

## Temporal Change Study and its Consequent impact on economic, socio-economic and demographic conditions of Indus Delta

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### Abstract

*A study has been conducted on the Indus delta to evaluate the environmental degradation and spatially geomorphic change occurred over the region in last three to four decades. Based on the results, it has been identified that i) the coastline is rapidly receding; ii) creeks' network are enlarging ; iii) tidally influenced areas are rapidly encroaching; v) river morphology is being changed. During the last three decades, it has been observed that the enormous water divergence of Indus river system in the upstream areas have tremendously depleted the water-flow and the sediment discharges to downstream areas particularly into the delta region resulting in the deterioration of deltaic environment, ecosystem, geomorphology and consequently causing the socioeconomic crises in the area. Study also found that overall delta degradation has severely affected the agriculture activities of the deltaic region, resulting in the decreasing in cultivated land, production and yield of the crops.*

**Key Words:** Indus Delta, Satellite Images, Water, Geomorphology, Indus River

### Introduction

River deltas in the world are among the world's most fertile and densely populated ecosystems (Siddique 1993). They serve as critical hubs for agriculture, fisheries, economic activity, and cultural heritage. However, since the end of the last century, these vital landscapes are facing unending degradation leading to existential threats, primarily due to human activities and climate change (Tessler et al. 2015; Szabo et al. 2015).

The growth, development and decay or reduction of the deltas depend on the relationship between the supply of the water and sediments by rivers and the ability of the receiving system, which may be marine or the fresh water (Mahar, 2010).

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The formation of the delta and its subsequent progressive development need specific conditions where the rate of water and sediment supply from the river system is greater than the combined power of tidal currents, sea waves and other coastal activities. The degradation of the delta starts when above mentioned governing phenomena is reversed. Under this situation freshwater hydrostatic pressure conditions are decreased due to the depletion of water-flow and sediment supply, then the domination of the marine tidal current and sea wave dynamic pressure conditions may start prevailing in the coastal region causing degradation impact on different components of the deltaic ecosystem, i.e. coastline, creeks, wetland areas, agriculture activities, coastal/deltaic forests, human settlements and their socio-economic activities etc (Renaud et al. 2013).

During the last three decades, the impact of human activities on the geomorphic features, causing consequent degradation of the delta and subsequent deterioration of the socioeconomics, has been the subject of great debate and the research activities as well (Kuenzer and Renaud 2012). In general, it is observed that the enormous water divergence of the Indus River System within the upstream areas have depleted the water-flow and the sediment discharges to the downstream areas particularly into the Indus delta resulting in the deterioration of the deltaic region and causing the socio-economic crises (Wright, 1978; Well and Coleman, 1984; Milliman, et al., 1984; Siddique 1993; Qureshee, 1999; 2000; Khan et al., 2002; Ghalib and Bhagat, 2004; Ahmed, 2004; Memon, 2005; Kravtsova, 2009). The present literature research study shows that most of the researchers have analyzed the degradation impacts with respect to different environmental disciplines time to time. The remote sensing study of Indus delta authenticates these changes occurred over the delta regions in last decades.

## Methodology

In view to identify the major changes occurred over the deltaic region, temporal study with the help of the satellite data was conducted. Landsat MSS, ETM and ETM+ for the period 1978, 2000 and 2007 were employed for the study. Images were set on the projection of UTM zone 42 and datum of WGS-1984. Composit image was made from each set of bands. Band 3, 4, 5 and 8 were in many spectral combinations were utilized to get the land water delineations and onshore land conditions. Process of digitization of different coastal features and overlay analysis were conducted to get the required results and also analyzed the water flow data of Indus River for about 78 years. Area of features and differences of the area was also calculated. Following delta components have been considered to analyze on the satellite images for the comparative study with respect to the data of the periods of 1978, 2000, 2007:

- Change in the shelf of the delta

- Coastline changes
- Changes in attitude of creeks
- Changes in tidal-influenced area
- Cross-sectional widths variations of Indus river

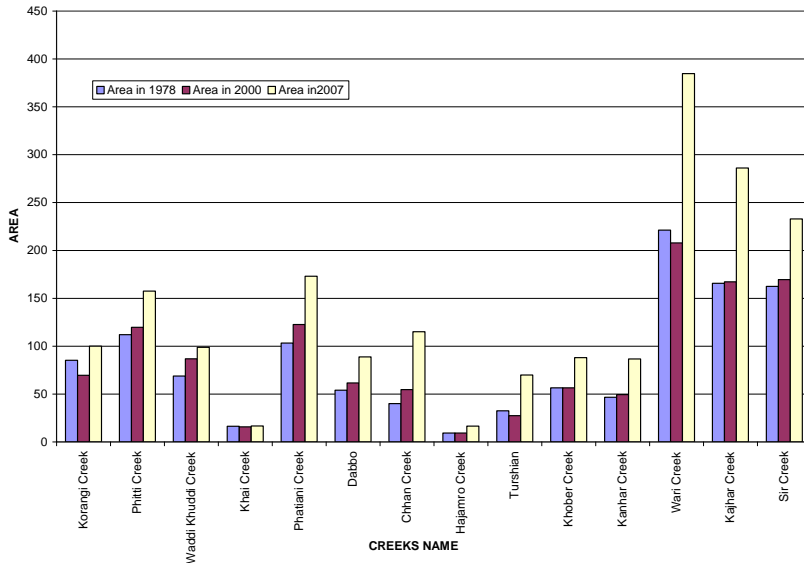
Data of water flow and sediment discharge have been collected from irrigation department for more than 70 years. Another aspect of the study has been observed from the field survey, observation and secondary data. A survey was conducted to know about the land use practices, its consequent effects on peoples' socioeconomic conditions. An unstructured questionnaires were prepared and survey of the whole area has been conducted, almost on all Talukas of the district Thatta.

**Table 1: Major average retreat, submergence and emergence statistics**

Period	Average Retreat (m)	Retreat rate (meter/year)	Submergence area (km <sup>2</sup> )	Rate of submergence (km <sup>2</sup> /year)	Emergence area (km <sup>2</sup> )	Rate of emergence (km <sup>2</sup> /year)
1895-1978	306.87	3.69	331.96	3.99	228.85	2.75
1978-2000	185.80	8.44	124.66	5.66	62.23	2.82
2000-2007	208.33	29.76	76.5	10.92	6.05	0.86
1978-2007	396.66	13.67	169.64	5.84	36.36	1.25
1895-2007	710.80	6.34	400.83	3.57	162	1.44

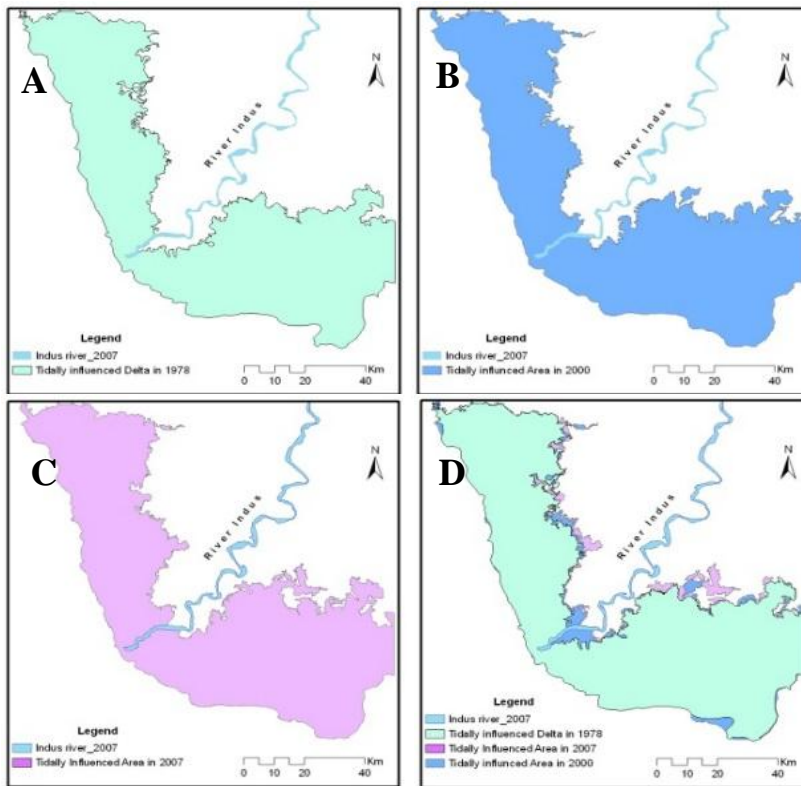
## Results and Discussion

The present results of the bathymetry coastline of 1895 and satellite images of 1975, 1978, 2000 and 2007 show prominent changes on larger scale. In general, the average coastline retreat has been calculated to be at the rate of 6.4 m/year during the period of 112 years from 1895 to 2007 along Indus delta. However, the rate of retreat is estimated as 3.69 m/year during the initial period of 83 years from 1895 to 1978, which has considerably increased to the rate of 8.44 m/years during the 22 years period from 1978 to 2000. Furthermore, the analyses of satellite images of 2000 and 2007 and the correlation of their results show a rapid retreating trend at the rate of about 29.76 m/year during the period of 7 years (*Table 1*).



**Figure 1: Plot shows the comparison among the calculated areas of major creeks from images of 1978, 2000 and 2007**

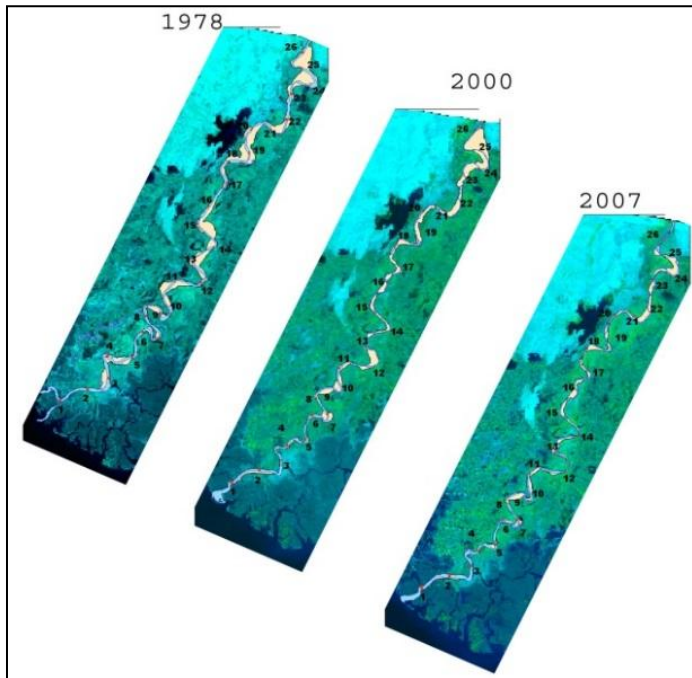
The correlation study of coastline changes also shows a continuous trend of submergence of the western part of the delta from the mouth of the river to the Karachi coast from 1895 to 2007. The southern part of the delta shows emergence, which is restricted to the shorter length of the delta towards southeast of the river mouth, and again submergence behavior continues further eastward. The areas of 332 km<sup>2</sup> at the rate of 4 km<sup>2</sup>/year, 125 km<sup>2</sup> at the rate of 6 km<sup>2</sup>/year, and 77 km<sup>2</sup> at the rate of 11 km<sup>2</sup>/year have been submerged during the period of 1895-1978 (83 years), 1978-2000 (22 years), and 2000-2007 (7 years), respectively. On the other hand, the areas of about 229 km<sup>2</sup> at the rate of 2.75km<sup>2</sup>/year, 62 km<sup>2</sup> at the rate of 2.82 km<sup>2</sup>/year, and 6 km<sup>2</sup> at the rate of 0.86 km<sup>2</sup>/year have emerged during the period of 1895-1978, 1978-2000, and 2000-2007. These trends show that during the latest period, the submergence activities are higher, indicating the intense erosional processes prevailing along the Indus deltaic coastline under the dominating environment of marine hydrodynamic conditions (Figure 1).



**Figure 2: Maps show variation trends of Tidal Influenced Areas (TIA) along the delta. Maps A, B, C, are from period 1978, 2000, and 2007, respectively, and Map D is over of all these maps.**

Based on the results of the present study, the creek network shows distinct changes in the dimension of the individual creek as well as the whole creek network with respect to the period 1978, 2000, and 2007. The total network area has been calculated as about 1173 km<sup>2</sup> on image 1978, 1217 km<sup>2</sup> on image 2000, and 1878 km<sup>2</sup> on image 2007. The results show that about 138.97 km<sup>2</sup> area during 1978-2000 at the rate of 6.31 km<sup>2</sup>/year and about 678.96 km<sup>2</sup> area during 2000-2007 at the rate of 96.99 km<sup>2</sup>/year have increased due to the erosional activities. On the other hand, about 82.89 km<sup>2</sup> areas at the rate of 3.76 km<sup>2</sup>/year and 18.59 km<sup>2</sup> area at the rate of 2.65 km<sup>2</sup>/year have been reduced due to the accretional/depositional activities during the periods 1978-2000 and 2000-2007, respectively. This trend further indicates the onset of severe intensity of landward sea invasion into the middle or upper deltaic region as reflected by the presence of extensive tidally

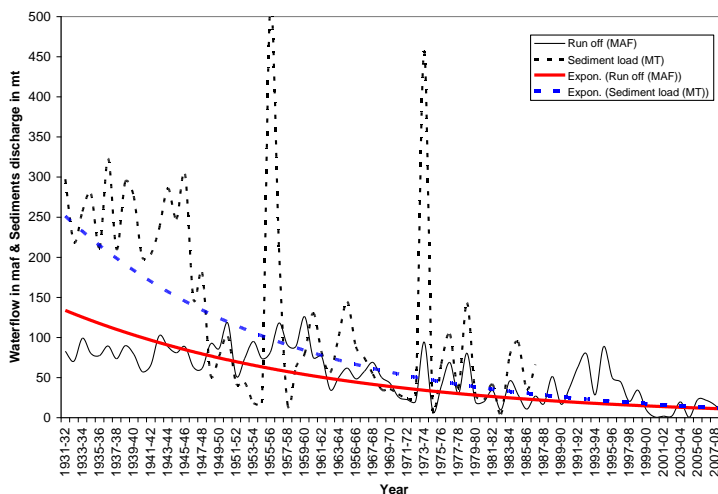
influenced areas. The comparison of tidally influenced identified areas measured as 5325 km<sup>2</sup>, 5413 km<sup>2</sup> and 5601 km<sup>2</sup> on images of 1978, 2000 and 2007 respectively, shows an increase of about 88 km<sup>2</sup> during the period of 22 years (1978-2000) at the rate of 4 km<sup>2</sup>/year and an increase of 188 km<sup>2</sup> during the period of 7 years (2000-2007) at the rate of 27 km<sup>2</sup>/year (Figure 2).



**Figure 3: The clips of the satellite images show the location of cross-sections and the measured width traces of the thalweg and course of the Indus River for the periods of 1978, 2000, and 2007.**

Moreover, significant changes have been observed in the widths of the thalweg and the course of the Indus River within the delta region as revealed from the analyses of the satellite images of different periods (Figure 3). Based on the results, it is inferred that the strong sea waves and tidal currents have caused erosion and subsequent widening of the thalweg and the course of the river during the last 30 years from 1978 to 2007 at the river's mouth. In general, the widths of the Indus thalweg and course have increased with an average of 6 m/year and 26 m/year from 1978 to 2007, respectively, in the lower delta segment of the river. But in the upper delta segment, the widths of the thalweg and the course have reduced with an average of about 16 m/year and 64 m/year respectively, during the same period. The trend of the erosional behavior indicates the dominant control of the seawater

in the river thalweg up to the areas almost down to Kotri barrage, as the fluvial processes have practically been weakened due to the extreme depletion of Indus water flow into the delta. Quantitative as well as qualitative analyses have been carried out relevant to the Indus river water-flow and the sediments discharges from 1931 to April 2009 (Figure 4). The flow trends have also been analyzed with respect to the construction periods of dams and barrages serving as interrupting features for the water-flow and sediments to the Indus delta region. The results of the present study reveal that the Indus water-flow has tremendously been decreased to the level of acute crises within the region.



**Figure 4: Graphic plot shows the water flow trend from 1931 to April 2009, the sediments discharge trend from 1931 to 1987.**

### Land Degradation Impact on Landuse and Demography

Deltaic area degradation leads to a decline in productivity is often the combination of unfavorable environmental factors as discussed above, but sometimes unsuitable or conventional farming techniques (*Worster, 1979; Zonn et al., 1994*). Such phenomenon is found in many parts of the world that lead to developed issues like population moment, land colonization, and environmental degradation (*Zonn et. al., 1994*). This study also found similar causes and affects situation as delta degradation has affected the land use practices leading to economic and demographic modification within the Indus delta.

A survey was conducted in 2000 by Sindh government to found out that how much land had been eroded by the sea. It was found from the data that the six Talukas situated along the coastline of the Indus delta, namely Ketu Bunder, Shah

Bunder, Kharochan, Jati, Mirpur Sakro, and Gorabari, have a total of 475 Dehs. Out of total 475 Dehs, 124 Dehs were found eroded from these Talukas. The results of this survey discovered the severe intensity of the sea invasion as well as sea intrusion, causing the degradation of the land of almost the whole delta. The sea intrusion impact on each affected Taluka was declared devastating. Ketu Bunder was found about 86% eroded, Shah Bunder was found about 30% eroded, Kharochan was found about 69% eroded, and Jati was about 57% eroded. Mirpur Sakro and Gorabari were found to have relatively less seawater impact. The sea intrusion pattern shows that the Talukas close to the mouth of the Indus River are eroded due to the sea invasion intensity.

### **Agricultural**

The area to the landward sides has also deteriorated due to scarcity of freshwater in the region. This phenomenon has resulted in the reduction of yield per acre in this region. It was also found that cultivable area is going to be converted into uncultivated area. Considering the enormous reduction of the cultivation activities and severe socioeconomic impact on the community living in these Talukas, the government has allotted alternate land to the affected communities for cultivation in the upper delta region without proposing any plan for the land rehabilitation (*DCO, 2003, Personal communication*). When no plan is found for the rehabilitation of the eroded land, it was assumed that the probability of more area being eroded is higher in the years to come.

In response to the land use activities, economic and socioeconomic impact was also found. A survey was conducted of the whole region to evaluate the pattern of crops, its production, and known losses. From the present discussion of the results regarding the degradation of deltaic land due to the intensive seawater intrusion affecting the i) the coastline, ii) the riverine part of delta, iii) the declining conditions of agricultural practices related to cultivable areas and iv) the decreasing yield of the cultivated crops, it is concluded that the loss of a big agricultural land, causes to decrease in the yield of main cashable and traditional crops (like rice, sugarcane and wheat), the change in the cropping trend towards the rain-fed growing crops have inverse impact on the socio-economic conditions of the people living in the deltaic region. The poor has become poorer, facing extreme environmental, economic, and socioeconomic conditions.

The study found that negative environmental effects lead to land degradation that consequently affects the socioeconomic conditions of the affected area. Deteriorating conditions of any place either effects on the living standard or force people to move from that place. During the survey, it was observed that the villages near the coastal area, like Ketu Bunder, Kharo Chan, Shah Bunder, etc., have almost been evacuated. In these areas, sometime back, fruit farming, vegetable,

wheat and rice, and many other crops were cultivated, is now abundant with no population.

The study has also found many imbalances. Hydrodynamics imbalance from freshwater to brackish water, land use disturbance and agriculture, economic and socioeconomic conditions. All these imbalances led to the devastating conditions in the delta that force people to move from this region. A large number of movement were observed in last two decades. Hydrodynamic conditions have deteriorated due to the construction of a big water storage and canal command system on the Indus River. It was observed that in the last 70 years, as number of canals has increased and dams & barrages are being constructed on the river Indus. Water after the Kotri barrage is going to decline. The declining trend is linked with the construction of dams and barrages. This situation has totally devastated the natural phenomena of the Indus Delta. It seems that conditions will not move to the right directions. The government, especially the coastal development authority, should make a concrete policy so that the delta can be saved from further destruction.

### **Conclusion**

During the present study, the degradation of the geomorphic features of the Indus delta has been studied in response to the ever-changing water-flow and sediment discharging trends of the Indus River with the passage of time. The study covers the detailed analyses of the coastal morphology and the main causes of these degradation changes that occurred over this region. Study found that river morphology, coastal line, tidally influenced area, and creek network have been devastated due to the sea invasion/intrusion and freshwater scarcity. The diversion of Indus River System, due to the construction of dams and barrages, has severely affected the deltaic land. Due to these environmental stresses, fertile land of the delta is going to be abandoned. Land is going to be incapable of cultivation, causing to decline in agricultural practices in the deltaic region. These conditions have affected the economic, socioeconomic and demographic conditions of the Indus Delta.

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