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Quantify Assessment of Flood Affected Areas (2010-2012) Using Remotely Sensed Data

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Abstract— The objective of this research is to give a way how MODIS time serious imagery is utilized to monitor the extent of flood temporally affected areas by quantify assessment of land cover/land use. MODIS time serious imagery is very useful to map out the flood extent. In addition of other spatial data infrastructure damage assessment is quantified as flood is risk to society and economy therefore a better and sustainable management plan is required to access flood risk. Remotely sensed data is used to monitor the land use changes and to locate the flood prone areas in the lower Indus basin, Sindh, Pakistan. For monitoring and mapping MODIS (Terra) with daily rainfall and discharge data is used while for the detail assessments of selected areas, medium resolution satellite data.

Index Terms— Extent of flood, Flood prone areas, Damage assessment, Discharge data, Land cover/land use, MODIS, Sustainable management.

1 Introduction

Any unusual high stream flows that overtop the natural or manmade levees of a river are normally defined as a flood. When rivers outflows their banks they inundate the low lying areas and cause as damage to property, crops and loss of humans life (Dhillon, 2008). Usually floods are events did not last long but can be widely and sometimes it can be catastrophic, warning occurs with little or no prior. The floods are most happened by the prolonged rainfall that saturates the ground and caused the surface water to runoff into nearby streams and rivers that increasing the discharge.

The Asian region experience frequent flood disaster of high magnitude. In some region of the world flood is caused by the excessive rainfall like in monsoon, while in some other parts it is caused by the melting of snow and ice due to climate change. Reservoirs normally help to prevent downstream areas of dams from flooding. They allow maintaining, regulating the water levels to avoid from overflowing. If the water is not properly regulated, dams can break resulting as a flood causing loss of human life and settlements.

Geographically, Pakistan is situated in hazard-prone region and it is exposed to unpredictable seasonal monsoons that bring rain like other South Asian countries. Pakistan is continuously suffering from severe natural disasters that threatened to affect the lives and livelihood of its citizens.

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Floods are the most recurrent natural calamity in Pakistan, followed by earthquakes, and drought. Pakistan was chopped by awful flood in its history by covering one-fifth of the country under water in the year of 2010. As a result, all the four provinces of Pakistan were strongly influenced during the monsoon rains due to this rains dams, rivers and lakes were overflowed, killed at least 1,750 people ,injured 2,500 and 23 million people were affected. The lower half of the Sindh province received record breaking rains. Average rainfall in the lower Sindh was between 200-250 mm in 2011, which usually occurs from July to August. In 2012, it became late in September and the districts of Mirpurkhas, Badin and Shaheed Benazirabad received 810, 680 and 640 mm rain respectively; way beyond the normal mean.

In Pakistan floods are almost yearly occurring event, Pakistan, since its foundation faced several floods during 1950, 1956, 1957, 1973, 1976, 1978, 1988, 1992, 1995, 2001, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011 and 2012, which causes huge amount of human and financial losses. Floods of different magnitude have been occurred 1952 to 2012 in Punjab, Sindh, and Khyber Pakhtunkhwa; Flash flood caused damage

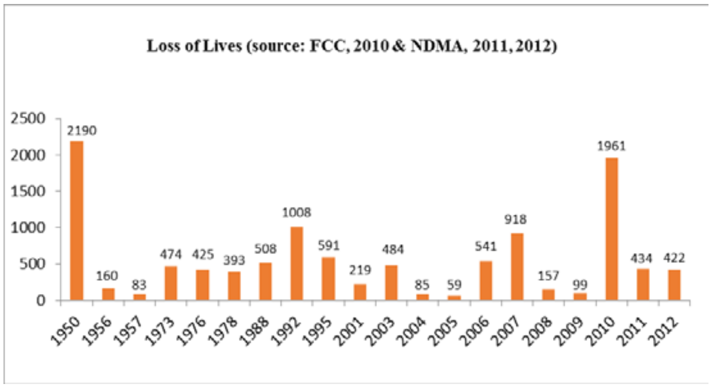

Fig. 1. Graphs shows loss of lives (source: FCC, 2010 & NDMA, 2011, 2012)

hilly areas of Khyber Pakhtunkhwa, FATA, Gilgit Baltistan and Punjab (FFC, 2010). The graph of loss of lives and number of affected villages are shown in figure 1 and figure 2.

In Sindh there are two reasons of flood, one is riverine and other is torrential flood. Riverine flood is a calculable and allow an enough time to respond while torrential flood takes less time to react. The intensity of torrential flood is high but has less frequency and duration. This type of flood occurs mostly in months of monsoon when the catchment areas in Balochistan receives heavy rains, western boundary of Sindh is connected with Balochistan through Khirthar hills. Peak floods are 1942, 1944, 1948, 1956, 1973, 1975, 1976, and 1995, among these floods1976 and 1995 were large in weight and marked great failure to the flood protection communities.

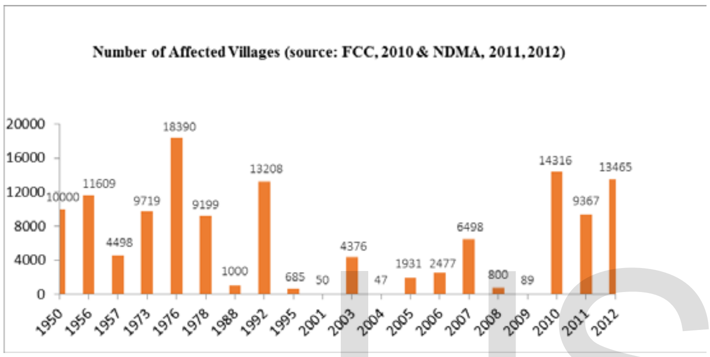

Fig. 2. Graphs shows number of affected villages (source: FCC, 2010 & NDMA, 2011, 2012).

From 2010 to 2012 Pakistan continuously faced furious flood's conditions in monsoon periods, during such conditions Sindh province faced different problem like lack communication disturbance and information about the flood extent was not available due to limitation of ground service reporting which can help for taking timely decisions. The floods 2010, 2011 and 2012 were witnessed one of worst floods in the history of Pakistan, damaging crops, infrastructure, settlements, large number of human's life and livestock. In 2010 almost all the rivers and creeks were over flooded and inundating large areas. Heavy damages to urban sprawl of Nowshera and adjoin areas were due to Kabul River. The Indus River broke out its banks downstream Taunsa near Muzaffargarh as a result large areas were covered with water (SUPARCO, 2012).

In July 2010 monsoon floods hit almost whole country. The record heavy rains have set off both rivers and flash floods in many regions of the country resulting in huge number of deaths, large scales displacement of People and property damages. The 2010 flood take lives of approximately 1,539 people all over the country. The total effected population reported was approximately 17,176,908. Approximately 1,226,678 houses were destroyed or damaged (USAID, 2010). In 2011 monsoon manifested much heavy rainfall with remarkable intensity in Sindh. The cumulative rainfall in Sindh varied from 400 mm to 1299 mm. These rains inundated large areas of the Sindh, almost disturbed the human life very badly (SUPARCO, 2012).

In 2012 flood had hit the province Sindh province but with less intensity as compare with 2010 and 2011 floods. According to latest statistics of NDMA 2012, the 451 people dead and 2,916 injured and disturbed the human life again very badly which already were in the stage of rehabilitation due the effect of flood 2011 (NDMA, 2012).

From last few years due to consecutive floods situation the Sindh is under consideration and in this regards many study are carried out in different prospects including quantifying damage assessment and detection of flood prone areas in order to minimize the loss occurred due to such situation.

To classify the open water flooding quite accurately synthetic aperture radar imagery has been used (ISPAN, 1995). Martin et al., 1997 reported that to identify the full extent of flooding by using radar images are difficult because water under moderate amount of vegetation can be identify from only radar. Benz et al., 2004 mapped flood water extent by using object based image classification algorithm. In first step an image is divided into contiguous and homogeneous objects, in this technique and then on the biases of their spectral and textual properties is classified and for used this process for pre and post flood images and extracts the water class to map out the flood water extent.

A ratio of NOAA/AVHRR was proposed by Sheng and Gong (2001) for the spatio-temporal assessment of flooding occurred during the summer 1991 in Huaihe River Basin China, data of channel 1 and channel 2 to separate out water from land surface. Anderson et al., 2005 MODIS data Dartmouth Flood Observatory (DFO), (2006) all over the world monitors the disasters and up to 2005 annually flood map of Lower Mekong River is published online. Toshihiro Sakamoto et al., 2007 has presented a methodology to detect the spatio-temporal shifts in the extent of flood inundation; in the region of Cambodia shifts in the span of inundated flood area is assessed from 2000 to 2004 by using remotely sensed data of 500 m spatial resolution. Nobi et al., 2009 has used the supervised classification for quantifying assessment of land cover change; they classified the land cover into various classes to find out the area covered by each class corresponding to other classes. Issa (2009) used mapping trajectory of land cover mapped the land cover/land use of Al Sammalyah Islan, Abu Dhabi for the period 1999 and 2005. Ejaz Hussian et al., (2010) estimated the damage assessment to infrastructure with the help classified Land sat data and spatial data during flood occurred in 2010 and analysis of these results revealed that road connecting with small villages and towns passing through floodplain are mostly affected.

2 Objectives

Pakistan continuously facing devastation floods from last three years (2010-2012). Number of peoples had died, several towns and villages completely vanished and large areas of agriculture lands become no productive for coming several years. Any disaster has two components (1) Rehabilitation. (2)

Quantify damage assessment. Army, Government agencies and INGOs are involved to address the humans that how can face such situation. In the most affected flooded areas no proper planning/assessment was done, now it's time to monitor and to do a quantify assessment of damage areas and land use changes due to floods in lower Indus basin which is most affected area. Remotely sensed data provide bird eye to analyze the large phenomena's on frequently basis. In several studies integration of satellite images with meteorological data provides most accurate and reliable results and planning.

The primary goal of this research was resulted in flood detection and proper management. This study will be accomplished by the following objectives.

- Relationship between land use and flood risk and flood extent
- Detection of disaster prone areas using remotely sensed data
- Location of protection measures

3 Methodology

Pre and post flood satellite images MODIS (Terra) 250 meter resolution depends on the availability of the images will be acquire from the data provides online platforms. To maintain the consistency and accuracy among the satellite data and ground realities geometric correction of each scene will be taken care. Satellite data will be included for the detail assessment of selected side depends on availability. From the selected hydrological measurement stations, the inlet and outlet discharge data acquired. Thematic layer generated through raw satellite data and correlate with the rainfall, hydrological data and spatial data sets. Statistical analysis will be performing to quantify the details of damage assessment and mapped the flood extent. On the basis of three years data analysis, most threaten areas which might be vulnerable in future will be predict using the spatial analysis.

4 Study Area

The area selected for present research was Sindh province, Pakistan. The name of Sindh derived from Indus River which separates it from Balochistan and greater Iranian plateau. Sindh is located on southern corner of south Asia it is third largest province of Pakistan covered an area 54,408 sq. mi. (140,915 sq. km), also known as the lower value of Indus. Sindh is bounded to the north by Punjab, the southern side by Arabian sea, the east side is bounded by the Indian State of Gujarat and Rajasthan, while the west is bounded by the Indus River and Balochistan. Karachi is the capital of Sindh and largest city as well as financial hub of the Pakistan, the coordinate of area in WGS 1984 are 25° 53′ 39.6558″ N and 68° 31′ 28.9308″ E. There are 23 districts in Sindh province. Location map of the study area is shown in figure 3. Sindh produces main crops including, wheat, cotton, sugarcane and rice, only rice is the most cultivated crop here, grown in the annually inundated lands within the delta of Indus River.

The topography of the study area is almost flat, the elevation range of study area. The altitude and appearance information of an area is displayed by topographic map. The difference between a topographic map and a slope map is that degree of inclination between two points having different heights has shown by slope map while from datum usually sea level heights of different places have shown in topographic map. Pakistan Meteorological Department (PMD) is said that the climate of Sindh is very hot in summer and in winter it is cold as it is situated in subtropical region. Between May to August the temperature frequently rise above 460 C and during December to January minimum average temperature is 20 C. The rainy season is from June to September which is monsoon period. Highest temperature ever recorded in Sindh was 520 C in 1919.

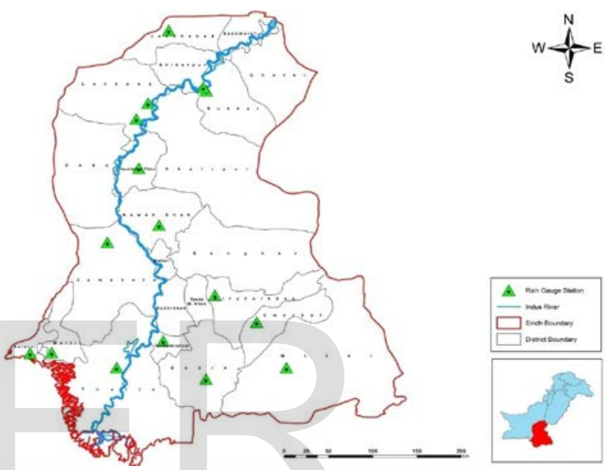

Fig. 3. Location map of study area

Rainfall in Sindh is occur in almost every season but monsoon season is more prominent and organized, monsoon rainy season is between July to September. In last three years due to heavy rain in monsoon periods Sind faced divesting floods in the result of these floods Pakistan bared a huge loss in all ways, like a number of human life, damage of agriculture, economic and social loss. The average rainfall in Sindh is only 15- to 18 cm per year. Cumulative rainfall in monsoon was recorded 381 (mm) in 2010 and in 2011 it was recorded 1299 (mm) at Mithi, 483 (mm) in 2012 in Jacobabad. Generally air is very dry in Sindh during summer. According to PMD on May 2010 maximum temperature ever recorded at Mohenjo-Daro was 53.5 0C and it was the highest temperature ever recorded in Pakistan. Previous record in Sindh and Pakistan for Asia had been 52.8 0C reached on 12 June 1919 .The temperature falls near to 0 0C in December and January.

Indus River has wide and braided channel, where five rivers meet in Punjab near Mithankot. Below Hyderabad until it reaches the upstream limit of Indus Delta it becomes narrower and meandering downstream. Past depositional patterns is related to longitudinal profile of its irregularities as its general trend changed this trend also related past, present tectonic movements and human activities. There are 49 gauges stations along the lower Indus River and the water level taken from these gauges is used for geomorphic analysis as the

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cross-sections and longitudinal profiles of the river channel are not available.

5 Results and Discussion

5.1 Classification of Satellite Images

Land cover/Land use maps are prepared using MODIS time series satellite data sets using supervised classification algorithm in which area classified into vegetation, soil, water and clouds thematic layers for year of 2010, 2011 and 2012. The analysis highlighted that how the land cover/land use changed temporally during flood situation.

Temporal images were obtained during 2010 flood. One image was taken as a pre flood on 15 July 2010 and other was as a post flood on 30 September 2010. These two images are processed and estimated the area of land cover/land use during flood. Maximum Likelihood classifier algorithm was used, classified maps of land use/land cover of 15 July 2010 and 30 September 2010 of land cover/land use shown in figures 4 (a), 4 (b), 4 (c), 4 (d), 4 (e), 4 (f). In July the more area was covered with water whereas in September it was less, the classification results indicated that there was more clouds in September as compared in July. There was 37905 km2 area was covered with vegetation which increased after flood as well as 81866.7 km2 area was covered with soil after flood left 65131 square kilometer which was replace by vegetation. Time series images for pre and post flood 2011 were obtained during flood. One image was taken on 1st August 2011 while 2nd image was takes on 25 September 2011 and classified these two images and estimated the area of land cover/land use. The classified maps and graphical representation of land cover/land use of 1st August 2011 and 25 September 2011 given in figure 4 (c), 4 (d). In August there was 25182.2 km2 area covered with water while in September only 13829.5 km2 and it was the monsoon period and the more rainfall and clouds in southern side of Sindh was covered with clouds as compared in September, classification results also indicated that there was 46439.3 km2 area of Sindh covered with bare soil and in September 53048.2 km2 area of Sindh covered with bare soil. Pre and post flood 2012 images were obtained during flood. 1st image was taken on 14 August 2012 and other was takes on 1 October 2012, supervised classification of these two images result the area of land cover/land use. The classified maps of land use/land cover of 14 August 2012 and 1 October 2012 given in figure 4 (f). In August there is 37576.1 km2 area covered with vegetation and in October 57427.8 km2. In August 8853.3 km2 area of Sindh covered with water whereas in October 11665.7 km2 area of Sindh covered with water also there was no cloud on 1 October. Area of each class in different years as shown in figure 5.

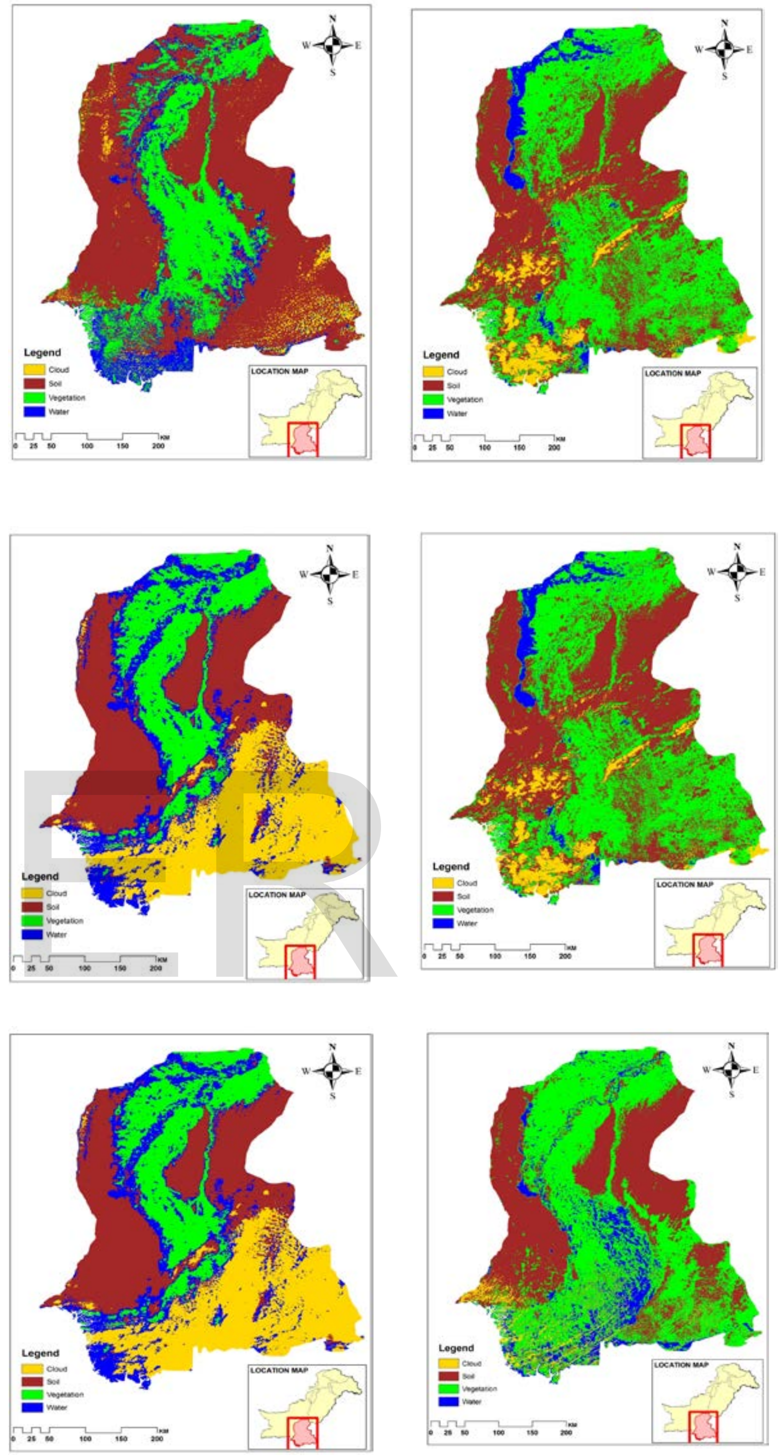

Fig. 4(a). Classified map of 15-july-2010, 4(b). Classified map of 30-september-2010, 4(c). Classified map of 1-august-2011 4(d). Classified map of 25-september-2011, 4(e). Classified map of 14-august-2012, 4 (f). Classified map of 1-october-2012.

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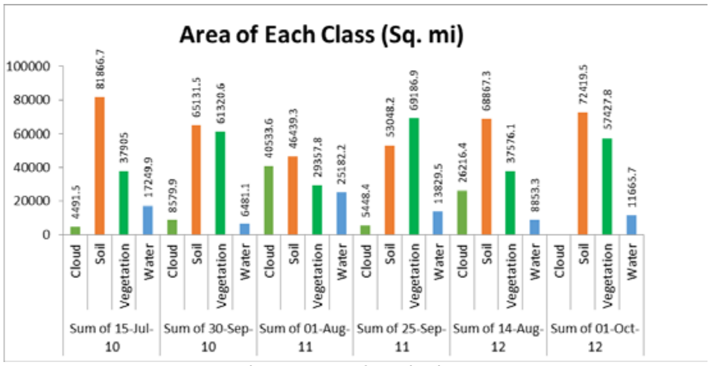

Fig. 5. Area of each class

6 Extraction of Flood Extent

Flood extent map indicated the estimated area which is inundated during the flood event. Pakistan since last 3 years continuously faces the flood situation due to monsoon rainfall.

The rainfall data was obtained from Pakistan Meteorological Department stationing located in the Sindh areas. During the monsoon period of 2010 almost ten stations received rainfall more than 200 mm and only six stations, Dadu, Moin-Jo-Daro, Rohri, Jacobabad, Sukkur, Hyderabad received rainfall less than 200 mm. The cumulative rainfall from 1 July to 30 September 2010 in mm of each rainfall station situated in Sindh, red bars show the rainfall amount greater than 200 mm whereas blue bar show the rainfall less than 200 mm. The highest order of rainfall of the order was 381 mm in Mithi and minimum order of rainfall was 45 mm in Sukkur. During monsoon period of 2011 flood, almost eleven stations received rainfall greater than 200 mm whereas only 5 stations, Moin-Jo-Daro, Sukkur, Rohri and Larkana received rainfall less than 200 mm. The highest cumulative rainfall of the order was 1299 mm in Mithi and lower 101.1 mm in Moin-Jo-Daro. The cumulative rainfall for 1st July to 30 September 2011, red bars shown the rainfall amount greater than 200 mm whereas blue bar shown the rainfall less than 200 mm. During monsoon period of 2012 flood in Sindh, only five stations named Sukkur, Rohri, Jacobabad and Chhor received rainfall greater than 200 mm whereas ten stations received rainfall less than 200 mm. The highest cumulative rainfall was 484.3 mm in Jacobabad and 76 mm in Mirpur Khas. The cumulative rainfall of 2012 from 1 July to 30 September, The cumulative rainfall for 1 July to 30 September 2012, red bars shown the rainfall amount greater than 200 mm whereas blue bar indicated the rainfall less than 200 mm.

The study carried out on the extraction of flood extent by using temporal images of MODIS satellite, on taking the pre and post images of satellite first examined the visual observation and picking up water pixels from satellite images and grouped into one class and all the other than water features grouped and separated and run the maximum likelihood classifier, to analyze the variance and covariance result for classification, to differentiate the classes. After that separate the water class from other class and the raster is converted into vector for calculation the area of flood extent of each image. The analysis shown the flood extent of each pre and post images of flood 2010, 2011 and 2012 and merged the pre and post flood extent of each year resulted, as final flood extent map for each flooded year. Flood extent map of 2010, 2011 and 2012 given in figure 6(a), 6(b) and 6(c). During the monsoon flood of 2010 in Pakistan, the flood waters in Sindh province covered at least 22010 km2 of the total area, it is found by using the MODIS satellite imagery, 2011 flood covered 34563 km2 and 2012 flood covered 17447 km2. Flood extent map clearly indicated that the Jacobabad, Shikarpur, Badin and Thata were vernal able districts that continuously faced the flood situation. In 2010 Mirpurkhas and Nowshera Feroz, Nawab Shah, Umerkot, Shanghar, Larkana, Dadu, Hyderabad has faced the flood situation and totally disturbs habitants of the areas. In 2011 and 2012 floods the habitants of the Umerkot, Larkana, Shikarpur, Gotki, Dadu, Shanghar, Nawab Shah, Nowshera Feroz were badly affected, as well as these flood caused huge economically and socially loss.

Fig. 6(a). 2010

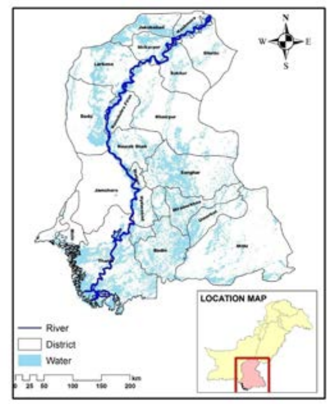

Fig. 6(b). 2011

Fig. 6(a). 2010

Fig. 6. Extent of flood

7 Quantifying Assessment of Infrastructure

The road data was obtained from SOP (Survey of Pakistan). The digitized road data was classified in three categories: metaled, unmetaled and tracks it does not include the detail roads and streets. The road layer compared with water layer which extracted from classified satellite images. Roads that were damaged in 2010 shown in following figure 7(a).

The spatial analysis was performed. The result clearly depicted that 858.244 km metaled, 1413.453 km unmetaled and 667.756 km track were underwater during 2010 flood time and disconnect the roads communication between different flooded districts. The roads affected during flood 2011 shown in the following figure 7(b), the 1568.949 km metaled, 2061.057 km unmetaled and 1265.578 km tracks were covered with water and these roads were un useable due to flood condition, caused problem for mobilization. In 2012 flood the flood water covered the roads, shown in figure 7(c). Figure pictured that 501.023 km metaled, 875.644 km unmetaled and 493.101 km tracks were covered under water due to flood, although the roads play an important role during flooding.

Railway lines was digitized from topographic sheet and clasfied into four classes, i) meter gauge, ii) multi track railway lines, iii) railway lines connector and iv) single track railroad. Spatial analysis has shown most of the railway lines were gone underwater during flooding time. Rail lines which were covered with flood given in figure 8(a), 8(b) and 8(c). The spatial analysis shown that in 2010 and 2011more rail lines were covered under water as compared in 2012 flooding.

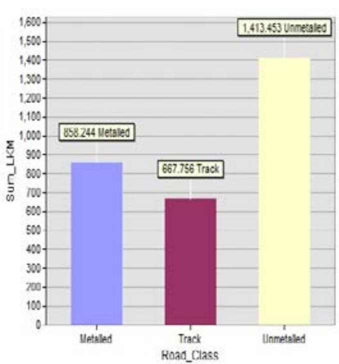

Fig. 7(a). 2010

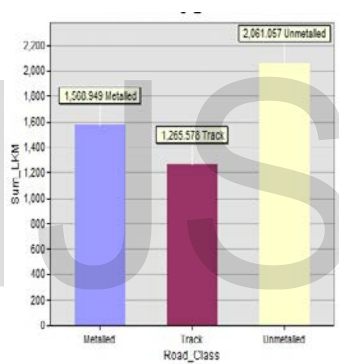

Fig. 7(b). 2011

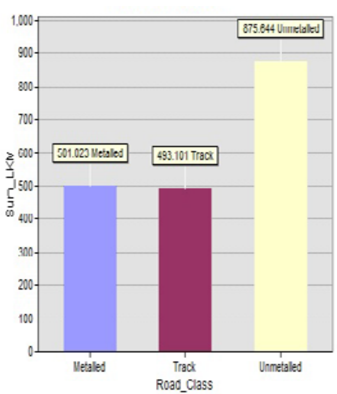

Fig. 7(a). 2012

Fig. 7. Flood affected roads

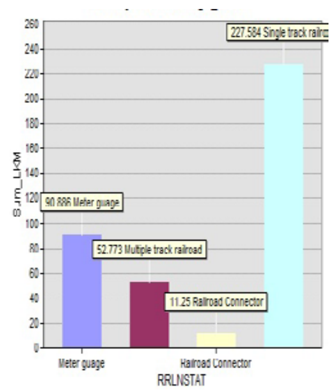

Fig. 8(a). 2010

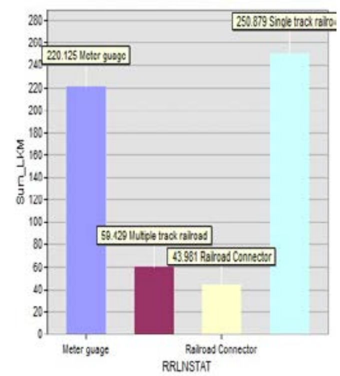

Fig. 8(b). 2011

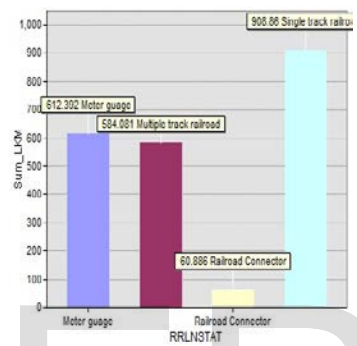

Fig. 8(a). 2010

Fig. 8. Flood affected railways

8 CONCLUSIONS

The following conclusion is drawn on the basis of analysis. High concentration of loss to agriculture along the Indus River and nullahs are estimated by spatial distribution. The quantified damage assessment of road and railway lines also estimated a huge loss in past three flooding. Large area was prone to with flooded water caused a large number of deaths and loss of property. Extent of flood has been mapped for last three years and integration of other data like detail roads, railway line a fine damage estimation was done and being part of fertile land this area produced a variety of summer crops.

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REFERENCES

[1] Lillesand, T.H., Ralph. W.K., and Jonathan, W.C. 2004. Remote Sensing and Image Interpretation. 5th ed. WILEY-INDIA, New Delhi.

[2] Stryker, T., and B. Jones, 2009. Disaster Response and the International Charter Program, Photogrammetric Engineering and Remote Sensing, Vol. 75, No. 12

[3] Shan, J., E. Hussain, K. Kim, and Larry Biehl, 2010. Highlight Article: Flood Mapping with Satellite Images and its Web Service, Photogrammetric Engineering and Remote Sensing, Journal of the American Society for Photogrammetry and Remote Sensing, Vol. 76, No. 2

[4] Hussain, E., and J. Shan, 2010. Mapping major floods with optical and SAR satellite images, IEEE Geoscience and Remote Sensing Symposium, Honolulu, Hawaii, USA, July 25-30.

[5] Shroder, J. F. (n.d.). Himalaya to the Sea: Geology, Geomorphology, and the Quaternary. (J. F. Shroder, Ed.) (illustrate.). Routledge, 1993.

[6] Li, X., Sun, Y., Li, X., Gong, H., & Ma, Y. (2011). Flood risk assessment in Pakistan at 1km grid scale. 2011 International Conference on Multimedia Technology, 321–325.

[7] Zhang, R., & Sun, Y. (2012). Rapid Extraction of Pakistan F loods from TM Images, 1–4

[8] Assessment and Monitoring Approach & Multi-Sector Initial Rapid Assessment (MIRA) in Pakistan. (n.d.).

[9] Crop, R., & Assessment, D. (2010). PAKISTAN : FLOODS / RAINS 2010, (2)

[10] Irfan, H. (n.d.). Quantifying land use and land cover change using satellite remote sensing : A case study of Delhi, India., 1–18.

[11] Baecher, G. B. (2009). Quantifying Flood Risk 1 1., (September), 1–24

[12] Islam, A. S., Bala, S. K., & Haque, A. (2009). FLOOD INUNDATION MAP OF BANGLADESH USING MODIS.

[13] Devlin, M., & Schaffelke, B. (2009). Spatial extent of riverine flood plumes and exposure of marine ecosystems in the Tully coastal region, Great Barrier Reef. Marine and Freshwater Research, 60(11), 1109.

[14] Brakenridge, G. R., Andersona, E., Nghiemb, S. V, Caquard, S., & Shabaneh, T. B. (n.d.). Flood Warnings , Flood Disaster Assessments , and Flood Hazard Reduction : The Roles of Orbital Remote Sensing, (Vv)

[15] Sakamoto, T., Van Nguyen, N., Kotera, A., Ohno, H., Ishitsuka, N., & Yokozawa, M. (2007). Detecting temporal changes in the extent of annual flooding within the Cambodia and the Vietnamese Mekong Delta from MODIS time-series imagery. Remote Sensing of Environment, 109(3), 295–313

[16] Xiao, X., Boles, S., Frolking, S., Li, C., Babu, J. Y., Salas, W., & Moore, B. (2006). Mapping paddy rice agriculture in South and Southeast Asia using multi-temporal MODIS images. *Remote Sensing of Environment*, *100*(1), 95–113.

[17] NDMA, (2010). Annual Report 2010. National Disaster Management Authority, Isla**m**abad, Pakistan.

[18] OCHA Pakistan, (2010). Situation Report: Monsoon Floods in Pakistan - 29 July 2010.Office for the Coordination of Humanitarian Affairs.

[19] USAID, (2010). Pakistan Floods, August 23. Bureau for Democracy, Conflict, and Humanitarian Assistance (DCHA) Office of U.S. Foreign Disaster Assistance (OFDA). Fact Sheet #7, Fiscal Year (FY) 2010.

[20] Palmer, T.N., R.as.anen, J., 2002. Quantifying the risk of extreme seasonal precipitation events in a changing climate. Nature 415,512–514.

[21] Khan, B., Iqbal, M. J., and Yousufzai, M. A. K. (2009). Flood risk assessment of River Indus of Pakistan. Arab Journal of Geo-science. doi: 10.1007/s12517-009-0110-9.

[22] Taylor, P., Apel, H., Merz, B., & Thieken, A. H. (2010). International Journal of River Basin Management Quantification of uncertainties in flood risk assessments, (February 2013), 37–41.

[23] ISPAN (1995) Satellite-based radar for flood monitoring in Bangladesh. Flood Action Plan 19. Ministry of Water Resources, Dhaka, Bangladesh.