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Research Paper

Techniques of Remote Sensing and GIS for flood monitoring and damage assessment: A case study of Sindh province, Pakistan

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KEYWORDS

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Damage assessment;
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Abstract Remote Sensing has made substantial contribution in flood monitoring and damage assessment that leads the disaster management authorities to contribute significantly. In this paper, techniques for mapping flood extent and assessing flood damages have been developed which can be served as a guideline for Remote Sensing (RS) and Geographical Information System (GIS) operations to improve the efficiency of flood disaster monitoring and management.

High temporal resolution played a major role in Remote Sensing data for flood monitoring to encounter the cloud cover. In this regard, MODIS Aqua and Terra images of Sindh province in Pakistan were acquired during the flood events and used as the main input to assess the damages with the help of GIS analysis tools. The information derived was very essential and valuable for immediate response and rehabilitation.

1. Introduction

Floods are among the most devastating natural hazards in the world, widely distributed leading to significant economic and social damages than any other natural phenomenon (DMSG, 2001). The flooding has been affecting the entire country incoherently since 1928 during the monsoon period between July and September and the country has experienced major floods during the years 1928, 1929, 1955, 1973, 1976, 1980, 1988, 1992 and 2010 (Solheim et al., 2001; Natalia Kussul et al., 2008). Since 1947–2008, floods in the Indus River Basin in Pakistan have claimed more than 7,000 lives; inundated zone was 7.7 million acres round and caused massive infrastructure and crop losses (Muhammad Shahzad Sardar et al., 2008). The flood in 2010 began in late July inundated Pakistan with approximately 60,000 km^2, affected 15–20 million people along with the death toll close to 2000 (Mateeul-Haq et al., 2010; Wikipedia, 2010). In the recent year large-scale heavy

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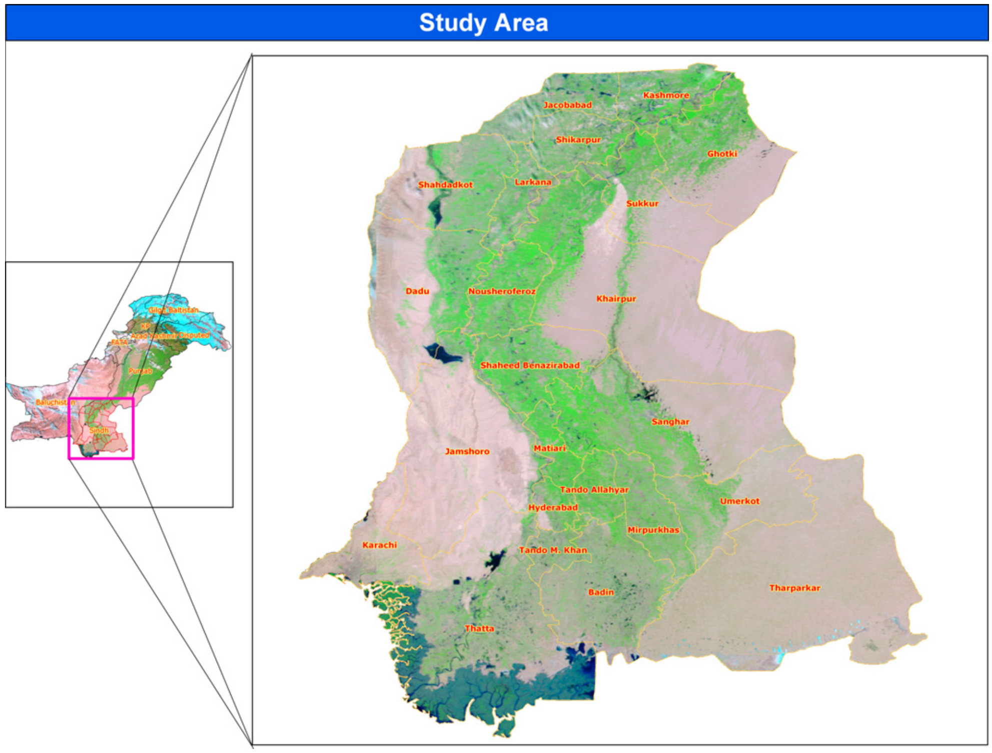

Figure 1 The location of study area.

rains have been observed in Sindh leading to huge economic losses, destruction of ecological resources, food shortages and starvation of million people.

In the age of modern technology, the integration of information extracted through Geographical Information System (GIS) and Remote Sensing (RS) with other datasets provides tremendous potential for identification, monitoring and assessment of flood disaster (Pradhan et al., 2009; Pradhan and Shafie, 2009). This paper describes the procedure for mapping inundated areas using MODIS data during Sindh flood 2011 to estimate the affected land use/land cover types and the number of people. This would be very useful information for disaster response and mitigation.

2. Study area and climate

The study area is located in southern part of the country stretching about 579 km from north to south and 442 km from east to west with an area of 140915 km^2 (See Fig. 1).

The annual rainfall of Sindh averages about 6–7 inches (15–18 cm) falling mainly during July and August. The study area lies between two monsoon—the southern monsoon from the Indian Ocean and the northeast or retreating monsoon, deflected towards it by the Himalayan mountains. The region's scarcity of water is compensated by the inundation of the Indus twice a year, caused by the spring and summer melting of Himalayan snow and by rainfall in the monsoon season (Wikipedia, 2012).

3. Data and softwares used

- Topographic maps had been used to extract different types of info-layers: administrative boundaries, rivers, lakes, roads, railway tracks, vegetated areas and other land use/land cover categories.
- Moderate Resolution Imaging Spectro-radiometer (MODIS) onboard TERRA and AQUA images of 250 m resolution comprising bands 7, 2 and 1 were acquired and used as the principal input to map the flood affected areas. The MODIS images of the study area are provided by NASA free of charge at the location: http://lance-modis.eosdis.nasa.gov/imagery/subsets/?project = other&subset = Pakistan
- District wise population density was used to estimate the affected people and the data are provided by Federal Bureau of Statistics, Pakistan (Statistical Bulletin, 2011).
- The Spot 5 images had been mosaicked and used for the verification of flood.
- ENVI 4.5 and ArcGIS 9.3 softwares were used for processing and analysis.

4. Methodology

MODIS images were acquired from the NASA's website: http://lance-modis.eosdis.nasa.gov/imagery/subsets/?project = other&subset = Pakistan and a standard supervised maximum likelihood classification of the images covering Sindh province was carried out and the required inundated class was converted into a shape file. Further editing of the images was carried out by visual interpretation (stagnant water has dark blue reflectance and flowing water has light blue color) of the inundated areas using expert knowledge. The topographic maps were then intersected with accumulated shape file of the inundated area to extract different types of info-layers for damage assessment. Flow chart of the methodology adopted in this study is shown in Fig. 2.

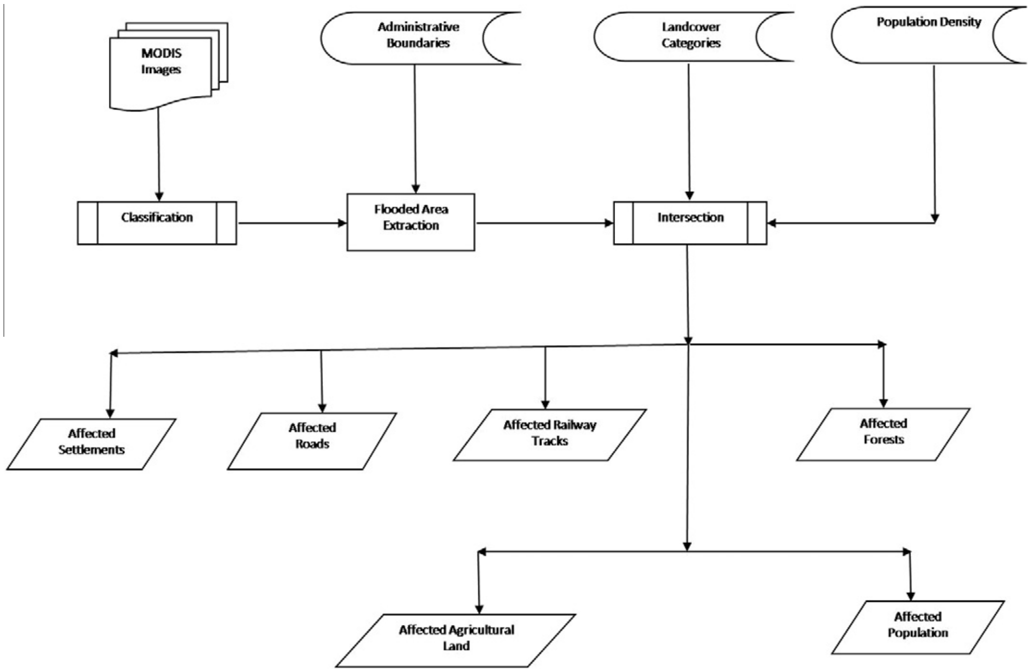

Figure 2 Flow chart of methodology.

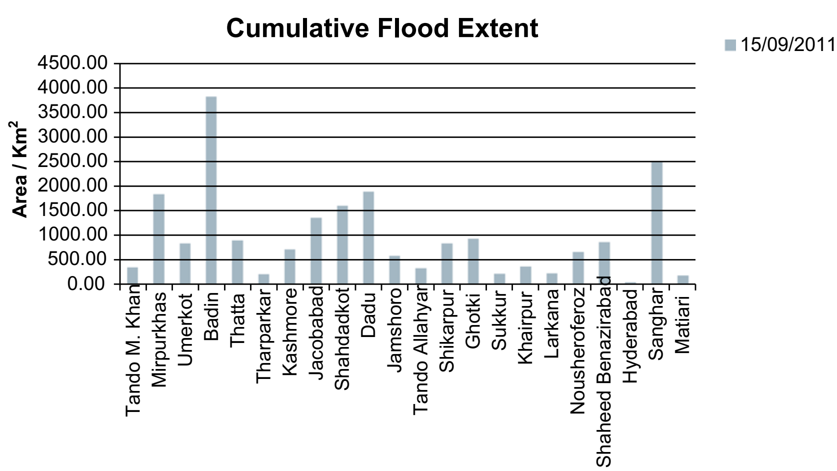

Figure 3 Cumulative flood extent of different districts.

5. Results and discussion

During floods, timely and detailed situation reports are required by the disaster management authorities to locate and identify the affected areas and to implement the corresponding damage mitigation; this is the most delicate management category since it involves rescue operations and the safety of people and property (Jeyaseelan, 2004). In this regard, cumulative and temporal flood extent maps were prepared. It was found that severe flood occurred in Badin and inundated it by 3820.39 km^2, Mirpurkhas by 1836.26 km^2, Jacobabad by 1352.32 km^2, Shahdadkot by 1597.50 km^2, Dadu by 1887.57 km^2 and Sanghar by 2494.18 km^2, in cumulative. Furthermore the above mentioned districts contributed 61% of the total inundated area among 23 districts in Sindh. Fig. 3 shows the cumulative inundated area of different districts on different dates while Figs. 4a–d show the cumulated inundated area in Sindh.

The flood was originated mostly because of rainfall and observed the highest ever recorded monsoon rain in Sindh started from Aug 11, 2011 to Sept 14, 2011. So the inundated area increased respectively with rainfall and ceased on Sept 15, 2011 effectively with the stop of rainfall. After Sept 15, 2011 the inundated area was reduced with the rate of 167 km^2/day in average as the following graph shows the recession. Table 1 shows the rainfall (in mm) data (See Fig. 5).

5.1. Damage assessment

The total cumulative flood extent was found to be 21,201 km^2 affected 5.88 million people, 5329 settlements, 1500.44 km of

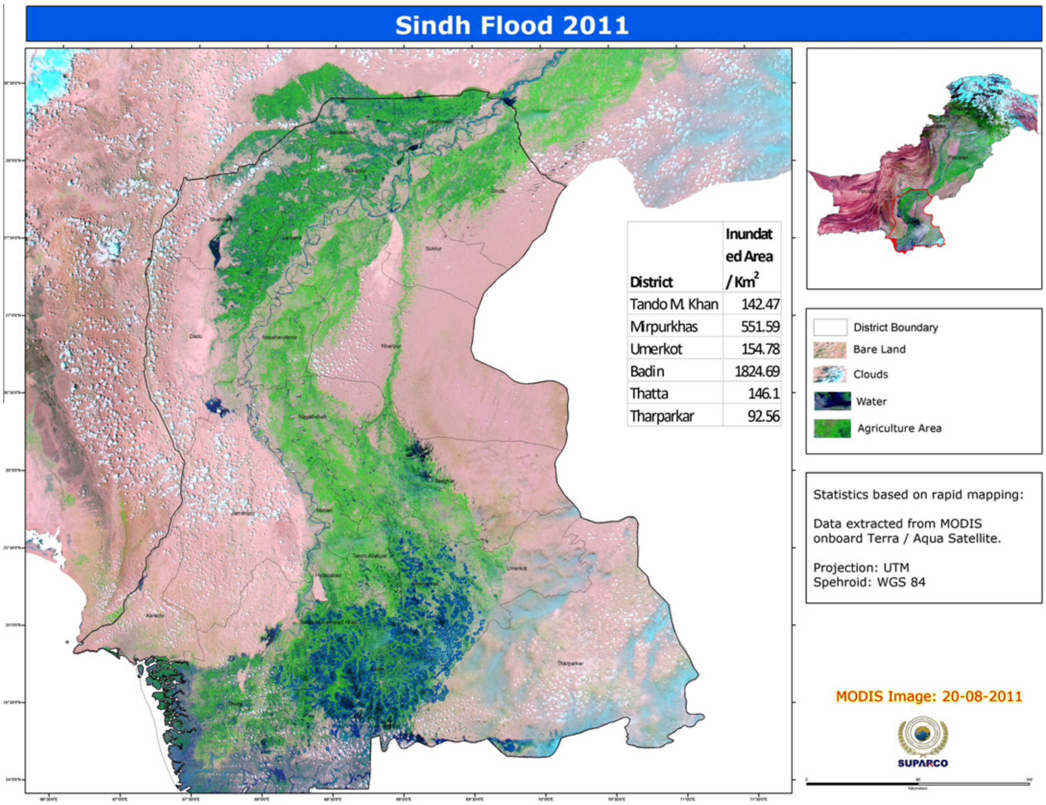

Figure 4a (a) MODIS image showing the inundated area on Aug 20, 2011.

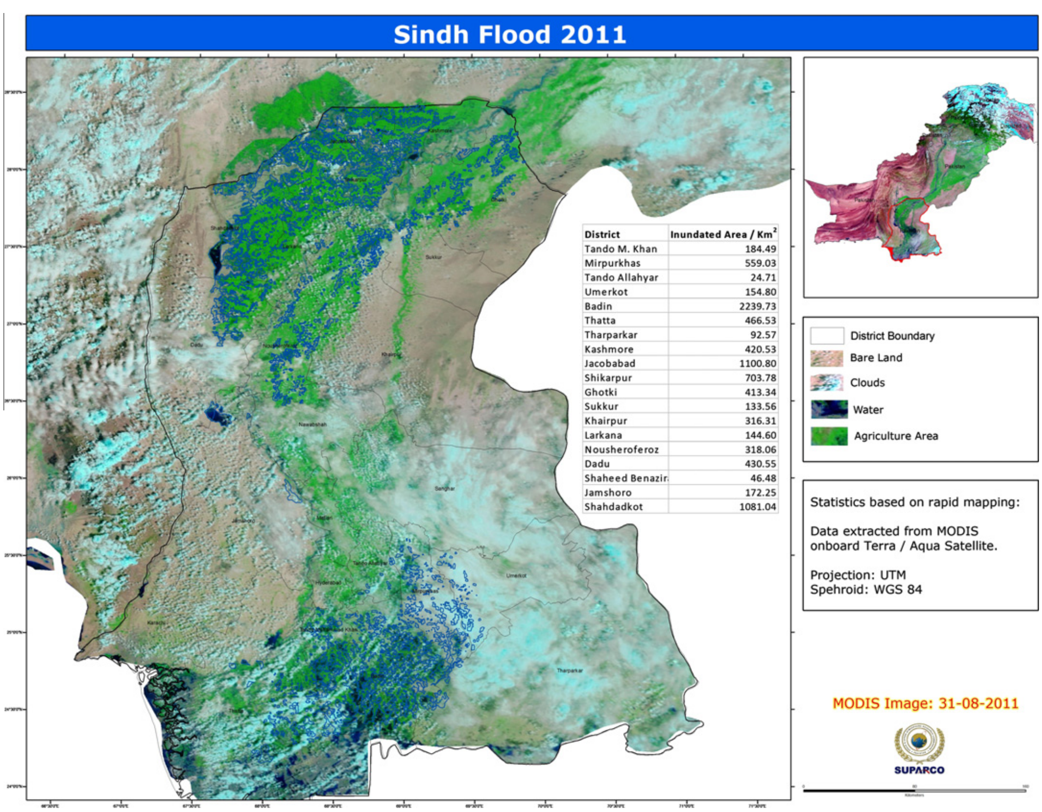

Figure 4b (b) MODIS image showing the inundated area on Aug 31, 2011.

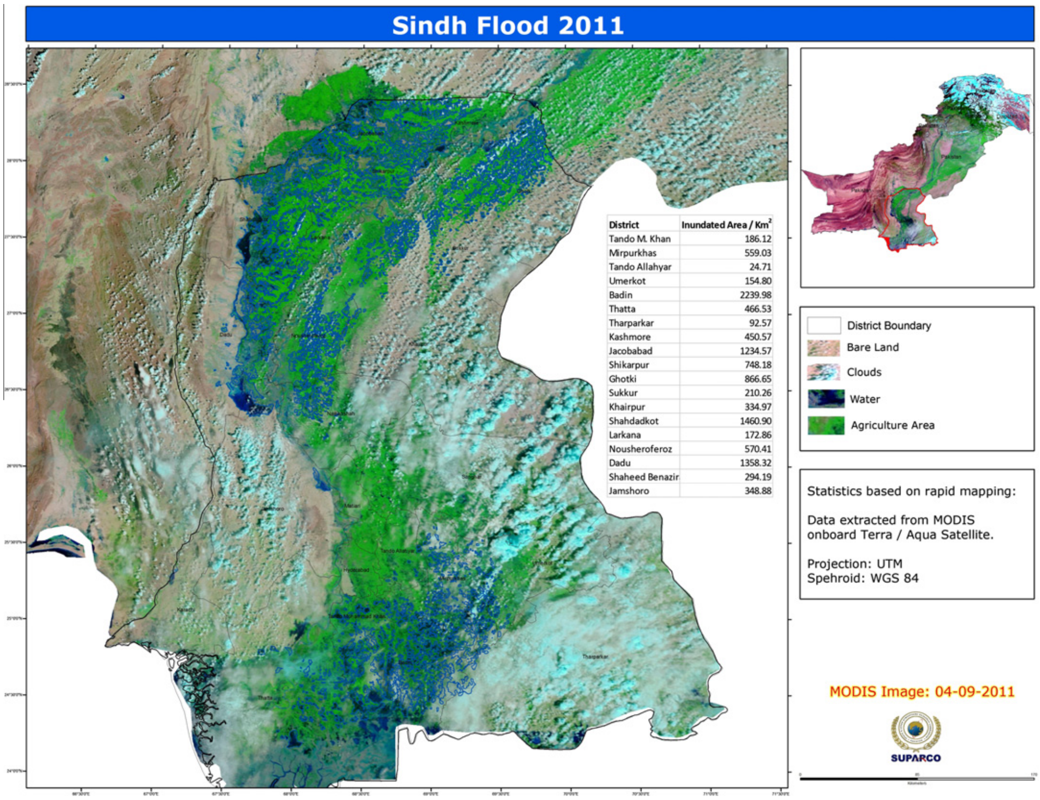

Figure 4c (c) MODIS image showing the inundated area on Sept 04, 2011.

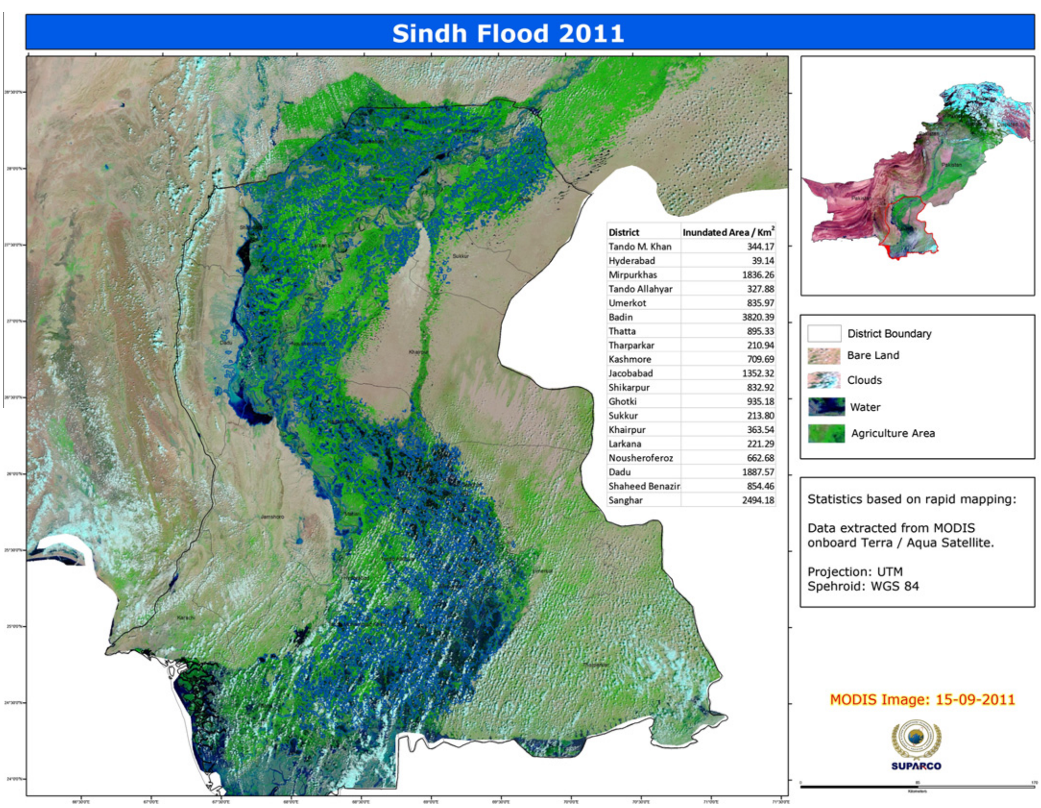

Figure 4d (d) MODIS image showing the inundated area on Sept 15, 2011.

Table 1 Data had been taken from website of Pakistan Meteorological Department (Pakmet, 2011).

Date	Aug-11				Sep-11								
District	11	12	30	31	1	2	4	7	8	9	13	14	Total
Badin	148	147	22	7	15	24	19	73	20	11	60	0	546
Umerkoat	129	7	19	57	6	5	11	55	84	8	56	0	437
Hyderabad	104	23	4	15	2	27	0	2	12	12	153	0	354
Jacobabad	0	0	0	4	99	0	0	0	0	0	**	82	185
Larkana	0	0	0	71	40	37	0	16	8	0	**	21	193
Therparkar	291	60	42	0	3	43	12	225	137	100	57	0	970
S. Benazeerabad	5	108	55	70	19	67	70	25	37	27	75	6	564
Nausheroferoz	1	0	8	238	10	57	0	0	18	2	42	0	376
Sukkur	0	0	0	66	33	28	4	4	0	0	4	12	151
Thatta	58	7	43	0	0	6	0	9	6	0	73	4	206
Dadu	0	0	0	130	2	48	0	0	66	9	115	108	478
Mirpurkhas	120	125	12	5	4	50	50	1	166	122	190	0	845

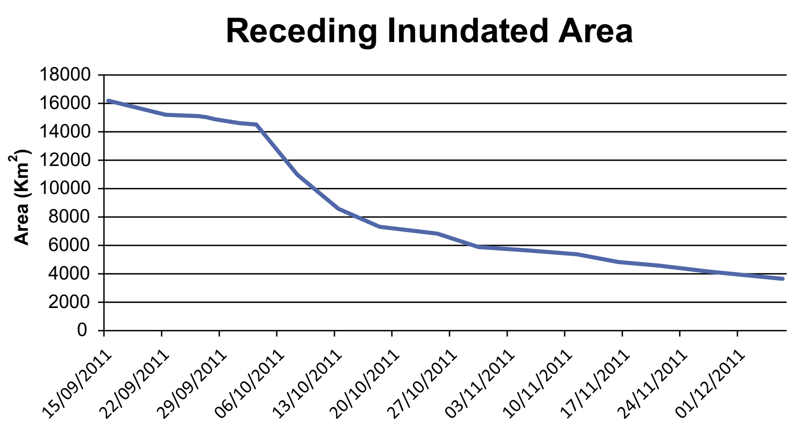

Figure 5 Graph showing the recession of the inundated area from Sept 15, 2011.

Table 2 Statistical analysis of flood-affected land cover/land use categories based on MODIS data.

S. No	District name	Affected settlements	Affected people	Affected agricultural land/Km^2	Affected forests/Km^2	Affected roads/km	Affected railway/km
1	Badin	967	853993	1219.05	12.64	146.09	14.65
2	Dadu	261	373386	1483.94	12.14	168.08	31.76
3	Ghotki	237	189753	880.43	83.04	29.04	14.55
4	Hyderabad	7	80951	25.07	5.67	5.96	4.08
5	Jacobabad	349	520535	1371.07	0.00	71.81	58.64
6	Jamshoro	59	42096	327.29	47.62	43.14	42.37
7	Kashmore	194	243371	690.38	28.69	31.04	11.63
8	Khairpur	144	49886	314.01	34.29	36.09	19.03
9	Larkana	68	158712	219.36	1.65	23.64	12.86
10	Matiari	24	91215	91.45	85.09	11.21	4.00
11	Mirpurkhas	544	869569	1852.84	4.18	196.12	18.18
12	Nousheroferoz	243	323765	630.46	32.19	48.71	36.83
13	Sanghar	657	427972	2203.68	0.00	268.21	19.87
14	Shahdadkot	316	375152	1196.09	0.00	79.23	13.25
15	Shaheed Benazirabad	328	298067	823.27	8.82	110.17	28.60
16	Shikarpur	248	389847	807.03	19.88	38.82	23.24
17	Sukkur	49	54282	188.42	2.05	6.13	9.01
18	Tando Allahyar	75	138732	329.38	0.00	14.52	3.64
19	Tando M. Khan	83	163307	270.34	4.71	21.54	1.64
20	Tharparkar	43	13779	193.07		4.19	0.00
21	Thatta	133	83069	437.52	115.81	42.07	0.00
22	Umerkot	300	139619	886.35	0.00	104.64	14.21
	Total	5329	5881056	16440.48	498.47	1500.44	382.05

road network, 382.05 km of railway tracks, 498.47 km^2 of forests and 16440.48 km^2 of agricultural land. Table 2 shows the damage assessment.

6. Conclusion

Flood monitoring using satellite data proved to be an effective method to get quick and precise overview of flooded areas. In the study, timely and detailed analysis had been carried out using RS & GIS for locating and identifying flood affected areas along with land use/land cover features. It was found that this method required processed satellite images which were then overlaid with population density data and land use/land cover maps for damage estimation. The process just required a few hours. The methodology used in this study has the capability to carry out rapid damage assessment.

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