BIOLOGIA (PAKISTAN)
December, 2019, 65 (II), Online

PKISSN 0006 – 3096 (Print)
ISSN 2313 – 206X (On-Line)

Monitoring mangroves plantation sites through integration of repeat terrestrial photographs and spaceborne imagery

UROOJ SAEED[1], SAJID RASHID AHMAD[2], HAMMAD GILANI[3]*, RAB NAWAZ[4], NAEEM SHAHZAD[5], IRFAN ASHRAF[6] & WAQAS AHMED QAZI[3]

[1]Urban Sector Planning and Management Services Unit (Pvt.) Ltd., Lahore, Pakistan
[2]Institute of Geology, University of the Punjab, Lahore, Pakistan
[3]Institute of Space Technology, Department of Space Science, Islamabad, Pakistan
[4]WWF –Pakistan Islamabad Office, Islamabad, Pakistan
[5]The Hong Kong Polytechnic University, Hong Kong
[6]Lahore Development Authority, Lahore 54770 Pakistan

ARTICLE INFORMAION

Received: 23-04-2019
Received in revised form: 07-07-2019
Accepted: 22-08-2019

***Corresponding Author:**

Urooj Saeed:
saeed.urooj@gmail.com

Original Research Article

ABSTRACT

This study shows the outcome of realistic steps towards the coastal habitat conservation through mangroves plantation in Keti Bunder (Indus delta), Thatta district, Sindh province, Pakistan. From the visual interpretation of repeat terrestrial photographs and Google Earth high-resolution satellite images, healthy growth of mangroves plantation was observed on previously barren mudflats. Even the canopy of sparse mangroves trees became enriched in various areas. In a small area of 372 km^2 around the plantation sites, the study quantified 0.44 km^2/year gross rate of afforestation using Normalized Difference Vegetation Index (NDVI) values derived from 30 m spatial resolution Landsat satellite images (April 2010 and May 2015). Through coastal conservation practices, plantation campaigns provide livelihood support to local communities; and hence the communities with NGOs and Government departments provided local support in plantation and protection of mangroves saplings. On the brighter side, in recent years Pakistan has taken enormous steps towards tree plantation under national (Green Pakistan Programme) and provincial (Billion Tree Tsunami in Khyber Pakhtunkhwa) initiatives. Through this study, we have proposed a cost-effective and convenient tree plantation-monitoring mechanism, which can be replicated over any plantation sites at diverse landscapes.

Keywords: Indus Delta, Mangroves plantation, Repeat terrestrial photographs, Coastal conservation and landsat- NDVI

INTRODUCTION

Within the coastal ecosystem, mangroves, tidal salt marshes, and sea grasses are fundamental components that exist in the tropical and subtropical areas of the world between about 30° N and 30° S range (Giri *et al.* 2011) The coastal ecosystem brings exceptional importance in the context of mitigation and adaptation to climate change. This unique ecosystem, sequestering and storing significant amounts of carbon from the atmosphere and oceans, is called “coastal blue carbon” (Mcleod *et al.* 2011) Regardless of benefits and importance of coastal environment, it is under continuous risk due to human pressure, climatic fluctuations and extreme events (e.g., cyclones, floods and so forth). According to Sifleet *et al.* 2011 approximately 3,400 to 9,800 km^2 coastal ecosystem is being destroyed annually. Alarmingly, the Intergovernmental Panel on Climate Change (IPCC) has predicted that in the subsequent 100 years, 30-40% coastal environment and an in particular 100% mangroves wooded areas could entirely vanish if the prevailing rate of loss continues (IPCC 2014; McCarthy 2001).

Coastal erosion is a natural phenomenon. Erosion risk is a combination of the occurrence of hazards (frequency, intensity), the exposure and vulnerability of people. Coastal lands are subject to multiple natural disasters like wave damage,

Author’s Contribution: U.S. Did image acquisition, field data collection, FPP and its related comparisons; **S.R.** Did satellite image processing, fixed point photography and contribution in write up; **H. G.** Contributed in write up and data analytics; **R.N.** Did field survey support for data collection, paper conceptualization; **N.S.** Did satellite image processing and supervised classification; **I.A.** Made maps & graphs, did field data compilation and analysis; **W.Q.** Accuracy assessment and contribution in write up tsunamis, storms, and flooding, and over the long-term, rising sea levels. Such hazards threaten lives, livelihoods, property, health and economic development. The presence of mangroves along coastal lines protects shorelines, minimizing the risk of natural hazards. Globally mangroves are decreasing drastically (Sifleet *et al.* 2011) but around the world, numerous mangroves restoration efforts are being implemented (e.g., in Sri Lanka, India, Indonesia, etc.). Many restored mangroves forests resemble forest plantation rather than truly integrated ecosystems, but still, the plantation is a very first step to attain an integrated coastal ecosystems for long-term climate change mitigation (Ellison 2000). In Southeast Asia, almost all countries (Dahdouh-Guebas *et al.* 2000;Iftekhar *et al.* 2004; Kathiresan *et al.* 2013) are planting mangroves to enhance forest cover and protect coastal ecosystem.

The coastline of Pakistan is 1,050 km long and 40–50 km wide, shared by the provinces of Sindh (350 km) and Balochistan (800 km), and lies between 24° to 25° N latitude and 61° to 68° E longitude (Figure 1). The international border of Pakistan oceanfront touches India in east and Iran on the western side. In 1958, mangroves forests of Pakistan were declared “protected forest” under the Pakistan Forest Act 1927 and alongside water channels as ‘wildlife sanctuaries’ in 1977 under the Sind Wildlife Safety Ordinance of 1972 (Qureshi 1993)

In a study conducted by Giri *et al.*, (2015) over the Indus Delta from 1973 to 2010 using Landsat satellite data, in the mangrove cover, a total net increase of 1530 ha (1.5%) was observed. with cumulative forest gain and loss of 45,126 ha and 43,596 ha respectively. Based on ALOS-AVNIR-2, 10 m spatial resolution satellite images of 2008 and 2009, (Abbas *et al.* 2013) reported 981.28 km^2 area covered by the mangroves forest in Pakistan; these mangrove forest areas are distributed in five distinct geographic pockets: Indus delta, Sandspit, Sonmiani, Kalmat Khor, and Jiwani) (Figure 1). A study conducted by SUPARCO over Keti Bandar, Gahbar Creek (near the mouth of Indus River), Shah Bandar in 2005 by using SPOT 2004-2005 data, the mangroves area was 557,60 ha. The International Union for Conservation of Nature (IUCN) and SUPARCO jointly worked on the four sites (Indus Delta, Miani Hor, Kalmat Khor and Jiwani) by using SPOT data and estimated 86,728 ha mangroves in 2003. In one of the study, by Space and Upper Atmosphere Research Commission (SUPARCO), Pakistan the mangroves were 260,000 ha in 1978 (SUPARCO, 1983). The World Wide Fund for Nature (WWF), Pakistan carried out study in 2005 on Keti Bandar, Sand spit, Sonmiani and Kalmat khor by using data of Landsat and ASTER and evaluated the net change in area of Indus, Kalmat and Sonmiani from 1990-2000. As per findings, the overall extent of deltaic vegetation remained almost static to 73,890 ha and 73,001 ha for 1992 and 2000 respectively, while its change analysis revealed an overall shift of the vegetation pattern from the southern part to the northern side of the delta. In 1992, under the Forest Sector Master Plan (FSMP), the mangrove forest extent was determined from Landsat Thematic Mapper (TM) images of 1988; and was estimated to be 155,369 ha with 55,697 ha categorized as dense and 99,672 ha categorized as medium mangrove forest.

The human population in and around mangroves forests of Pakistan is approximately 1.2 million, and almost 90% of the population derive their primary income from fishing and its associated activities (Ahmad *et al.*, 2005). Shahzad *et al.* (2018) observed that due to increases in population and transformation of livelihood pattern ecological resources were despoiled with the passage of time. According to Long-Term Climate Risk Index (CRI), Pakistan ranks eighth among countries affected by climate change from 1995 to 2014 (Kreft *et al.*, 2014). In 2010, Pakistan faced destructive floods, that afflicted approximately 20 million people in 78 districts, almost 1,800 people died, and about 2 million homes were damaged or destroyed (Warraich *et al.* 2011; Webster *et al.* 2011). However, Pakistan is attempting to mitigate future natural disasters such as floods through the implementation of conservation activities. In recent years, Pakistan has taken gigantic steps toward conservation of coastal ecosystems through mangroves plantation, community awareness programs, and eco-tourism activities. In the coastal areas, from 2006 onwards, Pakistan has been carrying out annual mangroves plantation campaigns. As an acknowledgment, in 2009, Pakistan received a certificate from Guinness Book of World Records on planting 541,176 mangroves saplings in a single day in Keti Bunder (Indus delta), Thatta district, Sindh province (IUCN, 2009). Indeed, even in later years, mangroves plantation activities continued with more determination to restore the degraded and clear mudflats. These Government initiatives of rehabilitation activities have been actively supported by national and international Non-Governmental Organizations (NGOs) and local Community-Based Organizations (CBOs) (Mukhtar & Hannan, 2011). For long-term sustainability and better management, the monitoring of plantation sites is essential.

In the Indus delta, the survival of mangroves forest is mainly associated with perennial freshwater supplies from the Indus river which irrigates approximately 180,000 km^2 of agriculture area (Harrison *et al.* 1994; Spalding 2010). In the Indus delta, to protect and improve the coastal ecosystem of Pakistan, mangroves plantation campaigns are being conducted at almost 60 places since more than a decade. These plantation campaigns provide livelihood support to local communities as they provide their services in the cultivation of mangroves saplings. In the most of the cases, they have used the earned money in the installation of solar panels for electricity generation, biogas plants to run smoke-free kitchens, and also to attain fishing equipment.

Over the years, the utilization of satellite remote sensing data has become prevalent among researchers for mapping, monitoring, and understanding the changes on Earth features. The consistent time series freely available remote sensing data (e.g., MODIS, Landsat, Sentinel, etc.) provide frequent and accurate measurements, monitoring and projections (Vogelmann *et al.*, 2012; Wulder *et al.*, 2008; Xin *et al.*, 2013). Ground information (field surveys, photographs, etc.) are essential for the accuracy and evaluation of any product derived from satellite images (Shao & Wu, 2008).

Since the late 19th century, repeat photography was used to study landscape changes (Hoffmann MT & Cowling, 1990; Vale, 1987; Veblen & Lorenz, 1991). Repeat photography represents long-term monitoring that is beneficial to researchers and land managers (Hendrick & Copenheaver, 2009; Nüsser, 2001). Integration of repeat photographs with satellite images are considered as an appropriate method for landscape change analysis transparently (Niraula *et al.*, 2013; Nüsser, 2000).

This paper describes a case study about monitoring coastal ecosystem, particularly concentrating on recently planted mangroves saplings on mudflats of Keti Bunder (Indus delta) in Pakistan. Over the period of 2010 to 2015, an openly accessible high and medium satellite images along with repeat photographs were utilized to assess and monitor plantation growth. We adopted a straightforward and easy to replicable methodology. Visual image interpretation of high-resolution satellite images (0.5 m spatial resolution) and repeat terrestrial photographs enabled to monitor changes at site level while thematic mapping from Landsat satellite images (30 m spatial resolution) permitted us to quantify changes in the study area.

MATERIALS AND METHODS

Study site

This study was conducted in Keti Bunder (Indus Delta), Thatta district, Sindh province, Pakistan (Figure 1). Keti Bandar is approximately 200 km from Karachi city. Our study area 372 km^2 lies within North Keti Bunder, a wildlife sanctuary. This study highlights the results from five creeks, i.e., Babar, Bhoori, Hajamro, Humbas and Turshan, where native to this area mangroves species i.e., *Avicennia marina* (Common name: grey mangroves or white mangroves) and *Rhizophora mucronata* (Common name: loop-root or red mangroves) were planted. From 2006 onwards, all five creeks were under continuous mangroves plantation (Table I). Approximately 97% population of Keti Bunder town is uneducated, and the majority of them are fishers. Mahar & Zaighiam (2019) briefly discussed that in Indus Delta, agriculture is prominent economic activity, and moreover the area mostly covered by the mangrove forest is coastal and marshy area. They also observed the economic activities in delta by field survey which showed that the poverty was at extreme low level.

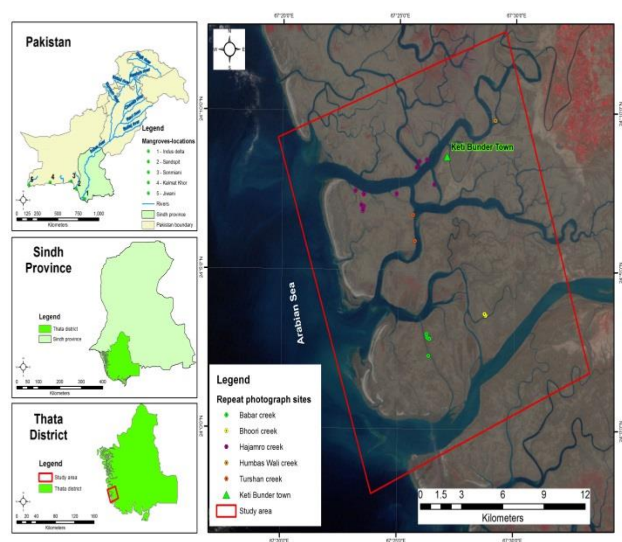

Fig. 1: Study area map

Data used

To monitor the status of planted mangroves, in this study, we have utilized two remotely acquired datasets 1). Repeat photographs 2). High and medium spatial resolution satellite images.

Altogether 32 pairs of digital photographs were used to assess the transformation of barren mudflats to mangroves. For this paper, all pictures were taken in May 2010 and May 2015. In the field, DSLR camera with built-in Global Positioning System (GPS) receiver was used to capture repeat terrestrial photographs. Repeat photography vantage points were accessed through the boat with the help of the local community. In May 2010 and 2015 and each photograph was captured at same camera focal length, height and bearing along geographical latitude, longitude, altitude and date/time information (Table l).

The launch of Keyhole Earth Viewer in 2001, later renamed as Google Earth in 2005, opened a new avenue for the layperson to visualize earth features through optical high-resolution satellite images (<5 m spatial resolution). In this article, we have utilized ~ 0.5 m high-resolution satellite images of January 2011 and November 2016 from Google Earth Pro at the same scale and eye altitude. Based on the GPS coordinates from the fixed-point repeat photographs (Table 1), cloud free high-resolution satellite images were acquired in photo image format (*.JPG*). In this paper, only selected repeat photographs have been presented after synchronization with Google Earth high-resolution temporal images.

Landsat represents the world's longest continuously acquired collection of space-based moderate spatial resolution land remote sensing data. Landsat 30 m medium resolution images were used to quantify the spread of mangroves over the plantation sites. We have downloaded freely available already ortho-rectified Landsat-5 (29 April 2010) and Landsat-8 (29 May 2015) satellite images from the United States Geological Survey (USGS) Global Visualization Viewer (GloVis) web portal. Our study area falls under the Landsat path 152 and row 043 of Worldwide Reference System (WRS-2) in descending order. In the coastal regions, the variation in tide heights, temperature, and humidity are leading factors in changing the strength and extent of mangroves, mud flats, algal bloom, saltbushes, and sea grasses (Abbas et al. 2013). In this study, all the terrestrial photographs were taken, and satellite images were downloaded at the time of low sea tide heights and moderate temperature and humidity. Figure 2 shows the workflow chart diagram with detailed annotation of methodology.

Workflow Chart

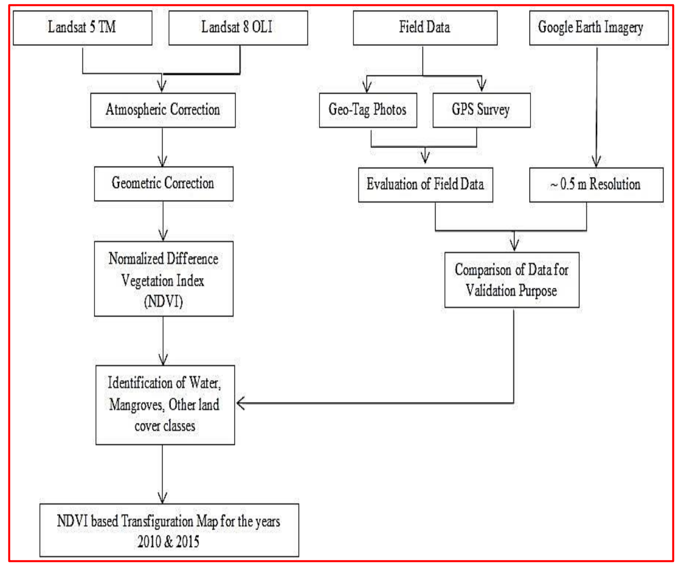

Fig. 2: Workflow chart diagram

Repeat photographs and high-resolution satellite images interpretation

A visual image interpretation technique was adopted to investigate the differences and similarities between the baseline (May 2010) and recent (May 2015) terrestrial repeat photographs. Through photointerpretation, in Google Earth on high-resolution satellite imagery (January 2011 and November 2016), the overlay of geographic coordinates of terrestrial repeat photographs helped and supported us to identify exact locations and changes. In Google Earth, 2015 high-resolution satellite images were absent, so we relied on 2016 images. We can assume, one-year deviation in satellite imagery may provide us slightly more flourishing planted mangroves than the previous year (i.e., 2015). Side by side, visual photo-interpretation comparison of terrestrial paragraphs and high-resolution satellite images enabled us to identify and present the changes in both datasets.

Texture is one of the important elements of visual image interpretation to distinguish features in the satellite images (Antrop & Van Eetvelde 2000). In this study, through texture analysis, in the high-resolution satellite images, we were able to examine the smooth surface of mudflat areas converted into a rough and irregular texture of tree cover.

Landsat satellite image processing

NDVI was used to identify the complex and dense vegetation pattern with precarious separation of healthy and stress vegetation excessively because the results of NDVI is totally based upon the red and near infrared bands of multispectral satellite data (Szilárd et al. 2016). Furthermore it was an emblem that could help us to analyze the area for the vegetation identification purpose (Mazhar et al. 2018). For this study, already ortho-rectified Landsat images were utilised. All the spectral bands of Landsat-5 (29 April 2010) and Landsat-8 (29 May 2015) satellite imagery were well co-registered geometrically. A reduction in-between-scenes variability was accomplished through normalization for solar irradiance with a two-steps process. First, we converted all pixels Digital Numbers (DNs) to radiance values using the bias and gain values, which were Landsat scene-specific. Second, we converted radiance data to the Top of Atmosphere (ToA) reflectance (Chander et al. 2009). Radiometric calibration of satellite data is fundamental for image-processing applications and quantitative scientific studies (Wukelic et al. 1989). The layer stacking was performed to construct 30 m spatial resolution multispectral images of 2010 and 2015.

We have calculated NDVI using the Red and Near InfraRed (NIR) spectral bands (see equation-1) of 2010 and 2015 Landsat images. (Tucker 1979).

$$NDVI = \frac{NIR-RED}{NIR+RED} \qquad \text{(Equation 1)}$$

Emch and Peterson (2006) also used the NDVI technique to perceive the temporal disparity of mangroves in Bangladesh and Tong et al. (2004) in Vietnam. Furthermore in the coastal areas they have meritoriously mapped the mangroves. The NDVI measures the chlorophyll content (via absorption of visible red radiation) and in spongy mesophyll (via reflected NIR radiation) within the vegetation canopy (Gu et al. 2007). The NDVI value for the 30 m pixel of Landsat results in a number that ranges from minus one (-1) to plus one (+1). Less than zero means no vegetation and close to plus one indicates the highest possible density of green leaves.

In the study area, the positive values of NDVI ranging from 0.14 to 0.74 reflected greater vigor and photosynthetic capacity (or greenness) of mangroves trees canopy. Based on the positive, NDVI values, we have mapped and quantified a single vegetation class “Mangroves”, while only for mapping purpose, negative values of NDVI thematic layers were segregated into two classes “Waterbody” and “Other land cover classes”. Our primary objective was to quantify the mangroves plantation within 372 km^2 study area, so we have combined agriculture, settlements, roads, algal mat, salt bushes, and grasses, etc. into one class, i.e., “Other land cover classes”. We have prepared, a map, which shows the land cover classes (i.e., Mangroves, Waterbody and Other land cover classes) of 2010 and 2015.

We have taken a 372 km^2 box (Figure 1), a small area around mangroves plantation sites, to assess an annual rate of the mangroves changes at 2010 and 2015 time periods using equation 2 (Puyravaud 2003).

$$r = \frac{1}{t2-t1}\ln\left(\frac{a2}{a1}\right) \qquad \text{(Equation 2)}$$

Where r is the annual rate of change, a1 and a2 area of mangroves calculated at time t1 (2010) and t2 (2015), respectively.

RESULTS

In the coastal areas, visual image interpretation and quantification of mangroves extent are typically associated with sea waves, currents, and tide heights. In this study, through fixed-point terrestrial repeat photographs and high-resolution satellite images, we were able to examine and show ongoing coastal conservation practices in the study area.

Repeat photographs and high-resolution satellite images interpretation

From the side by side visual image interpretation of high-resolution satellite images from January 2011 and November 2016, the barren or sparsely populated mangroves mudflat have been converted into relatively dense mangroves patches. Through selected repeat photographs, we observed that the canopy of sparse mangroves trees became thicker and denser. From the high-resolution satellite imagery, we also identified and recognized the tonal variation of mudflats transformed from beige to green (the color of trees). From 2010 to 2016 high-resolution satellite imagery, the smooth surface of the planted mangroves trees canopy converted into the rough texture. Although, the high resolution satellite imagery stipulate the difference of two scenarios because there two times slaps shown in figure 3, 4 and 5 respectively to justify the results of NDVI (Figure 6). Side by side connotation shows the same result in different ways which may not interpose the accuracy of dataset.

Along the Hajamro Creek (Figure 3), we have observed extensive and intensive improvements in the planted mangroves. The Hajamro creek receives fresh water from the upstream Indus River. In 2010 terrestrial photo and high-resolution satellite image, we have observed very spare and scattered distribution of planted mangroves, in 2015 which are transformed into mature trees; even we cannot look into the mudflat.

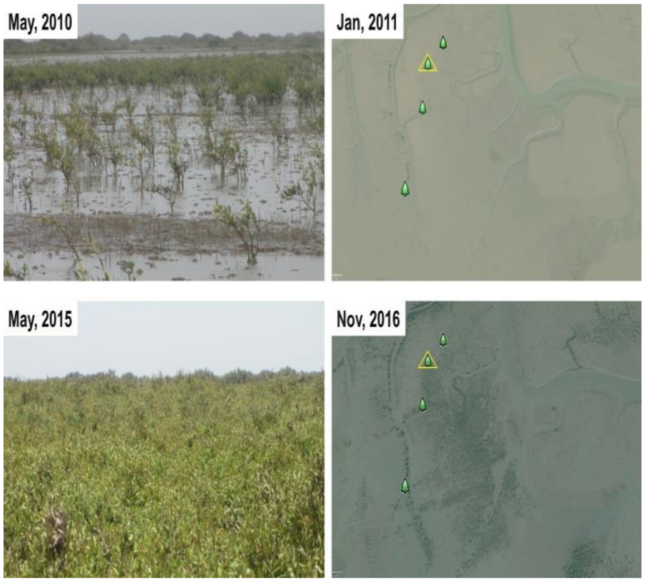

Fig. 3: Extensive improvement in mangroves plantation, Hajamro Creek (Yellow rectangle shows the exact location of repeat photographs i.e., 67.39126534° E and 24.11620779° N)

In the Babar Creek (Figure 4), pairs of repeat photographs and satellite images demonstrate the overall improvement around the plantation sites. We noticed the extent of planted mangroves is more than tree density enhancements. In the high-resolution satellite images, we can identify human settlements at the edge of the creek. The presence of human settlements around the plantations imposed a positive influence, as feed by human and animals waste, serves as fertilizer for small mangroves saplings.

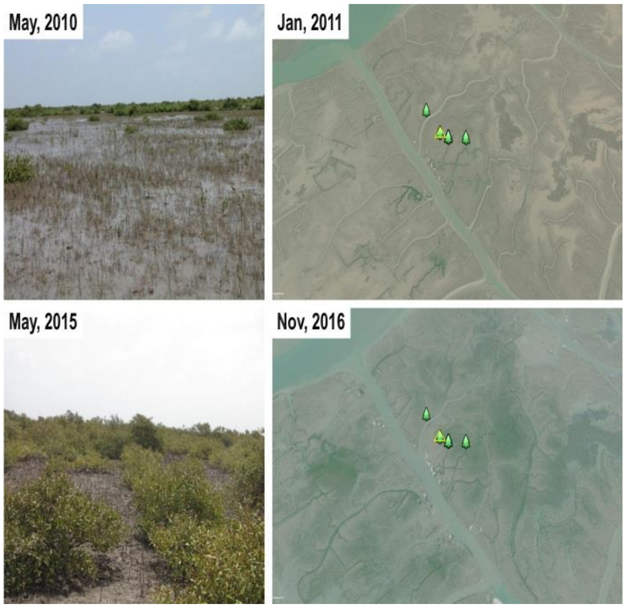

Fig. 4: Moderate growth in mangroves plantation, Babar Creek (Yellow rectangle shows the exact location of repeat photographs i.e., 67.43770159° E and 24.04825453° N)

In Turshan Creek (Figure 5), during images interpretation, we noticed overall positivity, but planted mangroves were growing at a slower pace. In the high-resolution satellite images, in main Turshan Creek around the plantation site, we could see dried smaller creeks. Hence, we accepted that this area lack fresh water i.e. the lifeline for the flourishment and growth of mangroves.

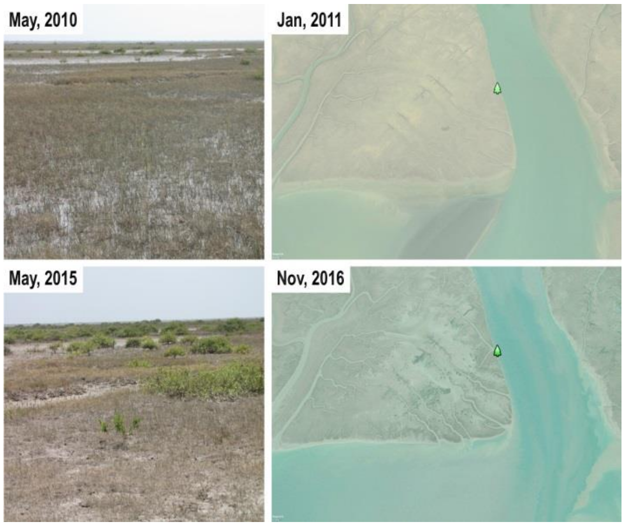

Fig. 5: Slight improvement in mangroves plantation, Turshan Creek (Yellow rectangle shows the exact location of repeat photographs i.e., 67.42862759° E and 24.09889648° N)

Quantification of mangroves plantation using Landsat images

Through Landsat based NDVI, inside 372 km^2 box visually an overall improvement can be observed in just 5 years (2010-2015). The central region of the study area, shows impressive growth of planted mangroves, in 2010 NDVI maps over the vicinity of plantation sites we can see tiny patches of the mangroves flourished in 2015 (Figure 6). Using equation-1, 0.44 km^2/year annual gross rate of afforestation was estimated between 2010 and 2015. NDVI time series trend from the year 2010 to 2015 were also observed in this research (Figure 7).

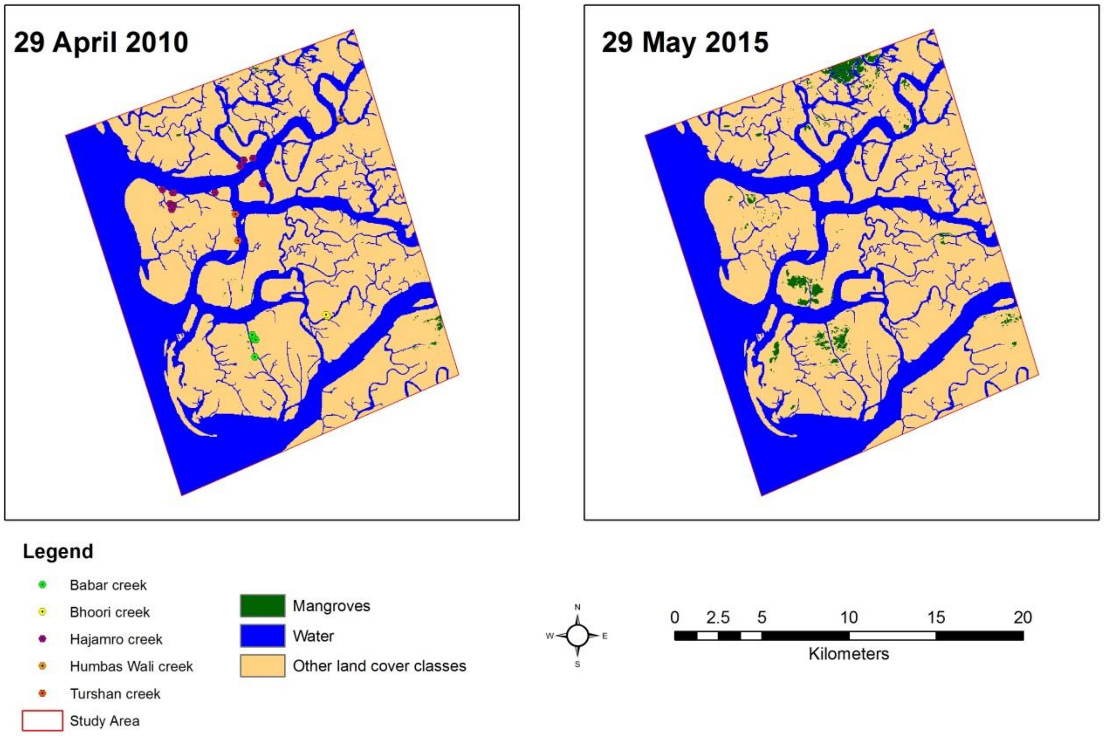

Fig. 6: Mangroves extent based on Landsat (30 m) NDVI between 2010 and 2015

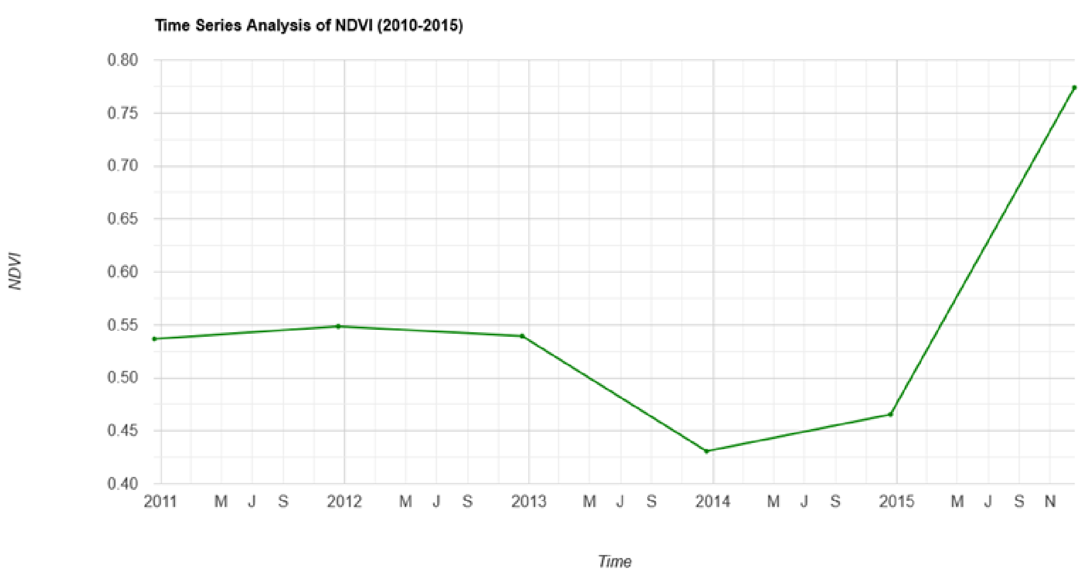

Fig. 7: Time series analysis of mangroves based on Landsat (30 m) NDVI between 2010 and 2015

DISCUSSION

In this study, based on visual and quantitative evidence over the plantation sites, we can notice remarkable progress towards conservation of coastal ecosystem of Pakistan. Based on 30 m spatial resolution Landsat satellite imagery, we have estimated 0.44 km^2/year growth rate of mangroves plantation between 2010 and 2015. Over the entire Indus delta (approximately 6,000 km^2), Giri et al. (2015) conducted a study using 60 m and 30 m spatial resolutions of Landsat images from 1973 to 2010, respectively. They have reported a total net increase of 15.3 km^2 (1.5%) with 0.41 km^2/year growth rate, which very much aligns with our results. If this growth rate remains consistent, then we can hope for a better mangroves coverage that can support the long-term sustainability of coastal ecosystem of Pakistan. Guha (2016) used the NDVI for discrimination of mangrove from the other vegetation and the overall accuracy of his research was 86.25 % in the year 2010. Main factor which differentiate the mangrove in the comparison of any other vegetation is near infrared band's reflectance. NIR reflectance is much increaser in the mangrove vegetation so it can be easily identified. The tone and texture of mangrove are totally different from any other type of plantation furthermore; the aspects and view-shade also play the important role for mangrove identification because tree has shadow due to the vertical height with respect to agriculture. According to Chen et al. (2013) usually mangrove was found in the areas where less than 30 meters elevation exists.

In the study area, the positive trend of mangroves is linked with the freshwater flux from Indus river (Amjad et al. 2007). During the field surveys and discussions with the local community, we identified that freshwater flooding of 2010 has created a very positive impact on the mangroves ecosystem, has a greener impact overall. During the fieldwork, we observed that the plantation sites closer to human settlements have grown faster, as feed by human and animals waste serves as fertilizer for small mangroves saplings. We have noticed, some of the plantation sites did not survive or did not progress as expected due to the plantation of mangroves species (i.e., *Rhizophora mucronata*), that is unsuitable for local conditions. The shoreline/coastline erosion also affected the planted sites. Based on the field experience, it is one of our recommendations, that it is better to do a thorough feasibility study before any plantation campaigns. The mangroves plantation feasibility study should be based on the availability of fresh and saline water, identification of suitable soil texture and type, and endemic plant species over specific mudflat areas.

On the bright side, in recent years Pakistan has taken immense steps towards trees plantation under national (Green Pakistan Programme) and provincial (Billion Tree Tsunami in Khyber Pakhtunkhwa province) initiatives. Through this paper, we have proposed a cost-effective and convenient monitoring scheme, which can be replicated over any plantation site.

At the time of higher tide heights, shorter mangroves trees disappear, so sometimes we had difficulty to move in the creeks to attain terrestrial repeat photographs. With the advancement of remote sensing data acquisition platforms, for example, the Unmanned Aerial Vehicle (UAV), terrestrial repeat photographs can be supported or even replaced by the acquisition of very high-resolution images with better accuracy and spatial coverage (Chaves et al. 2015). Although, in our study area, a number of other land cover classes exist, e.g., agriculture, settlements, roads, algal mat, salt bushes, and grasses, etc. but as our study objective was to monitor and quantify only mangroves plantation, so we have neglected other land cover classes. At the national to regional scales, besides mapping coastal ecosystem extent, with the integration of ground data, remote sensing can be used to map mangroves biomass, carbon stocks, species compositions, and height.

CONCLUSION

The study helped to anlayse mangroves growth for monitoring and mapping of plantation sites. The metholdology can be used to monitor coastal green gold, without purchasing high-resolution satellite imagery (freely available sources such as Google Earth service, OrbView-3). The proposed methods are applicable over any landscape for the mapping, monitoring, and validation of various earth features specifically tree canopy cover. The repeated photography can be adopted as often as possible, which encourages on ground monitoring of the plantation growth.

REFERENCES

Abbas, S., Qamer, F.M., Ali, G., Tripathi, N.K., Shehzad, K., Saleem, R. and Gilani, H., 2013. An assessment of status and distribution of mangrove forest cover in Pakistan. *Journal of Biodiversity and Environmental Sciences*, *3*(6), pp.64-78.

Ahmad, S., Main, O., Hai, A., Khurshid, N., Qadir, A.R. and Nisa, N., 2005. Pakistan: mangroves. *The Root Causes of Biodiversity Loss. Replika Press Pvt. Ltd., India*, pp.255-281.

Amjad, A.S., Kasawani, I. and Kamaruzaman, J., 2007. Degradation of Indus delta mangroves in Pakistan. *International Journal of Geology*, *3*(1), pp.27-34

Antrop, M. and Van Eetvelde, V., 2000. Holistic aspects of suburban landscapes: visual image interpretation and landscape metrics. *Landscape and urban planning*, *50*(1-3), pp.43-58.

Chander, G., Markham, B.L. and Helder, D.L., 2009. Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. *Remote sensing of environment*, *113*(5), pp.893-903.

Chaves, A.A., La Scalea, R.A., Colturato, A.B., Kawabata, C.L.O., Furtado, E.L. and Branco, K.C., 2015. Using UAVs and digital image processing to quantify areas of soil and vegetation. In *Journal of Physics: Conference Series* (Vol. 633, No. 1, p. 012112). IOP Publishing.

Chen, C.F., Nguyen, T.S., Chang, N.B., Chen, C.R., Chang, L.Y., Valdez, M., Centeno, G., Thompson, C.A. and Aceituno, J.I., 2013. Multi-Decadal Mangrove Forest Change Detection and Prediction in Honduras, Central America, with Landsat Imagery and a Markov Chain Model, *Journal of Remote Sensing, 5*, pp. 6408-6426.

Dahdouh-Guebas, F., Verheyden, A., De Genst, W., Hettiarachchi, S. and Koedam, N., 2000. Four decade vegetation dynamics in Sri Lankan mangroves as detected from sequential aerial photography: a case study in Galle. *Bulletin of Marine Science*, *67*(2), pp.741-759.

Ellison, A.M., 2000. Mangrove restoration: do we know enough? *Restoration Ecology*, *8*(3), pp.219-229.

Emch, M. and Peterson, M., 2006. Mangrove forest cover change in the Bangladesh Sundarbans from 1989-2000: a remote sensing approach. *Geocarto Int, 21*, pp. 5–12.

Giri, C., Long, J., Abbas, S., Murali, R.M., Qamer, F.M., Pengra, B. and Thau, D., 2015. Distribution and dynamics of mangrove forests of South Asia. *Journal of environmental management*, *148*, pp.101-111.

Giri, C., Ochieng, E., Tieszen, L.L., Zhu, Z., Singh, A., Loveland, T., Masek, J. and Duke, N., 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*, *20*(1), pp.154-159.

Gu, Y., Brown, J.F., Verdin, J.P. and Wardlow, B., 2007. A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States. *Geophysical Research Letters*, *34*(6).

Guha, S., 2016. Capability of NDVI Technique in Detecting Mangrove Vegetation. *International Journal of advanced biological research, 6(2),* pp. 253-258.

Harrison, P.J., Snedaker, S.C., Ahmed, S.I. and Azam, F., 1994. Primary producers of the arid climate mangrove ecosystem of the Indus River Delta, Pakistan: An overview. *Tropical Ecology*, *35*(2), pp.155-184.

Hendrick, L.E. and Copenheaver, C.A., 2009. Using repeat landscape photography to assess vegetation changes in rural communities of the southern Appalachian Mountains in Virginia, USA. *Mountain Research and Development*, *29*(1), pp.21-30.

Hoffman, M.T. and Cowling, R.M., 1990. Vegetation change in the semi-arid eastern Karoo over the last 200 years: an expanding Karoo-fact or fiction?. *South African Journal of Science*, *86*(7-10), pp.286-294.

Iftekhar, M.S. and Islam, M.R., 2004. Managing mangroves in Bangladesh: A strategy analysis. *Journal of Coastal Conservation*, *10*(1), pp.139-146.

Field, C.B. ed., 2014. *Climate change 2014–Impacts, adaptation and vulnerability: Regional aspects*. Cambridge University

Press.

Brown, B., 2017. The evolution of the practice and the need for strategic reform of policy and planning. *Routledge Handbook of Ecological and Environmental Restoration*, p.295.

Kathiresan, K., Anburaj, R., Gomathi, V. and Saravanakumar, K., 2013. Carbon sequestration potential of Rhizophora mucronata and Avicennia marina as influenced by age, season, growth and sediment characteristics in southeast coast of India. *Journal of coastal conservation*, *17*(3), pp.397-408.

Kreft, S., Eckstein, D., Junghans, L., Kerestan, C. and Hagen, U., 2014. Global climate risk index 2015: who suffers most From extreme weather events? weather-related loss events in 2013 and 1994 to 2013.

McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J. and White, K.S. eds., 2001. *Climate change 2001: impacts, adaptation, and vulnerability: contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2). Cambridge University Press.

Mcleod, E., Chmura, G.L., Bouillon, S., Salm, R., Björk, M., Duarte, C.M., Lovelock, C.E., Schlesinger, W.H. and Silliman, B.R., 2011. A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2. *Frontiers in Ecology and the Environment*, *9*(10), pp.552-560.

Mukhtar, I. and Hannan, A., 2012. Constrains on mangrove forests and conservation projects in Pakistan. *Journal of Coastal Conservation*, *16*(1), pp.51-62.

Mahar, G. A. and Zaighiam, N. A., 2019. Spatio-Temporal Assessment of Agriculture & Mangroves and its Impact on Socioeconomy of People in Indus Delta. *Pak. J. Bot, 51(1),* pp. 377-383.

Mazhar, N., Mirza, A.I., Zia, S., Butt, Z.S., Shahid, M.G. and Mirza, A.I., 2018. An Analysis of Glacial Retreat and Resultant Vegetation Expansion in the Karakorum: A case study of Passu Glacier in Hunza valley. *Biologia (Pakistan), 64(1)*, pp. 135-145.

Niraula, R.R., Gilani, H., Pokharel, B.K. and Qamer, F.M., 2013. Measuring impacts of community forestry program through repeat photography and satellite remote sensing in the Dolakha district of Nepal. *Journal of environmental management*, *126*, pp.20-29.

Nüsser, M., 2000. Change and persistence: contemporary landscape transformation in the Nanga Parbat region, northern Pakistan. *Mountain Research and Development*, *20*(4), pp.348-356.

Nüsser, M., 2001. Understanding cultural landscape transformation: a re-photographic survey in Chitral, eastern Hindukush, Pakistan. *Landscape and urban planning*, *57*(3-4), pp.241-255.

Puyravaud, J.P., 2003. Standardizing the calculation of the annual rate of deforestation. *Forest ecology and management*, *177*(1-3), pp.593-596.

Qureshi, R.H., Nawaz, S. and Mahmood, T., 1993. Performance of selected tree species under saline-sodic field conditions in Pakistan. In *Towards the rational use of high salinity tolerant plants* (pp. 259-269). Springer, Dordrecht.

Shao, G. and Wu, J., 2008. On the accuracy of landscape pattern analysis using remote sensing data. *Landscape Ecology*, *23*(5), pp.505-511.

Sifleet, S., Pendleton, L. and Murray, B.C., 2011. State of the science on coastal blue carbon: A summary for policy makers. *Nicholas Institute for Environmental Policy Solutions, Report NI*, *11*, p.06.

Spalding, M., 2010. *World atlas of mangroves*. Routledge.

Shahzad, L., Tahir, A. and Sharif, F., 2018. Understanding the community's perception of climate change and adaptations in the Mid Hills of Pakistan. *Biologia (Pakistan), 64(II)*, pp. 197-209.

Szilárd, S., Zoltán, G. and Boglárka, B., 2016. Specific features of NDVI, NDWI And MNDWI as reflected in land cover categories. *Landsc Environ, 10*, pp. 194-202.

Tucker, C.J., 1979. Red and photographic infrared linear combinations for monitoring vegetation. *Remote sensing of Environment*, *8*(2), pp.127-150.

Tong, P.H.S., Auda, Y., Populus, J., Aizpuru, M., Habshi, A.A. and Blasco, F., 2004. Assessment from space of mangroves evolution in the Mekong Delta in relation to extensive shrimp farming. *Int J Remote Sens, 25*, pp. 4795–4812.

Vale, T.R., 1987. Vegetation change and park purposes in the high elevations of Yosemite National Park, California. *Annals of the Association of American Geographers*, *77*(1), pp.1-18.

Veblen, T.T. and Lorenz, D.C., 1991. *The Colorado Front Range: a century of ecological change*. Univ of Utah Pr.

Vogelmann, J.E., Xian, G., Homer, C. and Tolk, B., 2012. Monitoring gradual ecosystem change using Landsat time series analyses: Case studies in selected forest and rangeland ecosystems. *Remote Sensing of Environment*, *122*, pp.92-105.

Warraich, Haider, Anita KM Zaidi, and Kavita Patel. "Floods in Pakistan: a public health crisis." *Bulletin of the World Health Organization* 89 (2011): 236-237.

Webster, P.J., Toma, V.E. and Kim, H.M., 2011. Were the 2010 Pakistan floods predictable?. *Geophysical research letters*, *38*(4).

Wukelic, G.E., Gibbons, D.E., Martucci, L.M. and Foote, H.P., 1989. Radiometric calibration of Landsat Thematic Mapper thermal band. Remote sensing of environment, 28, pp.339-347.

Wulder, M.A., White, J.C., Goward, S.N., Masek, J.G., Irons, J.R., Herold, M., Cohen, W.B., Loveland, T.R. and Woodcock, C.E., 2008. Landsat continuity: Issues and opportunities for land cover monitoring. Remote Sensing of Environment, 112(3), pp.955-969.

Table I: A database of mangroves plantation sites and repeat photographs (2010 and 2015) in Keti Bunder, Indus delta, Pakistan

Photo No.	Plot No.	Longitude	Latitude	Altitude (ft)	Creek name	Nearby village	Plantation year	Planted tree species	Camera focal length (mm)	Camera height (ft)	Camera bearing (˚)	Visibility (m)	Data	Time
1	P01	67.391361	24.123139	15	Hajamro	Tippan	2006	*Avicennia marina*	85	5	185	412	12-5-10	03:59 pm
3	P03	67.385660	24.124769	20	Hajamro	Tippan	2006	*Avicennia marina*	200	5	130	416	12-5-10	04:36 pm
4	P04	67.389892	24.117308	12	Hajamro	Tippan	2006	*Avicennia marina*	28	5	320	436	12-5-10	05:09 pm
14	P13	67.431264	24.140461	15	Hajamro	Kharion	2006	*Rhizophora*	85	from Boat	70	424	12-5-10	07:01 pm
13	P13	67.431264	24.140461	15	Hajamro	Kharion	2006	*Avicennia marina*	28	from Boat	70	424	12-5-10	07:00 pm
2	P02	67.391722	24.123611	15	Hajamro	Tippan	2006	*Avicennia marina*	85	5	105	412	12-5-10	04:00 pm
6	P06	67.391604	24.116568	27	Hajamro	Tippan	2008	*Avicennia marina*	200	5	150	434	12-5-10	05:19 pm
10	P10	67.391214	24.115521	19	Hajamro	Tippan	2008	*Avicennia marina*	180	3	155	418	12-5-10	05:32 pm
18	P16	67.479511	24.059933	3	Bhoori	Bhoori	2008	*Avicennia marina*	135	5	45	406	13-5-10	11:10 am
19	P17	67.478698	24.060771	14	Bhoori	Bhoori	2008	*Avicennia marina*	150	8	310	407	13-5-10	11:25 am
20	P18	67.437702	24.048255	16	Babar	Cheer dablo	2008	*Avicennia marina, Rhizophora*	50	5	90	409	13-5-10	12:34 pm
21	P19	67.438152	24.047813	15	Babar	Reer	2008	*Avicennia marina, Rhizophora*	28	5	215	410	13-5-10	12:38 pm
22	P19	67.438152	24.047813	15	Babar	Reer	2008	*Avicennia marina, Rhizophora*	85	5	65	410	13-5-10	12:41 pm
23	P19	67.438152	24.047813	15	Babar	Reer	2008	*Avicennia marina, Rhizophora*	30	5	145	410	13-5-10	12:42 pm
24	P20	67.439293	24.047344	14	Babar	Reer	2008	*Avicennia marina, Rhizophora*	120	5	80	411	13-5-10	12:50 pm
5	P05	67.391604	24.116568	27	Hajamro	Tippan	2009	*Avicennia marina*	85	5	280	435	12-5-10	05:15 pm
7	P07	67.391604	24.116568	27	Hajamro	Tippan	2009	*Avicennia marina*	200	5	210	435	12-5-10	05:20 pm
8	P08	67.391604	24.116568	27	Hajamro	Tippan	2009	*Avicennia marina*	200	3	180	435	12-5-10	05:22 pm
9	P09	67.391265	24.116208	24	Hajamro	Tippan	2009	*Avicennia marina*	300	4	140	431	12-5-10	05:25 pm
11	P11	67.390974	24.114410	22	Hajamro	Tippan	2009	*Avicennia marina*	400	5	155	417	12-5-10	05:40 pm

12	P12	67.415167	24.123389	33	Hajamro	Hadu dablo	2009	*Rhizophora*	135	2	65	422	12-5-10	06:29 pm
15	P14	67.436583	24.141472	33	Hajamro	Kharion	2009	*Rhizophora*	85	3	90	425	12-5-10	07:14 pm
16	P14	67.436583	24.141472	33	Hajamro	Kharion	2009	*Rhizophora*	85	5	300	425	12-5-10	07:18 pm
17	P15	67.442042	24.128370	8	Hajamro	Saddique Dablo	2009	*Rhizophora*	135	5	275	426	13-5-10	09:03 am
25	P21	67.437318	24.049904	20	Babar	Muhammad Hassan Shulbri	2009	*Avicennia marina, Rhizophora*	200	5	15	430	13-5-10	01:12 pm
26	P22	67.438816	24.038432	17	Babar	Karo Takro	2009	*Avicennia marina*	85	5	220	422	13-5-10	01:40 pm
29	P25	67.485649	24.162304	33	Humbas	Khadaim Wari	2009	*Rhizophora*	500	5	350	427	13-5-10	04:07 pm
27	P23	67.428628	24.098896	39	Turshan	Turshan	2009	*Avicennia marina*	135	5	210	419	13-5-10	02:59 pm
28	P24	67.427452	24.112169	34	Turshan	Turshan	2009	*Avicennia marina*	135	3	310	425	13-5-10	03:14 pm
31	P26	67.429398	24.137304	27	Hajamro	Kharion	2010	*Avicennia marina*	200	5	210	423	22-5-11	11:06 am
30	P26	67.429398	24.137304	27	Hajamro	Kharion	2010	*Avicennia marina*	135	5	290	423	22-5-11	11:06 am
32	P26	67.429398	24.137304	27	Hajamro	Kharion	2010	*Avicennia marina*	200	5	250	423	22-5-11	11:06 am