Sc. (hons) degree is equivalent to the ordinary Masters degree (M.Sc.) per the Pakistan Higher Education Commission (HEC) and represents 16 years of education. His fields of interest are remote sensing and Geographical Information Systems (GIS). He currently works for Telenor, a Telecom Company in Lahore, Pakistan.

Ms. Urooj Saeed, has an M.Sc. degree in Space Science from University of the Punjab, Pakistan which means that she also has completed 16 years of education according to Pakistan Higher Education Comission (HEC). Her fields of interest are remote sensing and Geographical Information System (GIS). Currently she is employed by WWF-Pakistan.

Mr. Hafiz Muhammad Rafique, is an Assistant Professor at the Department of Physics, University of the Punjab, Lahore, Pakistan and is currently doing his Ph.D. studies in experimental physics (surface science) at the University of Manchester, UK. His fields of interest are surface science, satellite remote sensing, and mathematical physics.

SUGGESTED CITATION

Sohl, M.A., A. Mehmood, M.H. Mazher, Najam, U. Saeed, and H.M. Rafique. 2010. “Temporal Mapping and Prediction of Coastal Biomass for Keti Bunder”. *Pacific Journal of Science and Technology*. 11(1):586-591.

Pacific Journal of Science and Technology