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Land Use/Land Cover Changes Through Satellite Remote Sensing Approach: A Case Study of Indus Delta, Pakistan

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Abstract. The Indus deltas with its coastal zones are the most important coastal environment for mangrove and related habitats in Pakistan. The aim of the study is to identify the land use/land cover (LULC) classes of the Indus Delta during 2000 and 2014 through satellite remote sensing (SRS), to evaluate the LULC changes of Indus Delta during this period and to investigate the LULC classes from ground truths. Satellite remote sensing is a modern technique for detection and mapping of LULC patterns and their changes without going into survey. Satellite images of Landsat-7 ETM+, March 8, 2000 and Landsat-8 OLI/TIRS, April 8, 2014 were used. A supervised classification technique was used to classify ten LULC classes. Results indicate that normal mangrove, cultivated land, dry mudflat, dry barren / vacant land and turbid water increased with 324.93 km^2 (23.21 km^2/year), 749.44 km^2 (53.53km^2/year), 171.01 km^2 (12.21 km^2/year), 375.31 km^2 (26.81 km^2/year) and 59 km^2 (4.21 km^2/year), respectively, during the period of 2000-2014 due to plantation of mangroves in various creek areas in Indus Delta by Sindh Forest and Wildlife Department, SCCP, IUCN, WWF, etc. in the year of 2009 to 2013. Cultivated land is increased after the flood of 2010 and 2013 in the northern part of Indus Delta, while dense mangrove, other vegetation, wet mudflat, wet barren/ vacant land and deep water decreased with 12.99 km^2 (0.93 km2/year), 280.58 km^2 (20.04 km^2/year), 290.54 km^2 (20.75 km^2/year), 844.59 km^2 (60.33 km^2/year) and 237.16 km^2 (16.94 km^2/year), respectively, during 2000-2014. Some areas of other vegetation lands are converted to cultivated lands during 2000 to 2014. Similarly, some wet mudflat and wet barren / vacant land are converted to normal mangrove in the southern part of Indus Delta. Many factors affect the LULC of Indus Delta like sea water intrusion, insufficient freshwater below Kotri barrage, and at least one annual cyclone destructive to Sindh coast.

Keywords: GIS, SRS, environment, mangrove, ecology, Indus Delta.

Introduction

Land use/Land cover (LULC) change deals with identification of various natural and human activities, qualitative assessments and the socio-economic context. LULC changes are used in human activities and natural hazards on land. Satellite Remote Sensing (SRS) is broadly used to investigate and monitor Land use/Land cover at different scales (Seto and Kaufman, 2003). Nowadays, remote sensing with Geographical Information Systems (GIS) and Global Positioning System (GPS) have provided more comprehensive monitoring of LULC changes than remote sensing alone. SRS is a technique for investigation, quantification and mapping of LULC patterns and their changes without field work. It is a useful technique to monitor LULC and environmental changes as results of human activities (Rehman *et al*., 2016). It is very well suited for reflection of wave currents, tides, shallow water, mangroves, wetland, soil degradation, vegetation, cultivated land and coastal changes.

The Indus Delta extends from Korangri Creek to Sir Creek (Fig.1). The Indus Delta consists of seventeen major and several minor creeks. The Indus Delta and its coastal zones are the most important coastal environment for mangroves and related habitats. It is important for fisheries, mineral resources and aquaculture. Once upon a time, the Indus Delta was close to Hyderabad and now it is in Thatta. Chandio *et al*. (2011) recognized the reasons of degradation of Indus Delta. This degradation is observed for last two decades due to decrease of freshwater from Kotri downstream. The saline water of Arabian Sea has been growing and water creeping under sub surface is dangerous for fauna, flora, crops and fish breading.

The objectives of the present study are as follows:

- To identify the land use/land cover patterns of the

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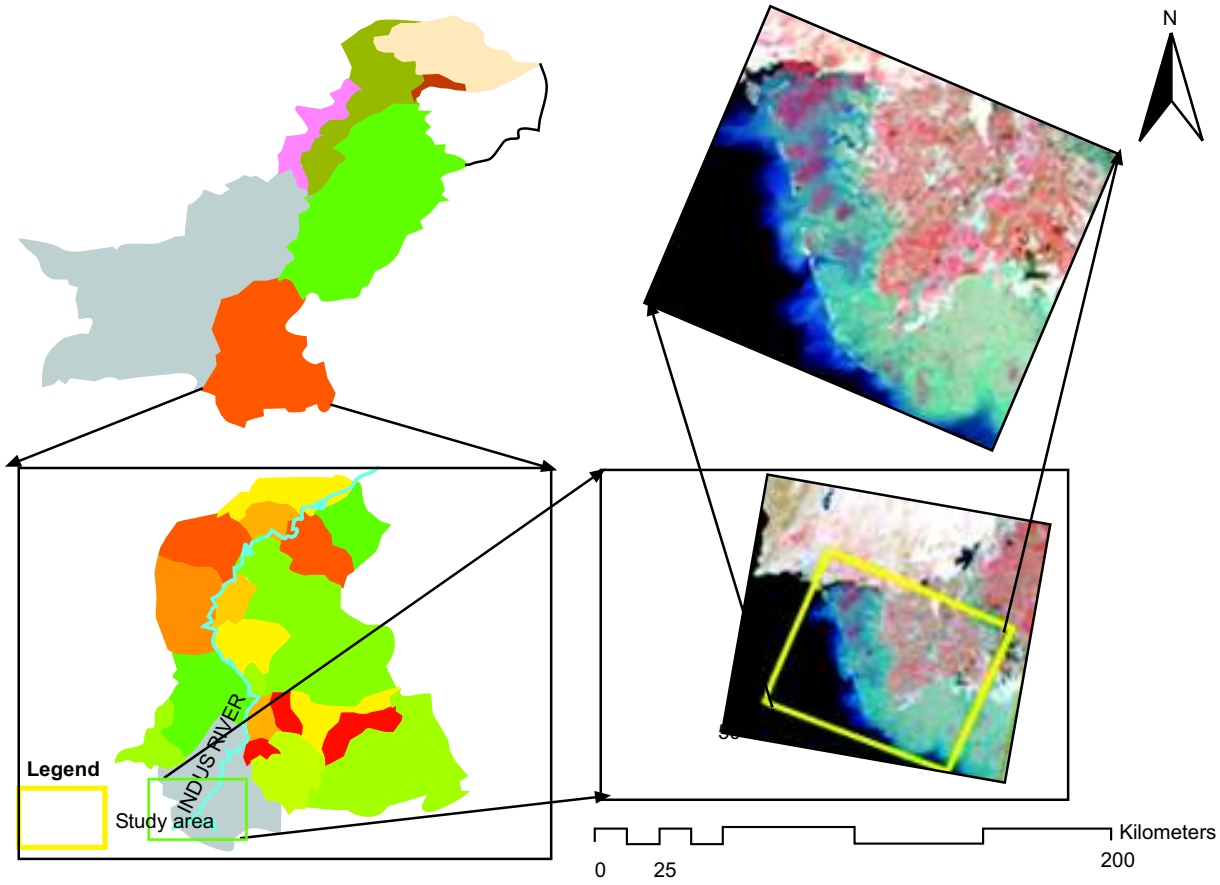

Fig. 1. Indus Delta study area.

Indus Delta in 2000 and 2014 with Satellite Remote Sensing.

- To evaluate the land use/land cover changes of Indus Delta between 2000 and 2014.
- To investigate the LULC classes with ground surveying.

Materials and Methods

The study used satellite remote sensing and GIS Landsat-7 ETM+ (March 8, 2000) and Landsat-8 OLI/TIRS (April 8, 2014) satellite images were downloaded from official Earth Explorer USGS distribution website *(http://*earthexplorer.usgs.gov) and Google Earth imageries were also used in the study.

Supervised classification is characterised as the way of utilizing samples of known identity to classify pixels of obscure character (Cambell, 2002). Samples of known personality are pixels situated inside preparing regions (Rehman *et al*., 2016; Sohail, 2012; Cambell, 2002). Supervised classification of the acquired images was carried out with the ERDAS Imagine 2013 software. Land use/Land cover classes were classified using supervised classification (Fig. 2).

Field work is a very important part of the research, for assessment of ground realities with classified maps through various parameters including questionnaires, interviews, photographs and location identified with a GPS device. All parameters of field survey are applied in the study.

Results and Discussion

The area of dense mangrove in the dark green colour is shown in Fig. 3 and Table-1 on the map. It is 56.82 km^2 in the supervised classification of 2000 and it declined to 43.82 km^2 in the supervised classification of 2014. The difference is 12.99 km^2 decreases and the rate of declined area of dense mangrove is 0.93 km^2 per year during 2000-2014. The normal mangrove shown in the light green colour is 584.46 km^2 in the year of 2000 and it increased to 909.39 km^2 in 2014.

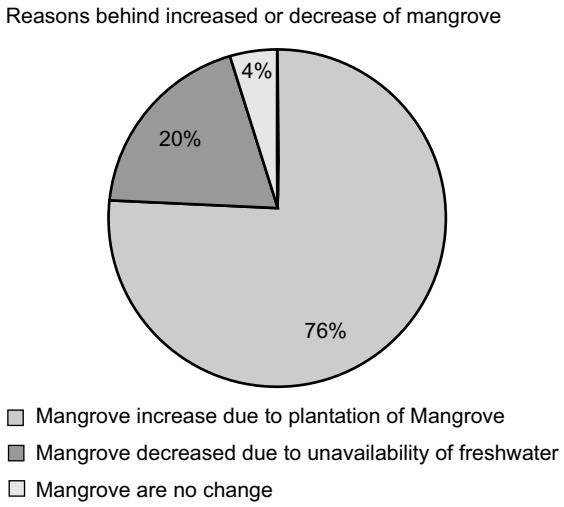

Fig. 2. Mangrove status according to many respondents in field survey.

The difference is 324.93 km^2 increases and the rate is 23.21 km^2 per year.

The Indus Delta covers an area of about 41,440 km^2 and is the 7th largest mangrove forest in the world. Eight mangrove species were reported before in the Indus Delta, but nowadays only three mangrove species (*Avicennia marina*, *Rhizophora mucronata* and *Aegiceras corniculata*) are found, of which *Avicennia marina* covers up to 95-98% of the mangrove forests (Rehman *et al*., 2015). On the basis of field survey, questionnaire and interviews, Fig. 2 shows that about 76% respondents out of 300 respondents, who participated in the survey, said that mangrove forest increased due to several plantations of mangroves, 20% respondents said mangroves decreased due to unavailability of fresh water and 4% of respondents said no change. Figure 4 shows the nursery of species of mangrove forest observed in field survey namely, *Avicennia marina*, *Aegiceras corniculata*, *Ceriops tagal* and *Rhizophora mucronata*.

Mangrove forest is very important for our environment, ecology and biodiversity. Mangrove forest functions as barrier of floods, storms and cyclones, and as habitats for fish, shrimp and migrating birds. Sindh Forest Department and other organizations like WWF, IUCN, and Indus Forever have planted mangroves in the creeks of Shah Bandar, Bin Qasim, Sajawal, and Keti Bandar. In 2009, Pakistan made World Record of Guinness Book for planting 545,000 mangroves in a single day.

Figure 3 and Table-1 show that the area of cultivated land is 1780.01 km^2 in 2000 and it increased to 2529.45 km^2 in 2014. The difference is 749.44 km^2 increase and the rate is 53.53 km^2 per year during 2000-2014. Other vegetation took 336.54 km^2 in 2000 and it reduced to 55.96 km^2 in 2014. The difference is 280.58 km^2 decrease and the rate is 20.04 km2 per year during 2000-2014.

Major crops in the Indus Delta region are cotton, rice, wheat, sugarcane, maize, mango, banana, dates, guava, water melon, musk melon, pumpkin, capsicum, chilies, brinjal, onion and tomatoes. On the basis of field survey and questionnaires, out of the 300 respondents who participated in the survey, 20% respondents have below 20 acres cultivated land, 12% respondents have 20 to 40 acres cultivated land, 8% respondents have above 40 acres cultivated land, 60% respondents have no cultivated land (Fig. 5). 80% aforementioned crops are grown at Indus River, lakes and canals area. The region

Table 1. Calculated area (km^2), Change (km^2) and Rate (km^2/year) from supervised classification of 2000 and 2014.

LULC Class Name	2000 Area (km^2)	2014 Area (km^2)	Change 2000-2014 Area (km^2)	Rate 2000-2014 (km^2 / year)
Dense mangrove	56.82	43.82	-12.99	-0.93
Normal mangrove	584.46	909.39	324.93	23.21
Cultivated land	1780.01	2529.45	749.44	53.53
Other vegetation	336.54	55.96	-280.58	-20.04
Wet mudflat	2439.85	2149.31	-290.54	-20.75
Dry mudflat	185.79	356.80	171.01	12.21
Wet barren/vacant land	1735.72	891.14	-844.59	-60.33
Dry barren/vacant land	152.96	528.27	375.31	26.81
Turbid water	2454.98	2513.98	59.00	4.21
Deep water	2220.82	1983.66	-237.16	-16.94
Total	11947.95	11961.77	13.82	0.99

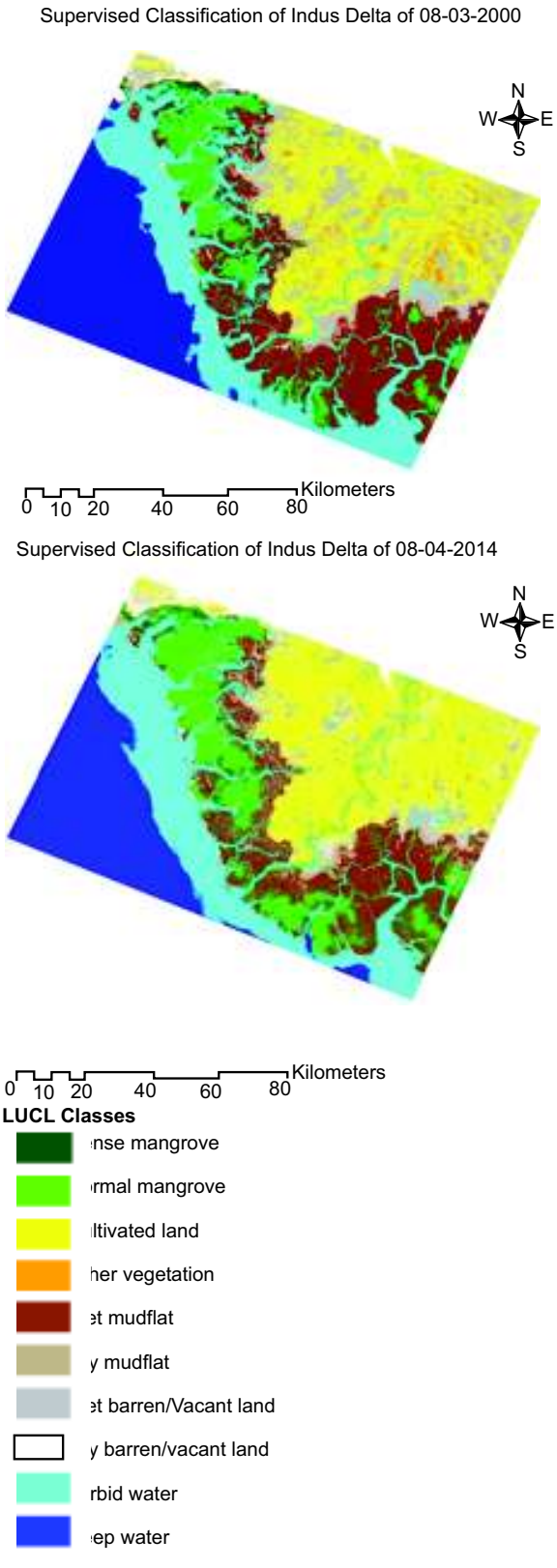

Fig. 3(a-b). Supervised Classification of Indus Delta in the year of 2000 and 2014.

Fig. 4(a-d). Mangrove species: (a),(b) & (c) Mixing of *Avicennia marina*, *Rhizophora mucronata*, and *Aegiceras corniculata* (d) Mixing of *Avicennia marina*, *Aegiceras corniculata* and *Ceriops tagal*.

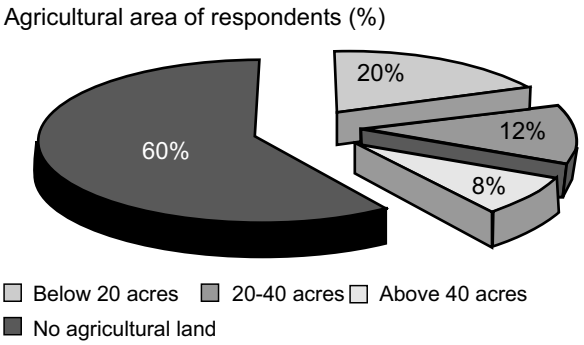

Fig. 5. Area of agriculture land.

has been experiencing many agricultural problems like sea water intrusion, water logging and salinity, unavailability of freshwater, and less rainfall, which bring significant impact to agricultural land use (Fig. 6).

Figure 3 and Table-1 show that the area of wet mudflat is 2439.85 km^2 in 2000 and it is declined to 2149.31 km^2 in 2014. The difference is 290.54 km^2 and the rate of reduction is 20.75 km^2 per year during 2000-2014. Some area of wet mudflat is converted and adds to some area of normal mangrove and dry mudflat area. As far as dry mudflat is concerned, the total area of dry mudflat is 185.79 km^2 from classification of 2000 that is increased to 356.80 km^2 from the classification of 2014. The extent of increase is 171.01 km^2 and the rate of increased area of dry mudflat is 12.21 km^2 / year during 2000-2014.

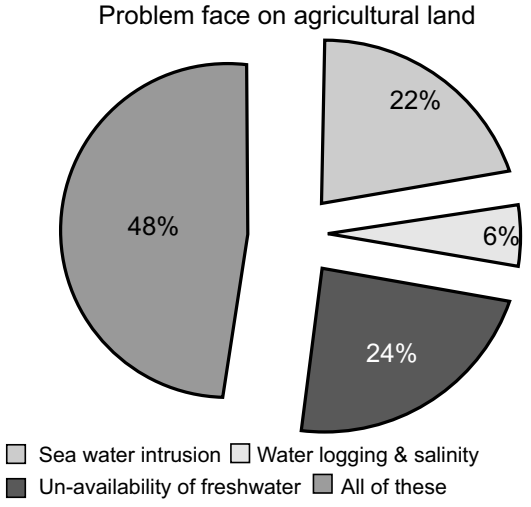

Fig. 6. Problems faced on agricultural land on the basis of field survey.

Figure 3 and Table-1 also show that the area of wet barren/vacant land cover is about 1735.72 km^2 from the classification of 2000 declined to 891.14 km^2 in the year of 2014. The change of reduced area of wet barren/ vacant land is 844.59 km^2 and the rate of reduced area is 60.33 km^2/year during 2000-2014. Due to some area of wet barren/vacant land is converted to some area of dry barren/vacant land. As far as dry barren/vacant land is concerned, the area of dry barren/vacant land is 152.96 km^2 in 2000 that is increased to 528.27 km^2 in 2014. The change of increase in area is 375.31 km^2 and the rate of increase area is 26.81 km^2/year during 2000-2014.

Figure 3 and Table-1 show that the area of turbid water is 2454.98 km^2 in 2000 that is increased to 2513.98 km^2 in the year of 2014. The change area during study period is increased to 59 km^2 and rate of increase is 4.21 km^2/year during 2000-2014. As far as deep water is concerned, the area of deep water is 2220.82 km^2 that is decreased to 1983.66 km^2 in 2014. The change of reduced area is 237.16 km^2 and rate of reduction of deep water is 16.94 km^2/year during 2000-2014.

Figure 7 indicates a strong and positive relationship between Satellite Remote Sensing techniques and ground realities of land use/land cover classes of Mirpur Sakro and Ghorabari area of Indus Delta. Black points show GPS location on field survey. Photos at the top of the figure show the area's environmental problems. First two photos capture to Armani Farm near Pitiari creek. A few years ago, this farm was very healthy, but now it has become dried due to sea level rise and unavailability of fresh water. The photos on the left and bottom of the figure mention agricultural practice in different areas. However, the photos on the right side of Fig. 8 indicate some socio-economic activities and lakes of that area.

Factors affecting LULC changes of Indus Delta. Several factors affect the land-use/land cover changes of the Indus delta.

- Freshwater plays a vital role for survival of mangrove ecosystem, biodiversity and ecology of the Indus Delta. After the construction of Kotri Barrage, the flow of fresh water below Kotri downstream is insufficient. For survival of natural habitat i.e., mangroves, fish, bird, mammals, agricultural land, and freshwater of 27 MAF is required (IUCN, 1991). But now, only 0.72 MAF freshwater released. Due to this shortage all major and minor creeks of Indus Delta fill in sea water except Khober creek. In the last three decades agricultural land around creeks

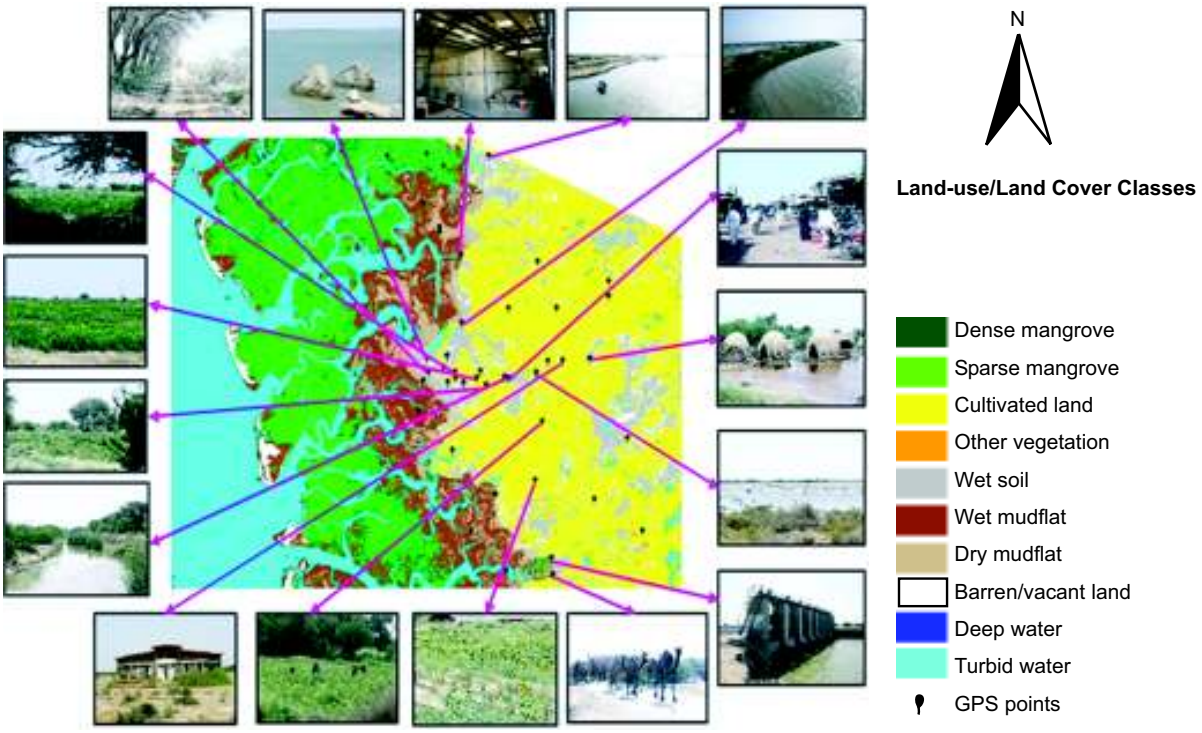

Fig. 7. Field survey of land use/land cover classes in different areas of Indus Delta.

of the Indus Delta was badly destroyed like the Armani Farm in Pitiari creek, shown in Fig. 8 (a-b). Furthermore, red rice was cultivated in this region but now it is absent here.

- Because of rising sea water level, the salinity of that area is also increased. Sea level rise is about 15 to 20 cm at the rate of 1.5 to 2 mm per year (IPCC, 2007). On the basis of satellite measurements, sea level rise is 3.1 mm/year. Around 525,000 ha of agricultural land of six sub-districts of Thatta were affected; due to this several people were migrated (Memon and Thappa, 2010). Salinity has up surged from 3.8% to 4.2% on the other hand salinity of Arabian Sea is 3.6%. It is observed in field survey that sea water entered in land as mentioned in Fig. 8 (c-d).
- Cyclones and heavy monsoon rainfall are also affected. In super flood of 2010 around 20 million individuals were affected, 1,781 deaths resulted, and the flood crushed more than 1.89 million homes. Cyclone A2 in 1999 was one of most powerful cyclones in Pakistan history. The cyclone eye developed in the Keti Bander area. This cyclone was most destructive and 6400 people died in the coastal belt of Sindh.

Conclusion

Satellite remote sensing is very helpful to analyse and monitor land cover changes. It provides vast range of bands for the detection of special patches in the area. Temporal datasets give good comparison of the historical and present condition in the study area. Landuse/Land cover of Indus Delta are continuously changing with respect to the time period. Normal mangrove, cultivated land, dry mudflat, dry barren/vacant land and turbid water increased with 324.93 km^2 (23.21 km^2/year), 749.44 km2 (53.53km2/year), 171.01 km2 (12.21 km^2/year), 375.31 km^2 (26.81 km^2/year), and 59 km^2 (4.21 km^2/year), respectively during the period of 2000-2014. Mangroves were planted in various creeks area by Sindh Forest and Wildlife Department, SCCP, IUCN, WWF etc. in the year of 2009 to 2013. Cultivated land increased after the flood of 2010 and 2013 in northern part of Indus Delta. While dense mangrove, other vegetation, wet mudflat, wet barren/vacant land and deep water decreased by 12.99 km^2 (0.93 km^2/year), 280.58 km^2 (20.04 km^2/year), 290.54 km^2 (20.75 km^2/year), 844.59 km^2 (60.33 km^2/year) and 237.16 km^2 (16.94 km^2/year), respectively during 2000-2014. Some areas of other vegetation land are converted and added to some other area of cultivated land during 2000 to

2014. Similarly some other areas of wet mudflat and wet barren/vacant land are converted and add to some area of normal mangrove in southern part of Indus Delta. Sea water intrusion and lack of fresh water have negatively affected the ecology, biodiversity and land use degradation.

Fig. 8. Problem faces of Indus Delta (a) & (b) Salinity & Water Logging (c) & (d) Sea Level Rise (Source: Author)

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