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SPATIO-TEMPORAL ASSESSMENT OF AGRICULTURE & MANGROVES AND ITS IMPACT ON SOCIOECONOMY OF PEOPLE IN INDUS DELTA

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Abstract

Landuse situation of agriculture and land cover situation of mangroves forests in the delta are traditionally old. Spatial expansion of agriculture and mangroves forestsis has not remain same in current situation. Results detected from the satellite images shows that cultivated lands are decreasing and the mangroves forests are increasing. In active part of the Delta, cultivated land was covered by 116928 acres in 1998 and 88172 acres in 2008 and 48787 acres in 2018. On the other hand, estimated spatial coverage of mangroves forests in 1998 was 21991 acres and in 2018 is 70850 acres.

Agriculture in the Indus Delta is severely affected since the last two decades. Out of a total 2 million hectare land, about 0.3 million hectare is cultivated each year in the delta. Almost major part of the delta comes under district thatta. It has total nine administrative subdivisions. Data of cultivated/uncultivated land between the period 1998 and 2008 shows that more than 80% land of these subdivisions are not used for cultivation during this period. Under the present conditions average farmer's family cultivates three acres of land. Average income per family estimated from the survey is 2.0 $ per day that indicates the prevalence of extreme poverty in the area.

Key words: Indus Delta, Agriculture, Socioeconomic, Cultivated land, Indus River.

Introduction

Indus delta, located in the south of Pakistan, is administratively covered by district Thatta. The triangular shape Indus delta which occupies lower Indus basin covers approximately two million hectares area. Its triangular fan shape structure was built up by the discharge of the large quantity of sediments and water into Arabian Sea. It is situated between latitude 23°15" N and 25°05" N and longitude 67°10" E and 69°E (Fig. 1). Currently the water from the River Indus flows into the Delta is controlled by Kotri Barrage that is situated about 174 km from the mouth of the River. Geographically the active coastal deltaic area is located near the Turshan and Hajamoro creek. Total length of the coast of the delta is approximately 300 km (Brohi, 2003).

The study area of the Indus Delta can be divided into two regions, one is reverine belt or upper deltaic flood plain and the other is active delta or lower deltaic area. The reverine land is formed by the flood plains of meandering and braided stream where a river pattern with oxbow lakes and silt deposits are also found. Forest, agriculture and fisheries are important economic activities found in the reverine belt (Sikander Brohi, 2003; I.U.C.N., 2003). Southern part of the Delta around the river mouth is called active delta. Either side of the active part of the delta consists of a complex network of creek, accreted/eroded shoreline and many other geomorphic features. Mangroves forests is a prominent feature found in the active part of the delta near the coast (Quershi, 1999). The production of these forests is also one of the major concerns of this study.

Economy of the study area depends to a great extent on agriculture. Cultivation of crops largely depends on Indus River water that is used for irrigation. Area of cultivation is increased when enough quantity of water is available for irrigation. Availability of freshwater has direct impact on the socioeconomics of the farmers. Women input in the dairy farming and horticulture activities can successfully improve these sectors of agriculture (Quisumbing, 2015). Big families with ignorance of women in economic activities also reflect on the socioeconomics of the deltaic society.

Methodology: Multidimensional research approaches have been applied for this study. Data required, are categorized according to types and source. Following three types of data are collected for the study to get results objectively.

General field visits: Five days field visit were conducted into the active delta (Keti Bunder, Kharochan & Gorabari). Primary objective of the study was to observe the environment including land use i.e., agriculture and forests (mangroves). Economic activities, social conditions and ground verification to correlate with satellite images have also been evaluated. An informal and unstructured questionnaire was developed to take interview of the farmers. Questionnaire was prepared, keeping in mind farmers economics and social status. Evaluation of practice of land cultivation and presence of mangroves in their lives was the main objective of the study. Global Positioning System (GPS) was also used in the field survey.

Mangroves survey: One day field survey for data collection was conducted in an island of Kharon Chan and Keti bunder. In survey ground truthing and Random Data collection techniques were used to calculate plant locations and density. The pattern used during plantation was to plant each mangrove sapling every after 10 feet distance in rows and columns (Fig. 2). This technique was employed to cover an area of 20 square feet with the help of a rope. During the counting *Rhizophora mucronata* was counted though *Avicinna marina* was also encountered.

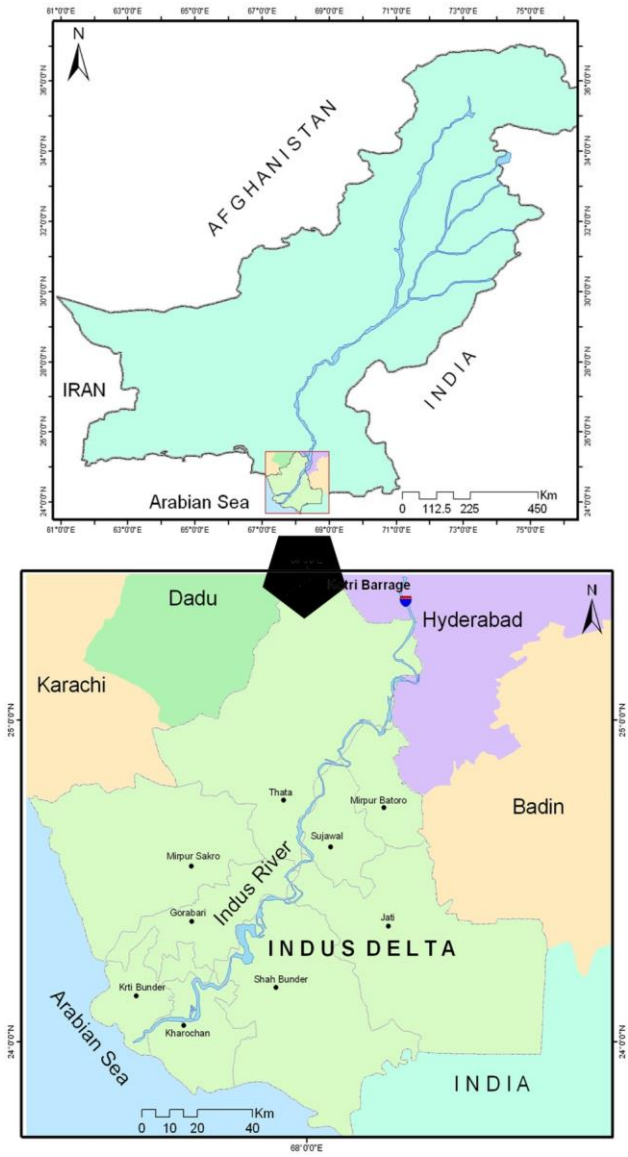

Fig. 1. Index map covering the study area boundary of Indus Delta Pakistan.

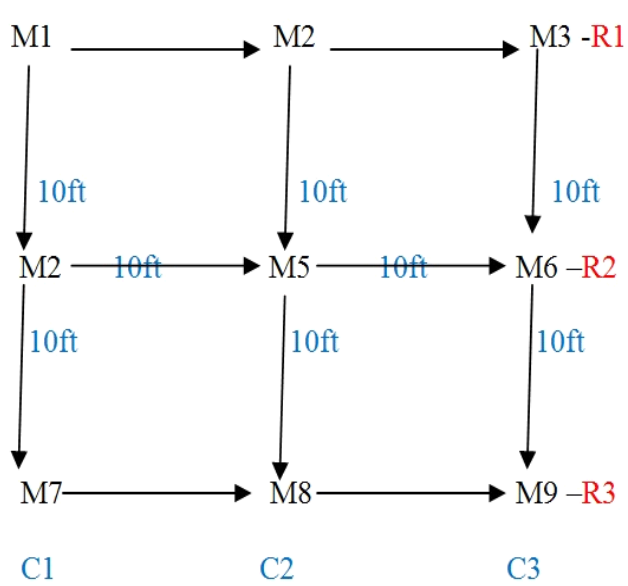

Fig. 2. Method used to count the number of Mangroves in the field.

Recorded data: Daily monthly or annual recorded data from different organization has been collected. Data about the cultivated/uncultivated land between 1998-1999 and 2007-2008 was collected from revenue department, provincial government of Sindh. Water flow and sediment data has been collected from Irrigation department, Provincial Government of Sind.

Satellite data: Spatial analysis using GIS technique and Remote Sensing data is highly recommended that provide geographical pattern, spatial classification and variation to achieve the required output of the research (Afza, 2018). Advancement in Satellite Remote Sensing (SRS) has proved the more precise and segregated results (Khan, 2018). Landsat ETM and OLI have been collected from www.usgs.org for the temporal change study of the active part of delta. Three satellite images dated 1998, 2008 and 2018 have been collected and processed to get the decadal temporal difference. These images were given Projection WGS-1984 and datum UTM-zone-42. Color Composit Image (CCI) of each set has been made to get spectral observation. Supervised Classified Image (SCI) of each data set has also been made. Three administrative Dehs (Keti bunder, Kharochan and Gorabari) have been delineated as target area of study in active delta. Mangroves and cultivated areas were the selected areas to be studied.

Agriculture in Delta: Agriculture in Indus Delta is leading economic activity, except the coastal and marshy area which is mostly covered by mangrove forest. This area used to be a large fertile land of the flood plain part of the Indus River in the past. In the first half of the 20th century, large part of the delta area was covered by forest. Increasing demand of food with growing population accelerated the process of deforestation that ultimately replaced cultivated area. Since the last three decades the situation related to crop cultivation, yield per acre and its impact on peoples' economy was not much favourable as before.

Agriculture of delta region mainly depends on Indus River but water also flows from western catchment area into the delta in good years. The main crops grown in the district during Rabi season (16 October to 15 April) are wheat, barley, grain and oil seed while in Kharif season (16 April to 15 October) the main crops grown are rice, maize and millets (D.C.R., 1998). As far as fruits are concerned date, palm, coconut and banana are also cultivated in the delta. Wheat and rice are the main staple crops.

Livestock also plays an important role in the economic development of agrarian society of the delta. Animal rearing is practiced as primary activity by the deltaic community. Delta degradation has also affected the forest area either located in active deltaic part or in the riverine part.

Agriculture types: Two distinct types of land use have developed over the years along both sides of the river, Irrigated cropping and animal husbandry (Irrigated field and range land). Fish farming and poultry farming were also found as an economic activity.

Irrigated field: Irrigated fields are very prominent and productive area used for crop farming in the deltaic region. 95% of the farming of delta dependents on irrigated cropping. Crops are irrigated by network of canals. Kalri Baghar, Sattar, Kanto, Ghar, Kodario, Gungro, Saida, Mirza and Gungri are the main canals (D.C.R., 1998). Water supply is made possible through these canals to every nook and corner of the delta.

High productivity and larger area for farming are mainly dependent on the availability of enough quantity of water from Kotri to downstream. Other factors of irrigated cropping are fertilizer, pesticide, herbicides etc. Due to two distinct cropping seasons (Rabi and Kharif) in a year, the selection of crops and their timing plays a vital role in agriculture of the deltaic area.

Range land and mangroves: Use of rangeland in Indus Delta basin for the herded grazing and browsing is widely spread and substantially covers larger area. These activities are higher in southern side of the delta, where rangeland and forest are abundantly found. Camels, Buffalos, Sheep and Goats are major economic livestock. Animal husbandry is the dominant profession because it exists even in drought condition or when there is scarcity of water supply. Camels, Horse, Mule and Ass are used for the transportation of humans and crop products. Domestic poultry is used in every house in the villages.

Mangroves are prominent forests used as range land for cattle's grazing and browsing. Camels were found in big numbers during the survey but other cattle have also been seen. Sindh Forest Department (SFD) has some regulations to prohibit some areas for animal grazing. There is other use of mangroves like boat or ship making, housing and as fuel. Regulations are imposed for sustainability of mangroves in this area. Many efforts have been made in the last decade to improve and sustain the mangrove in this area. A campaign was launched by SFD and Federal Ministry of Environment in 14 July 2009. About 541176 mangroves (*Rhizophora mucronata)* saplings were planted by 300 volunteers and made a Guiness World Record (GWR). Mangroves were planted on 23-june-2013 in the island of Kharo Chan. About 847250 saplings of mangroves in the island were planted by SFD that was second Guinness World Record (GWR-II). In 20 April 2018, a new record of 1129294 mangroves saplings plantations has been established by SFD, breaking their prevous records.

Status of agriculture: Thatta, being agriculture district with more than 300000 hectare land under cultivation each year, the delta is under stress for last few decades. Main reason is the shortage of irrigation water from Kotri barrage.

The historical data of agriculture land under cultivation from 1998-99 to 2007-08 was collected from District Coordination Office (DCO), Revenue Department, District Thatta, Government of Sindh and processed to find the variation in cultivated land between 1998 and 2008. The results show the constantly decreasing trend in cultivated land in the delta (Fig. 3).

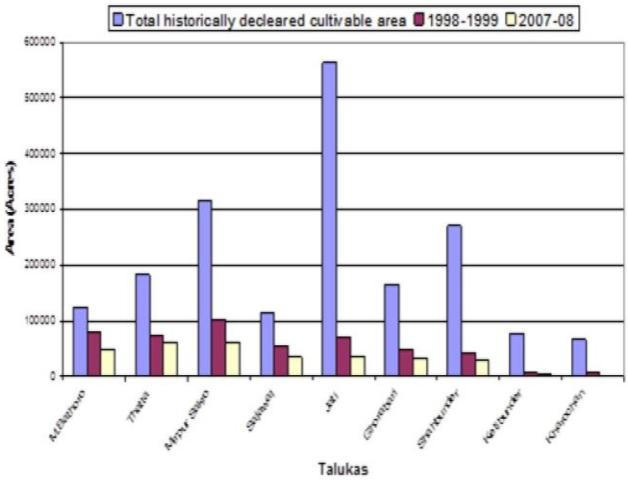

Fig. 3. Bar graph shows the comparison of total cultivable area with cultivated area in 1998-99 and 2007-08.

The difference of total cultivable area (declared by Revenue department) and cultivated area is larger. Variations were observed spatially as well as temporally. The Talukas (administrative boundaries after district) near the coast have small area of land for cultivation and due to the proximity of the coast; the rate of deterioration is also excessive. Results of the cultivable were not encouraging before 1998 but during the period from 1998 to 2008, continued degradation trend shows that the 90% of the total cultivated area of coastal subdivisions has been depleted. The northern area of the delta also does not have much degradation while comparing with the data of coastal administrative units, the cultivable areas were found between 60% and 70% in the Talukas of the Sajawal, Thatta and Mirpur Bathoro (Fig. 4).

Socioeconomic setup: In past the deltaic area has enjoyed discharge of enormous amount of freshwater and silts through Indus River. Therefore, socioeconomic setup developed over this area is based on agriculture. During the study, a survey was also conducted to evaluate the economic conditions of the residents of the area.

Economic of crops: Economic conditions of the farmers were evaluated by preparing unstructured and informal questionnaire. The field visits were conducted during 2004 to 2006 and about 50 farmers were randomly interviewed. Return (in cash) of crops from per acre of land was calculated. The objectives from the collected information were to find out (i) farmer's family size (ii) Average cultivated land per family and (iii) Total input (expenditures) and output (return) for the cultivation of rice and wheat from average cultivated land as to find out average net income per family (Table 1).

Eight persons average family size of a farmer with average three acres of land has been calculated from the collected data, which clearly indicates that a big family of eight persons is entirely dependent on the output of only 3 acres of land. The average output from wheat and rice (crops) is total of about 14500 rupees from an acre of land in a year. Thus, 43500 rupees (Approx.) is the annual earning of a farmers' family, which amounts to 120 rupees per day. Converting the same amount into (dollar = 60 rupees in 2007-8), per family income equals to 2($) which indicates that the poverty in the delta is at extremely low level.

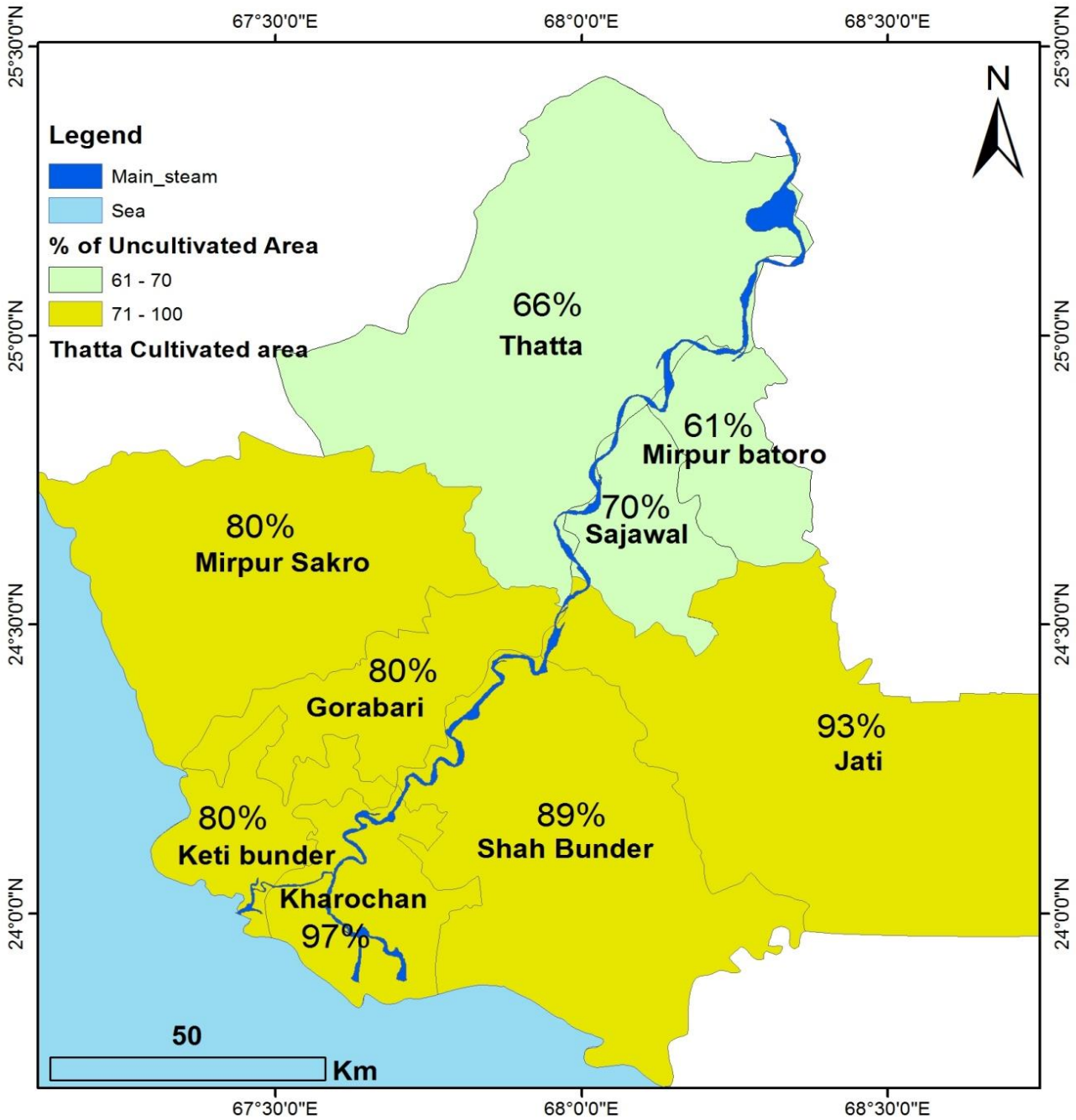

Fig. 4. Map shows the spatial variation (in %) of uncultivated area from 1889-99 to 2007-08.

Table 1. Temporal difference of different classes, extracted from satellite images of 1998, 2008 and 2018.

Classes/Year	1998	2008	2018
Mangroves	21991	28712	70850
Cultivated land	116928	88172	48787
Soil	248564	217867	257268
Wet soil	113519	80683	129077
Salty soil	49873	99508	53327
Water bodies	77595	112574	69264

Social responses: It was observed from the field visits of the study area that an agrarian society that was a stable society sometime back, is now going to be a fragile. The socio-economy and the agriculture in rural societies are inter-dependent as people are totally engaged directly or indirectly with agriculture. It was also observed that social and cultural values of the society are being affected in response to the degrading economic conditions.

Many factors responsible for degradation of delta are discussed like mangrove, sea invasion, salinity issue and (surface and groundwater) water quality, water scarcity etc. The freshwater flow depletion by human activities from the upstream area is the key factor. Moreover, being the degraded land, it requires major investment for rehabilitation which is beyond the reach of local community. The drastic decline in freshwater flow input to Indus Delta resulted in massive seawater intrusion over the riverine areas of the deltas which severely affected agriculture sector due to the land degradation.

Satellite image analysis: Result of image analysis was amazingly different but correlation of results related to crop

cultivation were found to some extent similar from satellite data and ground data. Field survey has been conducted in the cultivated areas. Three sets of images, dated 1998, 2008, 2018 were used to get the decadal temporal difference (Fig. 5). In this study, special concentration was given to mangroves forest and cultivated area. Three sets of classified image show that cultivated area has been in declining position since 1998. In the active part of the Delta, cultivated area in 1998 was covered by 116928 acres after that it was always be in declining condition. In 2008 and 2018, cultivated land cover was 88172 and 48787 acres respectively. Mangroves forests are located near the coast in the active delta. Last 20 years data showed that spatial growth of mangroves is promising. In 1998 mangroves spatial coverage was found about 21991 acres and in 2008 it was increased to 28712 acres. Results in 2018 are very encouraging that show coverage area of about 70850 acres.

Indus river fow: Water is a precious resource for each and every sector of economy and indispensable for agrobased country (Khan *et al.*, 2018). The freshwater availability in the deltaic area is the main environmental indicator that is deteriorating other components of environment. Analyses of water and sediment data from Kotri barrage during the period from 1937-38 to 2007-08 have been carried out. The data of the last seven decades show that water flow and sediment discharge have gradually been decreased (Fig. 6). In 1937-38, flow was 72 Million Acre Feet (MAF), while in last available data in 2007-08, the flow was 5 MAF. The flow trend was temporally analyzed with evaluating construction periods of reservoirs serving as interrupting structures for the water and sediments discharge to the downstream area (Indus delta)**.** The results reveal that the water flow of Indus River from the Kotri barrage is continuously declining. This scenario could create extreme level of crises within the region. The temporal assessment of water flow and sediment discharge also showed drastic degradation of the deltaic land. This situation also showed consequences of deterioration of the agriculture practices and socioeconomic setup.

The development activities in the upstream are responsible for the consequent impact of degradation in the delta and deteriorating socioeconomic conditions of the people in the delta. The present environmental scenario of Indus delta has been the subject of great debate since last six decades. It has been observed and discussed that the development of irrigation network system and water storage on the Indus River in the upstream area have regionally imbalanced the water-flow and the sediment discharge conditions in the region and consequently the degradation of the deltaic region created the socio-economic crises (Wright, 1978; Well & Coleman, 1984; Milliman *et al.*, 1984; Siddique & Jamal, 1991; Siddique 1993; Kahlown & Majeed, 2002; Qureshi, 1999; Qureshi, 2002; Khan *et al.*, 2002; Brohi, 2003; Ghalib & Bhagat, 2004; Ahmed, 2004; Memon, 2005; Kravtsova *et al.*, 2009; Mahar, 2010; Rafique, 2018). The data and review analysis support this situation of the land degradation and the consequent socioeconomic impacts with respect to different environmental disciplines.

Discussion

Food security, water scarcity, land use, socioeconomic and public health are topics of public debate. These issues are greatly related to the agricultural and food production, and more specifically to the work of farmers (Franck, 2016). Rural settlement remains sustained more often because of agriculture but they keep themselves settled because of the common ties and physical engagement with that place (Delind, 2002), that is why it is observed that even under the fragile conditions people remain settled on their native place like in the Delta.

Change in area of cultivation, environmental damage and social harms are the factors that have disturbed the agriculture practices. These are not the only issues of developed countries but it occurred throughout the world (Peterson, 2000). There is a need to address the different strategies to minimize environmental impact on agriculture (Welsh & Rivers, 2010). Same conditions were observed on Indus basin. With increasing population, demand of food is increasing in the upstream area and new technology has provided more capacity to increase the cultivated area and production in the upstream. The scenario of increasing cultivated land and food production in the upstream floodplain has badly affected the downstream area due to the shortage of water in the delta. Moreover, it is realized that farmers' choice to utilize particular agriculture practices can be influenced by many factors like access to technology, community norms and profitability or increasing production (Mcguire *et al*., 2013; Ajayi, 2007; Blesh & Barrett, 2006; Loftus & Kraft, 2003; Thomas *et al.*, 1990; Rickson *et al.*, 1999; Blake *et al.*, 1997; Saltiel *et al*., 1994).

Sea water intrusion and freshwater scarcity are the main indicators responsible for the degradation of Delta. Increasing salinity in groundwater is because of the sea intrusion that is also supported by the continued declining trend of freshwater. This condition has not only reduced the areas for cultivation but also affected the yield of crops in the deltaic area. However, some crops production has also increased in the deltas, these crops depend on the rain fed land. The huge losses of cultivated land and declining rate of productivity under the present environmental flow conditions have economically collapsed farming community of the delta region.

On the other hand, positive results were seen in mangrove forests. Increasing trend of mangrove forests shows that proper steps have taken to increase forestation in the Delta. A large number of *Rhizophora mucronata* have been planted by campaign in 2009 and 2013 that made world records. *Avicenna marina* has been growing naturally while *Rhizophora macronata* is planted because of the favorable conditions have developed in the islands. Floods in 2009 and 2010 have also contributed well for the progress of spatial mangroves growth because mangroves grow well in an environment where freshwater and seawater are mixed together.

In the result of this discussion, regarding the socioeconomic of deltaic land, it is evaluated that i) fresh water inflow has been drastically reduced, ii) that resulted in the intensive seawater intrusion, iii) discouraging agricultural practices related to crop cultivation iv) it affects the socioeconomic of the farmer's life. On the other hand, spatial enhancement in mangroves forest has provided an encouraging environment. All these factors are inter-related with each other. These factors have affected the economic activities that consequently affected the socioeconomics of the people. The eventual result is growing poverty.

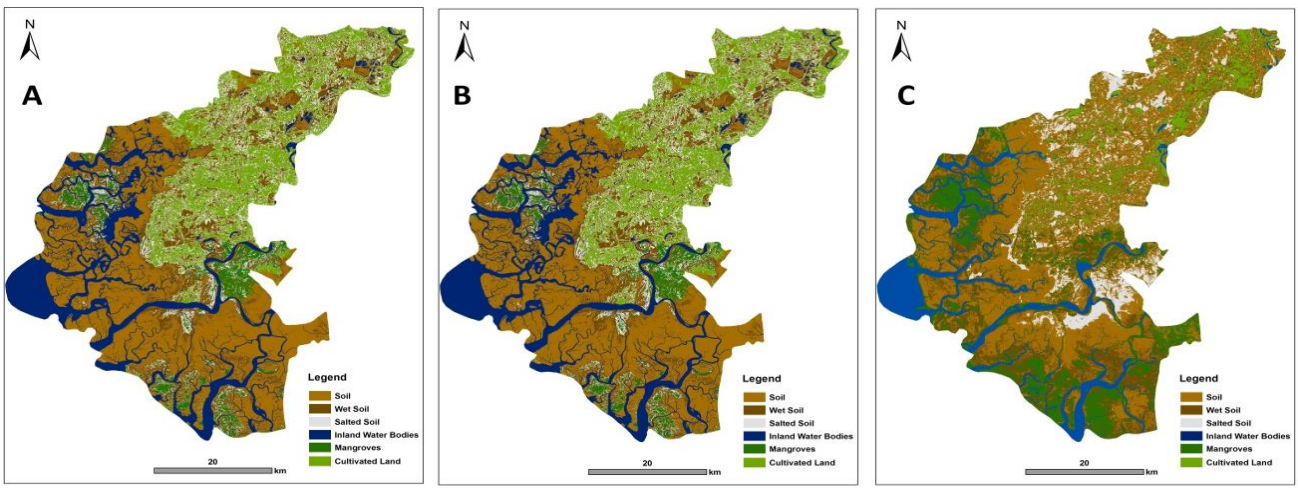

Fig. 5. Classified images from Land sat dated 1998 (A), 2008 (B) and 2018 (C) to identify the special variation of in landuse and land cover especially cultivated land and mangroves.

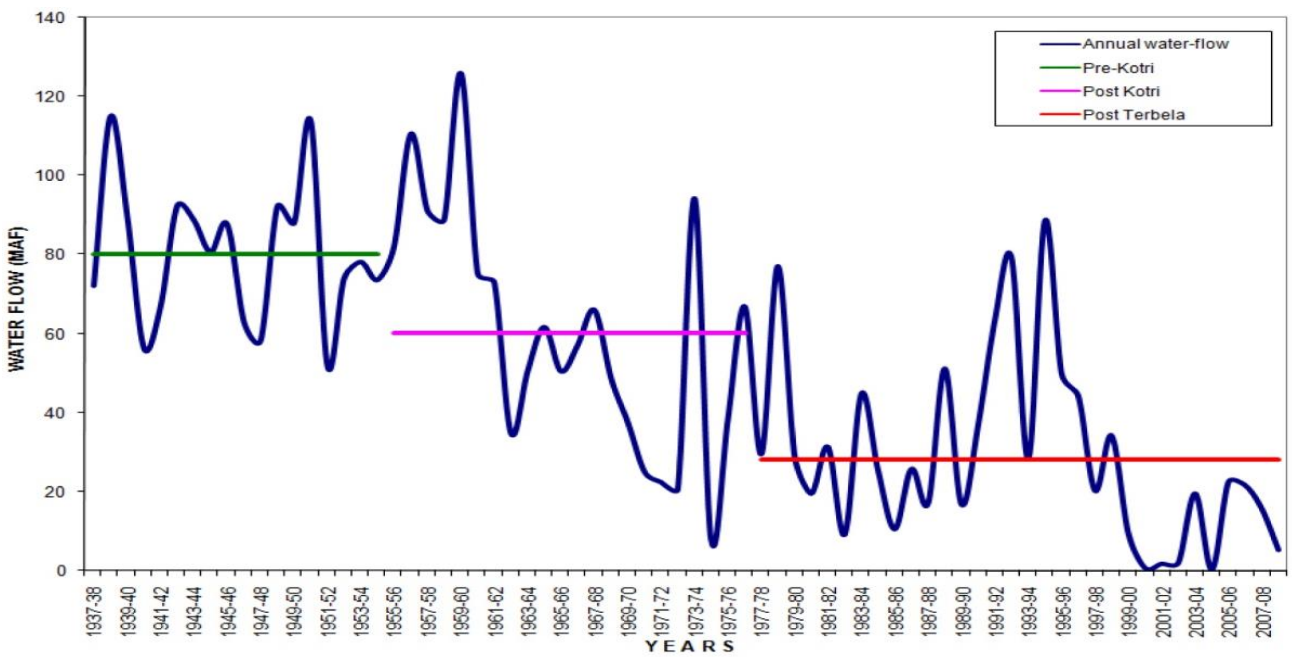

Fig. 6. Line graph shows the Indus River water flow rate from Kotri barrage during the period from 1937-38 to 2007-08. Average flow trend lines shows the average difference of decrease after or before mega projects.

Conclusions

Upper part of the Indus Delta has been a fertile land for agriculture practices in the past. The running down of water-flow and sediment discharge to the Indus delta in response to development activities in irrigation system and water reservoir has flipped scenario of overall economic activities. This situation has consequently affected all agriculture activities including cultivated land, crop production and range land. Increasing population and decreasing cultivated area has affected the economics of the average farmer's family. This situation has developed direct impact on the socioeconomic conditions of the people of the delta. Coastal forest area in active delta has shown a good progress in the last 20 years. Satellite data shows an increasing trend of mangroves forest in southern part of the delta. But overall scenario is not encouraging regarding socioeconomic conditions of the people.

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