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REMOTE SENSING (RS) MONITORING OF MANGROVES PLANTATION AGAINST THE GUINNESS WORLD RECORD (GWR) OF MAXIMUM PLANTATION IN INDUS DELTA

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Abstract

The present study was designed to monitor the growth pattern of mangroves (*Rhizophora mucronata*) planted by SFD in June 2013 at Kharochan island near Keti bunder and created world record for planting maximum number of plants in one day. Since, this activity was accepted by Guinness Book of World Record (GWR) that is known as GWR-II. A study was required to evaluate the impact of this task of GWR. This study was conducted using Remote Sensing Data, GIS as well as field survey of the plantation site. After about two and half years of plantation during the field survey on 24 November, 2016, it was observed that the *Rhizophora mucronata*, the planted species was growing well. The plants were very healthy and attained average height of 32.8 inches with several branches. Moreover, the analysis of the data collected during the field survey showed survival rate of 77.7%. Analysis of remote sensing data for the years 2013, 2015 and 2017 revealed increase in mangroves cover of 9 and 103 hectares during the 2013 to 2015 and 2015 to 2017, respectively. The increase in mangroves has also been calculated using GIS techniques and maps for different years have been prepared. It has been noticed that during field survey, *Avicennia marina* which is most abundant specie of Indus Delta has also grown on the plantation site with one and half year age groups of plants. Findings of the Remote sensing data as well as the field survey show that mangroves forest area has been increased.

Key words: Mangroves, Indus Delta, *Rhizophora mucronata*, *Avicennia marina*, landsat.

Introduction

Coastal community, marine scientists, coastal development authorities and other stakeholders understand the importance of mangrove ecosystem. Mangroves are known as 'coastal woodlands', 'tidal forests' and 'mangrove forests' (Saenger *et al*., 1983). They provide the space between marine and terrestrial environment, especially near the mouth of the river and those parts of the coastline where saline water is regularly flooded by tidal action (Sterling *et al.,* 2006; Bao, 2011). Mangroves are found in tropical and subtropical regions of the world. They provide livelihood and numerous ecosystem services to people living in coastal area (Rafique, 2018). Litter produced by mangroves forest forms a primary source of biomass available as food to a variety of detritus feeding organism (Farooqui *et al*., 2012). Role of phytoplankton and their interdependency with mangroves is very significant to provide the ideal ecosystem in mangroves estuary (Saifullah *et al.,* 2016). Phytoplankton with their components are found in mangroves ecosystem to provide a chain of food for fisheries (Shoab *et al.,* 2017; Gul *et al.,* 2018).

Asia occupies 14% of the World's forests with 432 million ha of natural forests and 116 million hectare of planted forests (Shahzad *et al*., 2019; MacDicken *et al.*, 2015). The world's forest occupy almost 3869 million hectare of land which have almost 421 x 106 tonnes of total aboveground biomass (Shahzad *et al*., 2019; Bain *et al.*, 2015). In the last few decades it had been difficult for biological conservationists and government regulators to establish nature reserves because it was hard to predict the future distribution ranges of species due to climate change (Wang *et al*., 2019; Araújo *et al*., 2011; Richardson & Whittaker, 2010). Similarly, worldwide trend of shrinking mangroves have been observed. Human intervention has converted the dense forest into scanty forest (Ivan *et al.,* 2009). But human efforts have also made possible the forestation trend of mangroves in some parts of the world (Al Mahasheer, 2018). Existence of mangroves is necessary for coastal society, as they play vital role for the benefits of natural environment and coastal communities. The coastal area, where mangroves are found, are protected even under the harsh conditions because their dense forests and deep roots provide the barrier against any catastrophe like Tsunami, cyclone, heavy wave action (Kathiresan & Rajendran, 2005; Wolanski, 2007; Barbier *et al.,* 2008; The *et al.,* 2009). It has been reported that the flooded area produced by Hurricane Wilma in 2005 in southwestern Florida could intrude up to 30 km inland zone of mangroves (Zhang *et al*., 2012; Liu *et al*., 2013), and in Orissa (India), in 1999 cyclone struck the coastal area. Mangroves protect the coast and loss of lives are reduced in cyclonic condition (Barbier, 2016). About 11 major cyclones have occurred along the eastern coast of Pakistan in Delta from 1901 to 2000 (Anon., 2018), but it has been observed by coastal communities in the deltaic region that intensity and impact of cyclone is found lessen under the shadow of Mangroves. Mangrove forests provide significant services around the globe to all sectors of environment including human. However, losses and gain of mangrove habitat have been recorded in many parts of the world, and losses are largely attributable to human activities and gains by sustaining natural environment (Ivan *et al.,* 2009; Alongi, 2002).

Indus delta, the fifth largest delta in the world has seventh largest mangroves forest ecosystem. Mangroves covered area in 1985 was estimated by landsat satellite. Approximately 240000 hectares was found sparsely and densely covered by mangroves (Anon., 2005). However during the past few decades, Indus delta mangroves were in serious degrading condition (Qasim, 2016). Estimated covered area in 1985 (IUCN) were lesser then previously

available figures (Anon., 2005). Scarcity of fresh water for mangroves, physical environment and ecological contributors are the main issue of Indus Delta (Anon., 2003; Mahar, 2010). *Rhizophora mucronata* and *Avicennia marina* are the two prominent species, out of eight found in the coastal zone of Pakistan (Farooqui, 2014). Efforts are being made by the Sindh Forest Department (SFD) for the restoration and plantation of endangered mangrove species. SFD with the help of local communities planted 847,250 saplings of *Rhizophora mucronata* in Kharo Chan, Indus delta in 2013 (Anon., 2013, Anon., 2018). *Rhizophora mucronata* was selected for plantation because it was under stress (Khan & Aziz, 2001). The plantation drew national and global attention for conservation of natural biodiversity. This plantation was recognized by Guinness Book of World Records (GWR) for "Maximum number of trees planted in a day" known as GWR-II.

The current research activity is aimed to understand the temporal and spatial variation in growth pattern of these planted mangroves in Kharo Chan area. The research will also facilitate the understanding of geomorphological changes in land area and the factors affecting the growth and survival of mangroves plantation.

Material and Methods

Location of the stdy area: The Study Area is Island (GWR-2) of Kharo Chan having distance of about 230 km away from the provincial Capital Karachi. Its geographical coordinates are 24°03'17.5"N and 67°34'36.5"E. Kharo Chan comprises of small islands surrounded by Indus delta creeks system in district Thatta of Sindh Province, Pakistan (Fig. 1). Mangroves forests are found in these islands. In the vicinity of study area, several old villages were found in these islands. Current population of Kharo chan according to 2017 survey is 10235 (Anon., 2017).

Data collection: Major data collection tasks were field survey and Land sat satellite data. Field survey was conducted to collect the data and observe the ground realities in 2016**.** Landsat data for monitoring the impact was collected (downloaded) from USGS site.

Sampling from study area: One day field survey for data collection was conducted on 24, November 2016. Survey included general observation, ground truthing and Random Data collection techniques to calculate plant locations, density, health and height. In island of Kharo Chan mangroves (*Rhizophora mucronata)* were planted on 22 June, 2013. The pattern used during plantation was to plant each mangrove sapling in rows and columns after 10 feet (Fig. 2).

Random sampling techniques were used during survey to collect the data about the number of plants, with the help of rope marked 20 x 20 feet to count mangroves in the area of 20 square feet with respect to their height, branches and age (Table 1). During the counting of *Rhizophora mucronata,* it was observed that few plants of *Avicennia marina* had also started growing on the island, which is the most dominant mangrove species of the Indus delta. Each area of 20 square feet is named as quadrats. GPS location of the each coordinate is noted (Table 2).

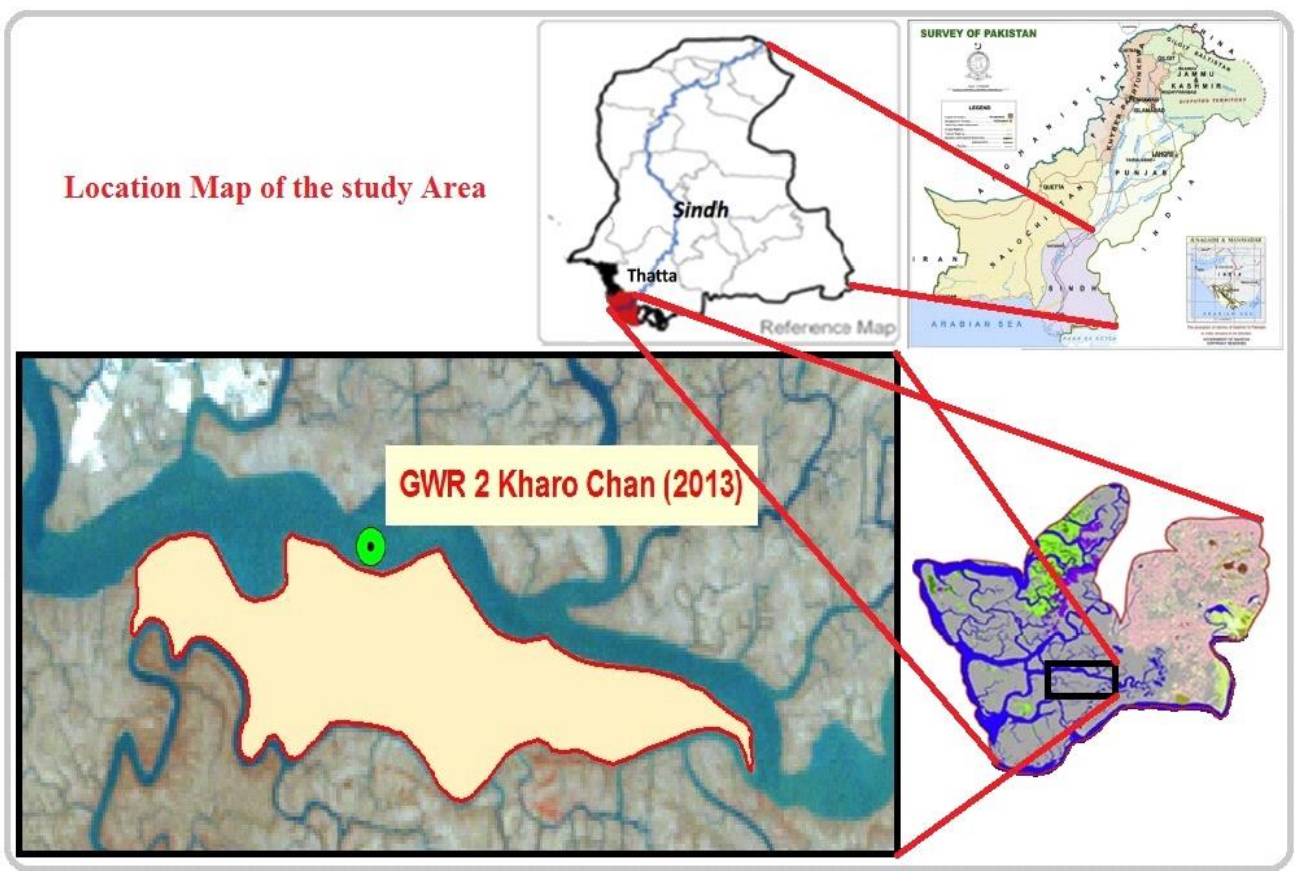

Fig. 1. Location map study area with reference to Pakistan.

Table 1. Data of *Rhizophora mucronata* planted in 2013 and *Avicennia marina* found in the survey in 2016.

Quadrats	*Rhizophora mucronata*				*Avicennia marina*	
#	Planted 2013	Survived	Avg. height	Avg. branches	found	Avg. age
1	9	7	18”	5	2	1-2.5 years
2	9	6	30”	13	2	1-2.5 years
3	9	8	40”	11	3	1-2.5 years
4	9	7	43”	20	0	1-2.5 years
5	9	9	35”	13	3	1-2.5 years
6	9	7	31”	13	1	1-2.5 years
7	9	8	41”	16	7	1-2.5 years
8	9	8	44”	18	3	1-2.5 years
9	9	5	37”	14	14	1-2.5 years
10	9	8	51”	25	14	1-2.5 years
11	9	4	8”	3	6	1-2.5 years
12	9	7	40”	15	1	1-2.5 years
13	9	7	24”	17	3	1-2.5 years
14	9	1	6”	2	2	1-2.5 years
15	9	9	44”	17	0	1-2.5 years

Table 2. GPS location of the ground data collection points.

Coordinate #	Latitude	Longitude
1	24.1125	67.48994
2	24.11295	67.4986
3	24.11241	67.48995
4	24.11225	67.48985
5	24.11196	67.48926
6	24.11175	67.48338
7	24.11166	67.48939
8	24.11275	67.47975
9	24.11281	67.48974
10	24.112329	67.48964
11	24.11186	67.48957
12	24.11154	67.48437
13	24.11135	67.48916
14	24.11263	67.48895
15	24.11213	67.48904

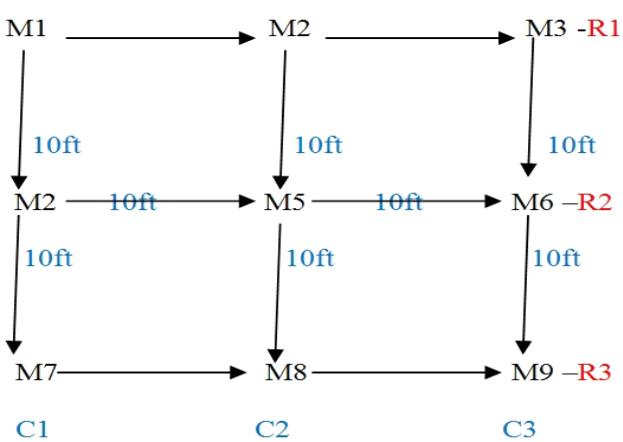

Fig. 2. Mangroves Plantation pattern conducted in 2013.

Satellite remote sensing (SRS): The Landsat 7 Thematic Mapper, (TM) & Landsat 8 (Operational Land Imager (OLI) & Thermal Infrared Sensor (TIRS), data of the study area was obtained from the official site of USGS (Table 3); the images were orthorectified in UTM-WGS84-42N. The study was aimed to detect the changes over the mangroves cover area in the delta particularly in the island of Kharo Chan (GWR-2). Landsat images of different years with suitable dates were obtained by considering "no cloud covers" (Table 3).

Drone aerial photography: Since the total planted area was large enough and it was not possible to cover the whole area in one day by our team, hence drone was used for acquiring aerial photography and observe growth pattern of planted mangroves in the whole area (Fig. 3).

Methods

Laboratory analysis: The Landsat 7 and 8 images have been processed for spatial, temporal, quantitative and statistical analysis. Images have been classified using different techniques like Normalized Difference Vegetative Index (NDVI), using image processing software, Erdas Imagine (Fig. 4). The ground verification was done with the help of Global Positioning System (GPS). GPS provides coordinates which is converted into spatial data by using Add Event Theme (AET) technique in Arc Map to see the exact location of the identified objects in study area. The images were also digitized in shape files format to create the creeks network, mangroves and other features in ArcMap to get more information for the final layout purpose.

Several algorithms were used in Erdas Imagine to enhance the contrast and quality of the images for better results. Images were also compared with high resolution Google earth images to get the best possible result, exact density of the mangroves plantation and for changes detection of the study area.

Table 3. Detail of the land sat images used for the study.

S. #	Date	Sensor	Resolution	WRS	Satellite	Tide height (m)	Could %
1.	25-Aug-2013	ETM	30m	152/42	Landsat 7	1.0 m	0.00
2.	07-Dec-2015	OLI_TIRS	30m	152/42	Landsat 8	0.6 m	0.00
3.	03-Jun-2017	OLI_TIRS	30m	152/42	Landsat 8	1.0 m	0.00

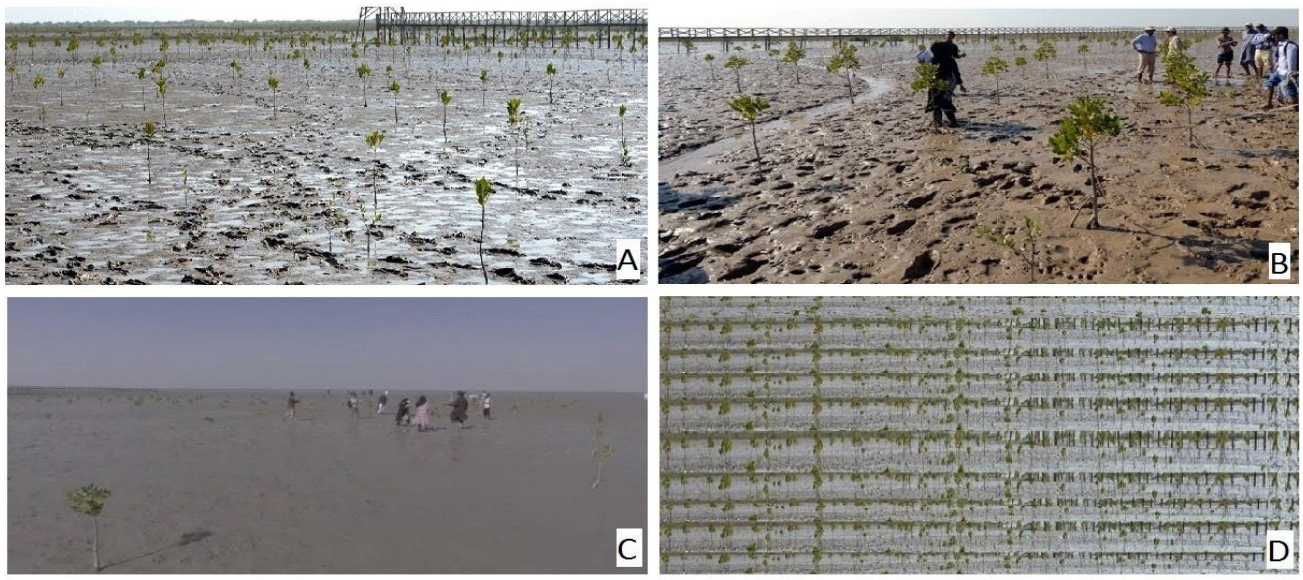

Fig. 3. Drone used in the study to get the oblique and vertical view of the study area.

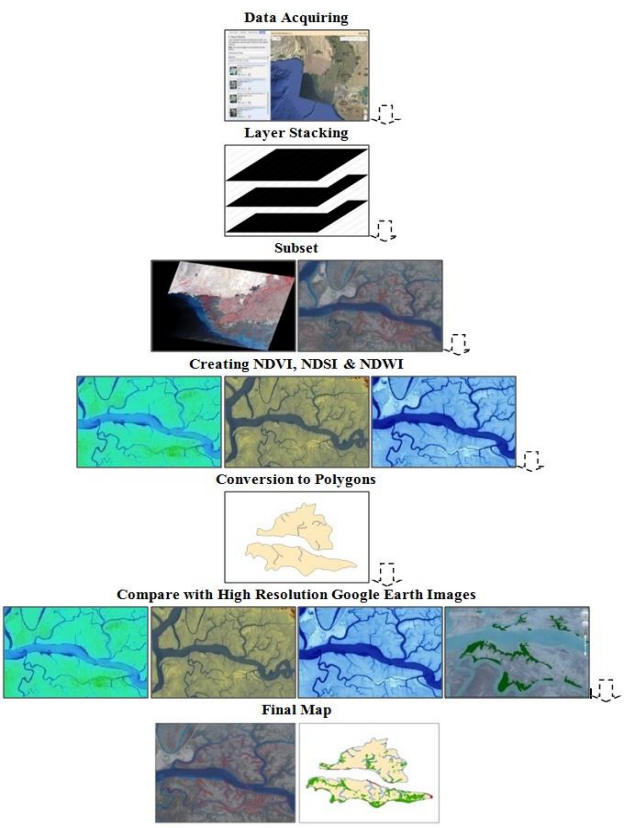

Fig. 4. Steps (methods) applied from data acquiring to final map to get results.

Quantitative and statistical analysis: The data collected regarding planted mangroves (Table 1) during the field survey was statistically analyzed to calculate the density, heights and branches of *Rhizophora mucronata* in the study area. For statistical analysis, mean equation was used to calculate the average number of mangrove plants, with height and number of branches in different quadrats by measuring 20 square feet area. The calculated mean of mangroves density, heights and branches are used to calculate the current status of mangroves in the study area, their survival rate as well as annual rate of growth in height and branching to study the growth pattern of planted mangroves in GWR-II Kharo Chan Island, using general mathematical expressions.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Here n is the number of quadrats and x is the number of mangroves in a quadrats.

For average number of *Rhizophora mucronata* per 20 square feet area of the GWR-II Island

$$\bar{x} = \frac{\sum_{i=1}^{15} x_i}{15} = \frac{(7+6+8+7+9+7+8+8+5+8+4+7+7+1+9)}{15} = 6.73$$

Mean = 6.73 (Around 7 *Rhizophora mucronata* in the 20 square feet area).

For average number of *Avicennia marina* within per 20 square feet area of the GWR-II Island

$$\bar{x} = \frac{\sum_{i=1}^{15} x_i}{15} = \frac{(2+2+3+0+3+1+7+3+14+14+6+1+3+2+0)}{15} = 4.06$$

Mean = 4.06 (Around 4 *Avicennia marina* in the 20 square feet area)

For average height of the *Rhizophora mucronata* mangroves at GWR-II Island

$$\bar{x} = \frac{\sum_{i=1}^{15} x_i}{15} = \frac{(18+30+40+43+35+31+41+44+37+51+8+40+24+6+44)}{15} = 32.8$$

Average height = 32.8 inches (around 33 inches)

For Average number of branches in *Rhizophora Mucronata* at GWR-II Island

$$\bar{x} = \frac{\sum_{i=1}^{15} x_i}{15} = \frac{(5+13+11+20+13+13+16+18+14+25+3+15+17+2+17)}{15} = 13.26$$

Average branches = 13.26 braches (around 13 branches)

Results and Discussions

Mangroves: Mangroves area seems to be increased after the plantation of *Rhizophora mucronata* in GWR-II Island in 2013. Figure 5a shows satellite image and map of island dated August 2013. This period of satellite image is transition stage because the planted mangrove saplings were starting to grow in the month of August 2013. It has been estimated that when plantation was carried out in 2013, approximately 45 ha area of the island was covered with mangroves. The presence of *Avicennia marina* in the study area also provided favorable environment for the seeds of other species to grow in GWR-II Island. Before the plantation, the area was barren and only 18 ha of the vegetation was estimated which is not exactly the mangroves vegetation (Fig. 5a). Bushes and microscopic organisms show chlorophyll activity which is generally the result of 2010's Super flood in Sindh coastal area (Rasul *et al*., 2012). Mangroves area increases from 124 ha (Fig. 5b) to 227 ha (Fig. 5c) between the period 2015 and 2017 (Table 4). The increasing trend in vegetative cover in the island shows that mangroves plantation in 2013 has effectively worked, its impact could be seen from the results of the images of 2017 (Fig. 6) and will have positive impact in the future over this island.

The images of various years clearly depict continuous growth of *Rhizophora mucronata* and the survey of the site during 2016 revealed 77.7% survival rate of the plantation carried out during 2013 at Kharochan Island. It has also been observed during the survey the plantation facilitated growth *of Avicennia marina* in the area and plants of about 1-2 years were observed.

Growth of *Rhizophora mucronata:* It is calculated from the above mean equation that 7 *Rhizophora mucronata* mangroves plants are found at the 20 square feet quatrats of the study area. In 2013, each quadrat was planted with 9 *Rhizophora mucronata* mangroves saplings where as during survey in 2016, it has been found that out of 9 plants, average 7 plants were growing well in each quadrat. It is found that the survival rate was very satisfactory and healthy growth has been observed during the survey.

During survey, plants height and average number of branches has also been considered for estimation. The Average height of the *Rhizophora mucronata* was measured 32.8 inches and 13 branches per plant was the average estimated number of branches of plants. In future, increasing rate of branches will increase exponentially as newly produced branches will produce more number of branches.

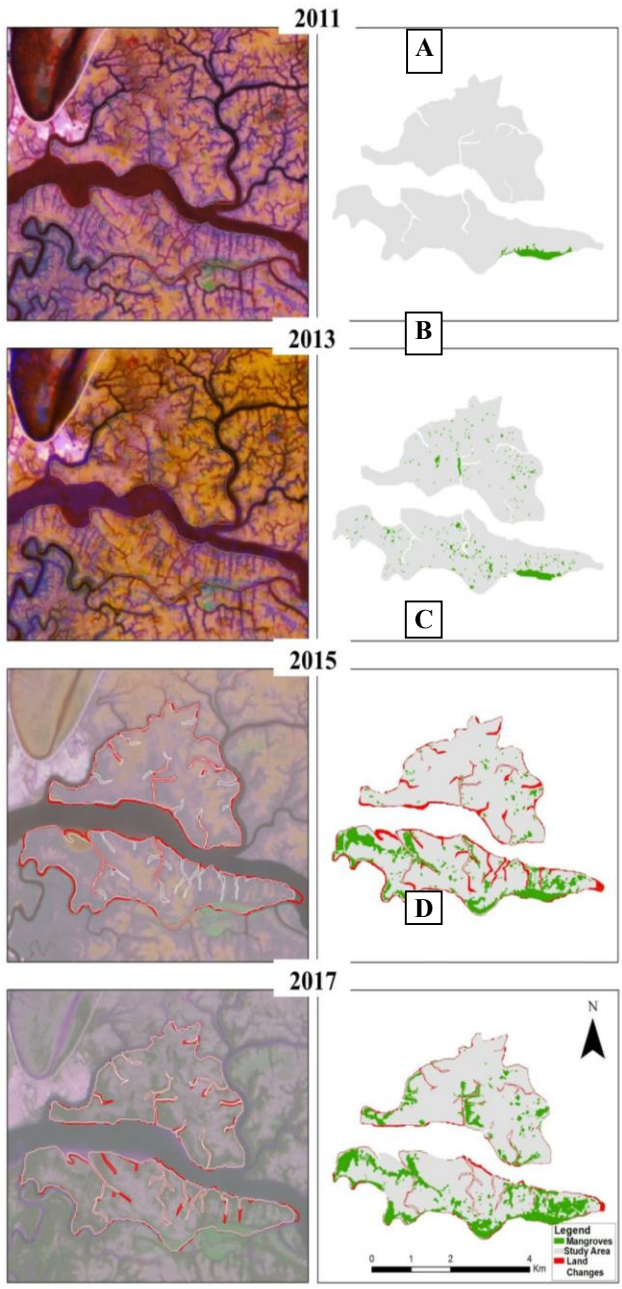

Fig. 5. Maps and images of the island known as GWR-2. "A" represents 2011, "B" represents 2013, "C" represents 2015 and "D" represents 2017 processed data of satellite images. Temporal change of mangroves aerial status is shown in a set of map and image.

Table 4. Island area and mangroves cover area are extracted from satellite images dated 2011, 2013, 2015 and 2017.

Year	Island area	Mangroves cover	Mangroves cover change	Island area changes
2011	1278 ha	18 ha	--	--
2013	1251 ha	45 ha	97 ha increased	27 ha land eroded
2015	1167 ha	124 ha	9 ha increased	84 ha land eroded
2017	1170 ha	227 ha	103 ha increased	3 ha land reclaimed

Growth rate of *Avicennia marina*: Growth and distribution pattern of the both species (*Rhizophora mucronata and Avicennia marina),* depend on soil factors, tide and salinity (Ahmed & Hamid, 2007).These factors are available in the island. *Avicennia marina* was randomly found in the island because showering of seeds of Avicennia marina was carried out two years ago. During the survey in addition to *Rhizophora mucronata* average 4 plants of *Avicennia marina* per 20 square feet quadrat were found in the study area. The age of *Avicennia marina* is estimated to be between 1 and 2 years.

Geomorphic changes: From the past many decades erosion rate was very high in Kharo Chan, hundreds of hectares has been eroded and submerged by sea intrusion (Anon., 2000; Mahar, 2010). Fluctuation in covered area of the island located near the coast is up to the behavior of waves and tides and the phenomena is not permanent. The data of study period, retrieved from satellite images of years 2013, 2015 and 2017 shows that island is continuously in degradation state under the influence of sea invasion and is reducing its size (Table 4).

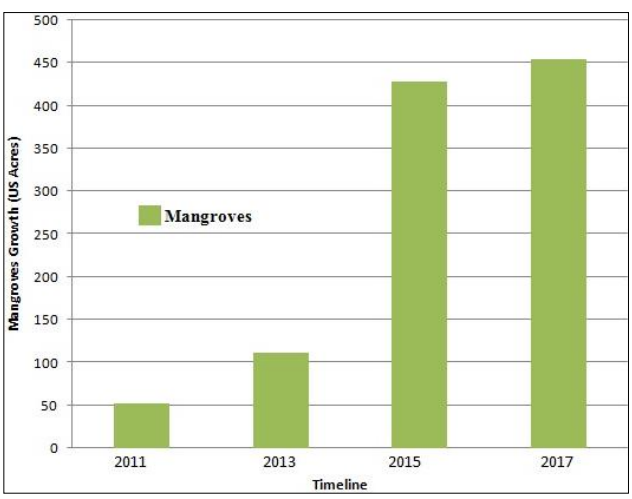

Fig. 6. Graph shows the temporal increasing trend in the island of GWR2.

Conclusion

The Mangroves planted in GWR-II Island of Kharo Chan on 22 June 2013 are successfully surviving with survival marginal rate. The plantation of *Rhizophora macronata* also provided base for the seeds of other mangroves species to grow in GWR-II Island. Mangroves cover area increased from 45 to 227 hectares, detected from the landsat satellite images of the GWR-II Island dated 2013, 2015 and 2017. Exercise of drone photography also shows lush vegetation cover in larger area of the island.

Sustainability of the mangroves in such environmental conditions shows proper institutional care and monitoring. Hundred percent survival rates was not found but 77.7% estimated rate of survival with good conditions/health of the plants and appropriate growth highlight that the mission of June 2013 was successfully conducted on the Kharo chan island known as GWR-II. *Avicennia marina* has been naturally growing in the island with little effort and will be growing parallel with *Rhizophora mucronata*. Based on the observation and present results, it is speculated that experiment of mangroves plantation was not only a successful task in 2013 but results show that real success will be shown in near future in the form of dense mangrove forest. This is the success of SFD, stakeholders and local community who organized this project and cared to maintain it.

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