Land use and land cover change analysis of District Charsadda, Pakistan along Kabul River in 2010 flood: using an advance geographic information system and remote sensing techniques

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Abstract. The objective of this research study was to quantify land use and land cover changes before and after the 2010 flood at District Charsadda, Pakistan. The land use and land cover changes were evaluated with the help of advanced geographic information systems (GIS) and remote sensing techniques (RST). Moreover, some remedial measures were taken to develop land use/land cover of the area to overcome future problems. Land use and land cover changes were measured by using satellite images. Two instances were compared, i.e. pre-flood and post-flood, to analyze the change in land use/land cover of District Charsadda within 5Km along the Kabul River. Comparative analysis of pre and post-flood imageries shows drastic changes over the water body, built-up area, agriculture land, and bare land during flood instances. The study area is rural and agricultural land is dominant in the area. We evaluated the percentage of different land uses/land covers within our study area, as agricultural land was about 68.5%, barren land was about 22.5 %, and the water body was 8.8 % before the flood. After inundation, the water body raised to 16.4 %, bare soil increased to 26.30 %, agriculture land degraded up to 57 %, and settlements (villages) along River Kabul were badly damaged and finished by this flood. Approximately, four villages of District Nowshera, six villages of District Peshawar, and twenty-seven villages of Charsadda District were badly damaged during the 2010 flood.

Keywords: Land Use and Land Cover Change; Change Detection; Supervised Classification; Geographic Information System; Remote Sensing; Flood Mapping

1 Introduction

Flood mostly occurs in the flood plain area of Reverie's body. It is the overflow of water in the flood plain area (Thomaz et al., 2007). The flood occurs when the land has no more capacity to absorb rainwater, and rivers and lakes rise over their banks. Thus, overflow of water occurs in the surrounding area which ultimately affects the ecosystem of the target area (Amoateng et al., 2018; Devi et al., 2019; Perry and Nawaz, 2008). A flood is a natural event that occurs as a result of heavy and prolongs rainfall, coastal hazards, tsunami, and earthquake (Kron, 2005). Floods are predominantly associated with severe hydro-meteorological behavior, geomorphic agent's viz. permeability, soil stabilization, vegetation cover, and river basin geometry. Urbanization, changing demographic features within flood plains, changes in flood regime, climate change, mismanagement of dam, deforestation, changes in land-use, and disturbance of ecological system due to anthropogenic actions considered the major factors which increase the flood risk (Khattak et al., 2016). Global warming leads to huge rainfall, overflow of water, climate change, and land cover infrastructure (Hunter, 2003; Patz et al., 2008).

Pakistan is a flood-prone country, renowned for its summer floods due to physical, geochemical, and climatic features, which pose an adverse effect on the ecology of the surrounding area. Many flash floods occurred before 2010 but the flood of 2010 is known to be the worst in the history of Pakistan. In the context of discharge, destruction, and volume of rainfall, it has broken all the prior records. The main causes of flooding in Pakistan include the affected area near the river, heavy monsoon rain, snowfall and glaciers melting. Most of the weather stations had observed rainfall above average. It shows that heavy and prolonged rainfall was a major cause of the 2010 flood for successive four days from 27–30, July. It has been observed that severe flood takes place in all flood plain areas of the Riverine environment of Pakistan due to the global warming phenomenon. As a result of flooding social, and economical loss occurs. Furthermore, primarily precious live forms such as humans, plants, animals, residential, industrial, commercial, and recreational zone were destroyed within no time. Overpopulation, ecosystem degradation, abrupt changes in climatic condition, further added new insights to the risk management system (Harper and Snowden, 2017).

Pakistan is adversely affected during the 2010 flood, about 11239 people died and around 1985 people were affected in the history of Pakistan. About 20 lac individuals in Pakistan were suffered due to the worst flood of 2010. So different people make an effort to make building resilience such as flood reduction approaches (Sardar et al., 2016). Some researchers believed that climate change is the dominant factor responsible for the prolonged rainfall in 2010. These factors were responsible for the disastrous flood in the country. In the KPK districts, a high flow rate has been estimated at Kabul, Indus, and Swat Rivers (Khan, 2013). There are two wet spells in a year, the winter and summer. Winter rainfall is caused by western fluctuations, high rainfall recorded in March and April every year. While the highest summer rainfall records in July and August. But comparatively, the winter rainfall is higher than summer (Bookhagen and Burbank, 2010).

Khyber Pakhtunkhwa Province recorded approximately 200-280 millimeters of heavy rainfall at end of July and the start of August 2010, especially in the area of Peshawar, Charsadda, and Nowshera Districts. An average of around 280 mm (11 inches) of rainfall was reported consecutively for three days in most affected areas. These rains are responsible for enormous flooding in the Indus, Swat, and Kabul Rivers, which stayed at high to extreme levels of floods. Many deaths were reported, thousands of houses were destroyed, millions of people had lost their homes, a large number of villages and towns were drowned away and most of the agricultural land was damaged due to flood. Kilometers of road sections were damaged, and a lot of bridges have been washed away.

Remote sensing is a worthwhile and accurate tool for mapping natural disasters such as land sliding, floods, and earthquake, covers large areas. Remote sensing data are pertinent for related hazards due to wide-area coverage, accessibility, and temporal frequency. Satellite imageries are useful data sources for detecting, evaluating, and estimating flood density, damage, and its consequences. However, timely acquisition and accessibility of images are crucial. Besides, mapping the actual flood extent required previous flood images collected at the same season or proximity to the flood period. Using this approach, the extent of the water bodies at their normal flow can be identified. The discharge of normal water during flood images gives the flood extent (Hussaina et al., 2011). Geographic Information Systems (GIS) is a powerful tool for storing, analyzing, and displaying geo-referenced data used for change detection studies. A combination of remote sensing (RS) and GIS has been recognized as an effective and efficient tool that is extensively applied for detecting land use and land cover changes of an area at different times. RS and GIS techniques have immeasurable advantages in comparison with previous methodologies, these tools are highly effective and efficient for monitoring dynamic changes of the land use/land cover (Ouedraogo, 2010).

Changes in land use and land covers are one of the driving factors of global climatic changes and environmental sustainability. Advances in technology such as GIS and RS offering a cost-effective and accurate approach for interpreting landscape patterns (Raziq et al., 2016). Land use/land cover change is a continuous process based on several natural and anthropogenic factors. The land use/land cover change study requires a comprehensive interpretation and evaluation of all the factors that trigger these changes in the environment. The conversion of rural land into urban land prospects rise in impervious regions (Rahman et al., 2012). The term land-use defined how the land-cover is being altered, comprises agricultural land, built-up land, nature reserve, wildlife conservation area, etc. While land-cover is used to demonstrate the type of physical land on the earth's surface. Land-covering may usually include; water, snow, grassland, forest, and bare soil (Zafar and Zaidi, 2015).

Based on the above discussion we studied the flood hazard, and its remedial measures by using geographic information system and remote sensing techniques to control chose and havoc of flood in the flood plain area of River Kabul in District Charsadda. Therefore, the objective of this research is to give an idea and workflow of the applications of the GIS technology for flood zonation and mention how GIS and RS technology can assist in evaluating the changes in land covers and taking the appropriate decisions. The main objectives of this study are:

1. to estimate and compare the pre and post-flood changes and their influences on land use and land cover changes,
2. to produce land use/land cover maps through GIS and remote sensing techniques to find out the flood zonation to reduce the impact of recurrent floods,
3. to suggest and recommend mitigation measures to reduce the impact of recurrent floods. This research is important in contributing future city planning, flood management and preserve the aesthetic value of the area.

2 Materials and methods

2.1 Study area

The studied area is located in the Khyber Pakhtunkhwa (KPK) province of Pakistan (Fig. 1). Geographically, the total area of District Charsadda is 996 km^2 (243753 acres). On the North, Charsadda Tehsil is bounded by Tangi, Mardan District on the East, Nowshera and Peshawar Districts on the Southside and Shabqadar on the Westside. Charsadda area lies between 71° 53' to 71° 28' East longitudes and 34° 03' to 34° 38' North latitudes. According to the 2017 census, the population of the Charsadda District is 1,616,198 (Statistics, 2017). Three main rivers flowing in Charsadda; the Kabul, Jindi, and the Swat; these rivers are the main source of irrigation in District Charsadda and its surrounding areas. The area surrounded by River Swat and River Kabul is called Doaaba and has prime importance in the District. River Kabul forms the boundary between Charsadda and Peshawar Districts. Kabul River is little more than a trickle for most of the year, the Warsak dam located on the South of River Kabul. Swat and Kabul Rivers are mainly snow-fed due to which the discharge rate increase in the spring season because of snowmelt in Hindu Kush Range. In late February, both the rivers start rising and reach the highest level of discharge in June and July due to snow melting is accompanied by summer rainfall. The discharge lasts until the end of October to January, disrupted by irregular flooding caused by erratic rainfall. The climate of the study area is extreme. Monsoon and Western disturbances are the two key factors responsible for the highest rainfall. The average rainfall fluctuates between 300 to 625 mm. There are two wet spells in a year, highest winter rainfall in a semi-arid zone, and summer rainfall in the sub-humid zone, according to climatic data (Bibi et al., 2018).

2.2 Image acquisition

We acquired two high-resolution Landsat-7 images (pre-flood and post-flood) of the year 2010 of Charsadda District from the USGS website. August 04, 2010, was the very first Landsat post-event imagery available for mapping the extent of the flood with an acquisition date quite close to the peak flood in Charsadda and Nowshera. Visually, we found that the areas of the North-West of Charsadda and East side of Nowshera seem to be the most affected area. This image covered the highly flooded areas of Charsadda, Nowshera, and Peshawar, which helped to visualize the extent of the flood 5 km along with the River Kabul. Other pre-flood Landsat image acquired on July 22, 2010, over the same area shows the slightly above normal water situation in the rivers and other nullahs and tributaries because of the normal monsoon rainfalls. The pre-flood and post-flood Landsat imageries are shown in Fig. 2. These satellite images were composed of 11 layers, tied by using a color composite algorithm in ArcGIS. We use band 7, 4, and 2 (natural-like), respectively.

2.3 Image processing

Satellite images have been processed step-wise with standard procedures. Firstly, we need to Geo-referenced Landsat images in ArcGIS 10.2.2 to place the image in its appropriate location in the real world. After Geo-referencing, Radiometric/Geometric distortions were checked and removed in Erdas Imagine by using a focal spatial analysis tool to process error-free data (see Fig. 3). Then we have done Image Enhancement for improving image quality for better classification. After that, we clipped out our area of interest by using extract via ArcGIS. Extraction is a helpful tool to improve the processing speed, time-consuming, and improve the accuracy of the extracted data.

2.4 Software used

In the present study following software's were used;

1. Arc GIS 10.2.2
2. Microsoft Office Word
3. Microsoft Excel
4. Erdas Imagine
5. Google Earth

2.5 Supervised image classification

The supervised classification is applied in ArcGIS to rectify satellite images to observe the spatial variation features of the imageries (see Fig. 3). In this process, we assign a representative sample (pixel) to each land cover class. During classification, we have classified the images into four major classes such as settlements, bare soil, water bodies, and vegetative land.

2.6 Area calculation

Classification results were then converted to shapefiles for further analysis and assessment through GIS and measure the actual percentage of change in these land covers (Fig. 3). The areas were computed and the following results were obtained. Then we export our result into Microsoft Excel and make graphs to see the actual changes in land covers of District Charsadda before and after the flood.

2.7 Precision and accuracy

We have checked the precision and accuracy of the classified imageries by following the Swipe technique through the Geographic Information System and Remote Sensing. The accuracy of the supervised imageries mostly depended on the spatial analyst tool to find out the differences in land use and land cover changes by examining different land features (see Fig. 3). During the overlying of images all land use and land cover classes exactly overlaid on the original image.

3 Results and discussions

3.1 Pre and post-flood analysis

Classification of Landsat images based on four major classes including vegetative area, water bodies, bare soil, and settlements. The vegetative area included the agricultural fields (crops) across the study area and the bare soil, the soil which is not covered by vegetation, litter, or duff. Waterbodies include all the rivers, small tributaries, and nullahs pass through the settlements of the study area which includes all Tehsil, towns, villages, and buildings. Pre and Post-flood classified images of the District Charsadda along 5 km River Kabul are shown in Fig. 4. We used classified images to determine each class area and percentage before and after the flood for different land covers for the year 2010 as shown in Table 1. The results of Table 1 demonstrate the conversion among different land covers of the study area. After the classification, it was clear that the build-up area, waterbody, bare soil, and vegetation is destroyed by the flooded water of 2010.

The pre-flood classified map of settlements shows villages of district Charsadda, Nowshera, and Peshawar 5 Km along river Kabul. A list of damaged villages of Charsadda, Peshawar, and Nowshera District are shown in Fig. 5. Results showed that the Charsadda District was the most affected during the 2010 flood. The study area is dominated by agricultural activities that have high fertile lands, produce a variety of crops and fruits. The spatial distributions mapping shows a high concentration of damage to agricultural lands along the rivers and nullahs. Charsadda District and surrounding areas are flood-prone due to torrential summer rainfall, glaciers melting, and deforestation and overgrazing in the catchment area of Rivers bodies. The flood of 2010 caused severe damages to settlements, agriculture land, standing crops, and other infrastructures. Most of the houses are made of mud which completely collapsed during flood occurrence in the study area. The houses were damaged during the flood and resulted in the displacement of 5500 families. Many governments, private health facilities, and water supply channels were completely damaged.

Based on research findings, it is suggested that flood channelization and embankments in the flood-prone areas should be improved to minimize flood hazards (Yousaf and Naveed, 2013). A flood control room is installed at the District headquarters to collect and get prior information about floods, but not effectively used. There is a lack of floodplain regulations and management in the area. Government agencies did not warn the localities about floods in time. Upstream localities did not receive any pre-flood warning. Downstream people were warned by local people sometime before flood occurrence. Flood protection measures are not satisfactory in the study area.

3.2 Comparison of pre and post-flood analysis

Comparative analysis of pre and post-flood classified images computed the following results as the agriculture land was decreased from 68.55 % to 55.10 %, water body increased up to 16.4 % from 8.81 %, build-up area was also decreased (see Fig. 6 and Fig. 7). Approximately 4 villages of District Nowshera, 6 villages of District Peshawar, and 27 villages of Charsadda District were damaged during the 2010 flood. The barren land increased from 23 % to 26.30 % due to a decrease in vegetation cover. Overall results showed a high concentration of damage to agricultural land and settlements along the rivers and nullahs, especially across the Charsadda area.

3.3 Mitigation measures

The study area is at a high risk of flooding, especially in the monsoon season. Under such conditions, the most important task is to propose mitigation measures to minimize the damages caused by the flood. Mitigation strategies reduce the risk of flooding to the people who lived in flood-prone areas. If we focus on flood resilience instead of on defense there is a possibility to reduce the damage. We should learn to live with the floods and need to be prepared during an epidemic situation. The following mitigation measures are suggested against flooding in the study area.

3.3.1 Evacuation and relocation

It has been strongly suggested that people of the higher risk areas should migrate to a safe allocated zone recommended by the government authorities. Thus, people leave the flood-prone zone during flood instead of staying over there and crossing of red hotspot areas declared by local and governmental authorities. At the same time awareness among the people of the red zone should be created and give some protection strategies. The best protection towards flood at the most primitive level is to seek higher ground level to overcome the potential risks of the flood. Areas at most risk for flooding could be temporarily abandoned to shift the people to safer areas when a flood is imminent. Approximately four villages of District Nowshera such as Banda Shaikh Ismail and Zangal Kalle, six villages of District Peshawar such as Garhi Afridi and Shagar Qala, and twenty-seven villages of Charsadda District includes Mian Qala, Dogar, Faqirabad, Tarnab, Tangi, etc., were severely damaged during 2010 flood. Governmental and non-governmental organizations and local communities are equally involved in the evacuation process. During the flood, local people were found to help the troubled people to evacuate from the flooded area to some extent. Although many people leave the flooded area by themselves (Kurosaki et al., 2011).

3.3.2 Modify infrastructures to control/withstand floods

Design and construct such type of structures that can control or withstand floods like dams, levees, reservoirs. Structures, such as bridges, which must inevitably be in flash flood zones, should be built to withstand the inundation. Flood control infrastructures, such as dams, should be constructed and managed over time to minimize the severity and consequences of floods. Large numbers of spurs and some reservoirs were also constructed on the Rivers Swat, Kurrum, and Kabul, including their tributaries, which accounts for the erosion. Construction of dams to reduce the flood discharge, water diversions to the side channels, or watersheds, levees can prevent flood spreading in the vulnerable reaches to reduce flood damages, storage reservoirs, and to build storm channels to carry flood water towards the protected areas (Heidari, 2009).

3.3.3 Flood proof buildings

Construction in the flood plain should be flood-proofed to mitigate future risks. Shift existing buildings and structures to the safer areas is also an alternative but it is not desirable and easy to shift buildings from the high-risk areas to a safe flood zone. This study area is very densely populated with intensive agricultural activity. It is difficult for such a large number of communities to shift their property and belongings. Thus, it is suggested that flood-proof buildings should be built in the study area to resist flood water to minimize the consequences of the flood. From now onwards while constructing new buildings should be built one or two meters above from the ground level to prevent flood damage in the study area.

3.3.4 Rehabilitation of flood affectees

Rehabilitation for community safety, emergency infrastructures should be constructed in the study area to overcome the risk of flooding, like hospitals, emergency operations centers, police, fire, and rescue service. The affected people need food, shelter, clothes, and reintegration for their normal life. Floods displace the people, affect their socio-economic life, and damage their properties. They need rehab on an immediate basis. During the flood, it was observed that the government, non-government organizations, and residents were equally involved in the rehabilitation process of victims. Food, medicine, shelters, and money were distributed among the flood victims to help them in fast recovery (Davies, 2011). During the 2010 flood, the Pakistan Army plays an important role in flood management and rehabilitation, provides emergency rescue and relief services to the affectees of the floods.

3.3.5 Flood protection embankments

Embankments are effective for minimizing the flood risk in a study area. Some specific measures should be taken to reduce losses to villages, property, and agricultural fields by making flood embankment and raising of village site through landfilling. Embankments are considered to be the most cost-effective and popular method for flood control, only suggested for some critical localities. Major flood-protective infrastructures in Pakistan comprises flood protection embankments 6,807 km, and 1,410 spurs, under control of Provincial Irrigation Departments (Aslam, 2018). During the flood 2010, a barrier occurred at the joining point of River Swat and Kabul, termed as Doaaba, due to which overflow in the River increase and water entered into the city. Islamic relief, a private organization developed an embankment at a small level but proper embankments still needed to control the risks of the flood (Akhter et al., 2017).

3.3.6 Re-meandering and channelization

River channelization is an effective technique to minimize the intensity of water in the water body during the flood. River swat is channelized properly so if a flood generates in River Swat excess amount of water can store in a channel but on the other hand, River Kabul is not channelized, so if a flood occurs in Kabul River, difficult to handle stormwater, that's why the channeling of the River Kabul might be an effective strategy to prevent flood-damaged in the flood plain zone of the area. Channelization of River Kabul can effectively increase water recharge of the surrounding wells which further increases the chances of water availability for agricultural and irrigation purposes (Akhter et al., 2017).

The study area is dominated by fertile agricultural land, which necessitates channelization of the drain. The path of the channel may be broadened and deepened so that floodwater may flow smoothly. Bridges across the drain may be designed at the highest level of rural flash floods. There should be an efficient system for storing excessive rainwater, to prevent the overflowing of water. One of the most important steps is to strengthening the drainage, which can avoid water logging to prevent floods. Sedimentation is another great issue due to rapid development. Rapidly moving water carries all the sediments with it and drops them into the riverbed due to a decrease in velocity, which in turn decreases the storage capacity of the rivers and streams, causes floods (Tariq and Van De Giesen, 2012).

Erosion control measurements should be taken in the riparian zones near streams and rivers, to slow or reverse the natural processes that cause many watercourses to bend for a prolonged period. Restore the rivers to their natural paths to overcome the damage. Re-meandering increases the length of the straightened river which reduces the flow of the transportation that can efficiently store water in the river. Consequently, Re-meandering can reduce the risk of flooding to downstream by reducing the hydrological response times during periods of extreme discharge.

3.3.7 Flood forecast and warning systems

The flood forecasting and warning Centre should be established in the study area to warn the community before the flood. Improve flood warning systems to give more time to people to take action before floods, potentially saving lives. Before the flooding, take all necessary precautions and warn the community to be prepared in advance. The impacts of the floods can be reduced by warnings and pre-planning. Forecasting about flood situations is important to provide some relief to the community. A flood warning center may be installed up-stream in the area to warn the down-stream people at least an hour or two before the flood. It is suggested to design a framework especially for Charsadda District to evaluate the flood severity and magnitude. In Pakistan, floods witnessed every year in the monsoon season. The model should be developed for flood prediction based on the rainfall and runoff data. Flood commission launches flood control plans every year in April and regulates the discharge of water at important dams and barrages, and regularly interact and communicate with all provincial governments in before, during and after flood situations.

3.3.8 Land-use planning

Land-use planning at the regional or local level is an efficient tool to reduce flood risks. Land near the river is highly valuable and attractive for parks, recreation, and ecological reserves. Land use planning plays an important role in reducing risks from floods, which leads to sustainability and improved resilience. Land-use planning can be helpful for flood mitigation and minimize risks by restricting construction activities in the flood-prone areas (MS, 2010).

3.3.9 Importance of land cover and tree plantation

Vegetation plays an important role in checking runoff and soil erosion and degradation. Farmers of the catchment area may be advised to grow more and more plants, and trees to check and control surface runoff and provide a maximum time gap between rainfall and flood occurrence. Reforestation could significantly reduce the impact of climate change on flooding. Loss of vegetation cover (deforestation) will lead to an increase in the risk of flooding. Natural forest cover compacts the soil so flood duration should be decreased. Deforestation magnifies the incidents and severity of floods. While afforestation helps to prevent mass wasting which reduces the amount of soil entering into the river and maintains the capacity of rivers, to reduce soil erosion. The degradation of soil increases the sediment deposition in the river bed which reduces the water carrying/bearing capacity of the rivers.

4 Conclusion

This study provides useful information on the land-cover change, the trends, and impacts of land-cover change. Remote Sensing and GIS techniques have proved useful to demarcate the flood-prone areas. It has become very easy to delineate the severity of the floodwater and estimated cost of rehabilitation using these innovative technologies. It allowed us to assess areas that were not physically accessible. These techniques have increased high spatial resolution. The comparative analysis of pre and post-flood classified images of agriculture land was decreased from 68.55 % to 55.10 %, water body increased from 8.81 % to 16.4 %, and construction build-up area was also decreased. Approximately 4 villages of District Nowshera, 6 villages of District Peshawar, and 27 villages of Charsadda District were damaged during the 2010 flood. Therefore, the barren land increased from 23 % to 26.30 % due to a decrease in vegetation cover. Moreover, heavier damage to agricultural land and settlements was observed along the rivers and nullahs of District Charsadda. This research will be helpful to develop a quick response strategy and move quickly to take necessary remedial measures. The effectiveness of remote sensing images for flood mapping has been extensively demonstrated in many recent flood events. It is strongly recommended that the government should take appropriate measures to mitigate and manage floods at the district level. All government bodies should prepare flood control plans and frameworks annually and ensure the timely spread of early warnings through modern means of communication. If appropriate flood mitigation measures have not been carried out and the pattern of land-use change continuously, it is suspected that future generations might not be able to watch the same beauty of the District Charsadda. This information will help to select, plan, and implement land-use strategies to address the challenges of land-use change.

Data availability. Satellites Images were downloaded from Earth Explorer website which is freely available (https://earthexplorer.usgs.gov/) and the population data were obtained from (Statistics, P.B.o., 2017. Province wise provisional results of census–2017. Pakistan Bureau of Statistics Islamabad.)

Authors Contribution. All authors discussed and conceptualized the whole article, leaded by MF, who conducted and prepared all the data, mapping and finished initial draft. IH had a leading role on Mitigation measures perspective and flow chart. SA contributed to data visualization and plagiarism check. WT reviewed the paper and suggest some changes. AR critically reviewed the paper and conducted the publication stages.

Competing Interests. The authors declare that there is no conflict of interest to disclose.

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Highlights

- Land use and land cover change were investigated by using GIS and RS techniques.
- Two instances pre-flood and post-flood were compared to analyze the change.
- Comparative analysis of pre and post-flood analysis shows drastic changes.
- Waterbody change (9-16.4 %), cropland (69-57 %), and bare land (23-26 %).
- The high rate of damage to agricultural land and settlements along the Kabul River.

Table 1 Represents land covers distribution for each class before and after 2010 flood occurred in the flood plain zone of District Charsadda, Pakistan.

Land Cover Classes	**22 July 2010, Before Flood**		**10 August 2010, After Flood**	
	Area (km^2)	**percentage**	**Area (km^2)**	**percentage**
Vegetation Cover	370125	68.5 %	307587	57 %
Water Body	47670	8.81 %	89030	16.4 %
Barren Land	121801	22.5 %	142979	26.30 %

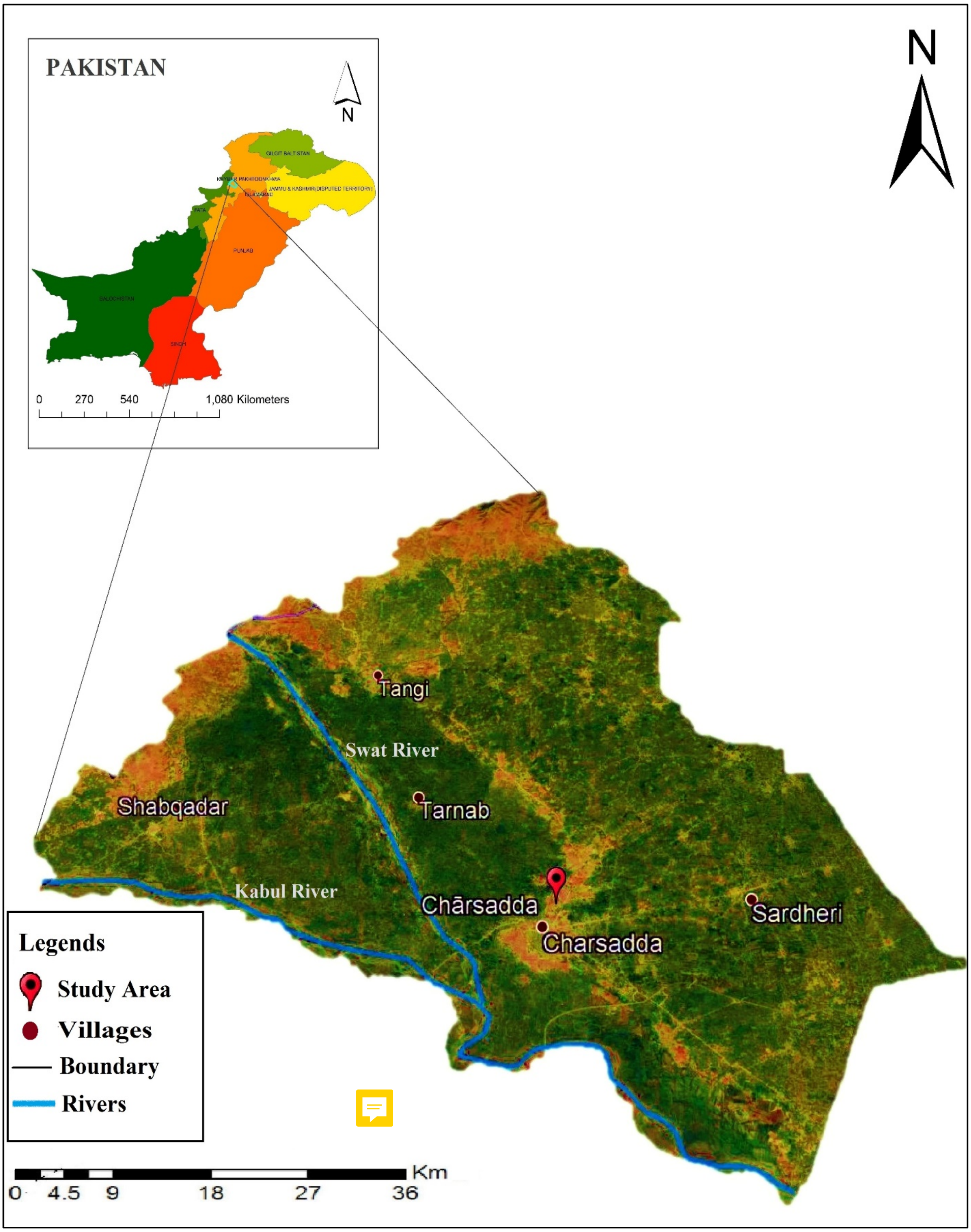

Figure 1. Location map of District Charsadda showing the extent of Kabul and Swat River. (The base map was adapted from © Google Earth).

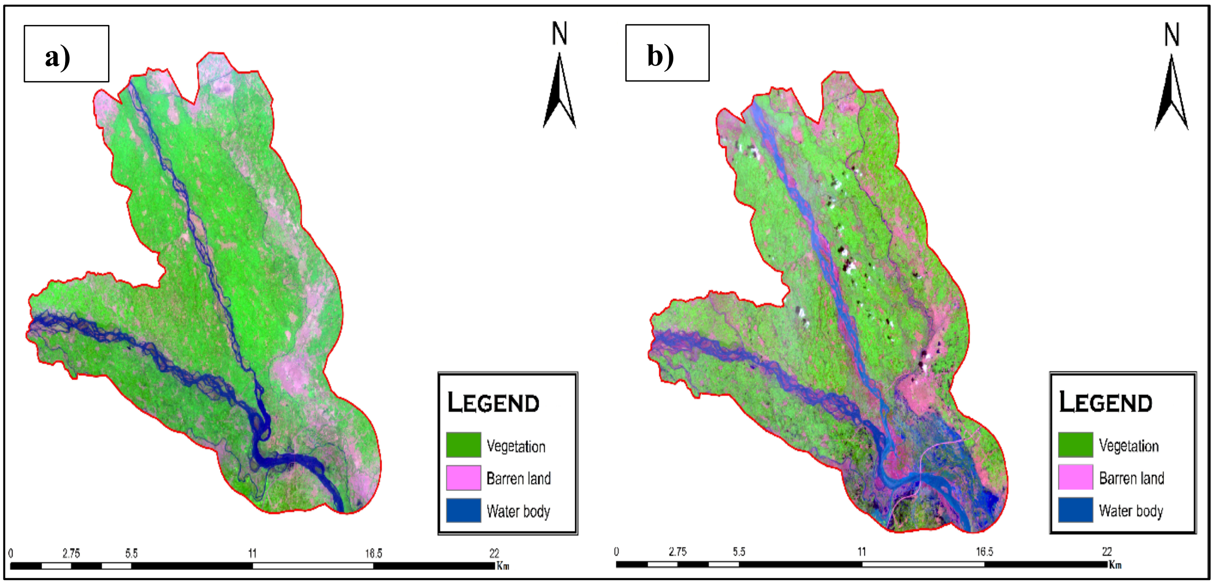

Figure 2. (a) Shows pre-flood Landsat 7 image of 22 July 2010, and, (b) indicate flood Landsat 7 image of 4 August 2010.

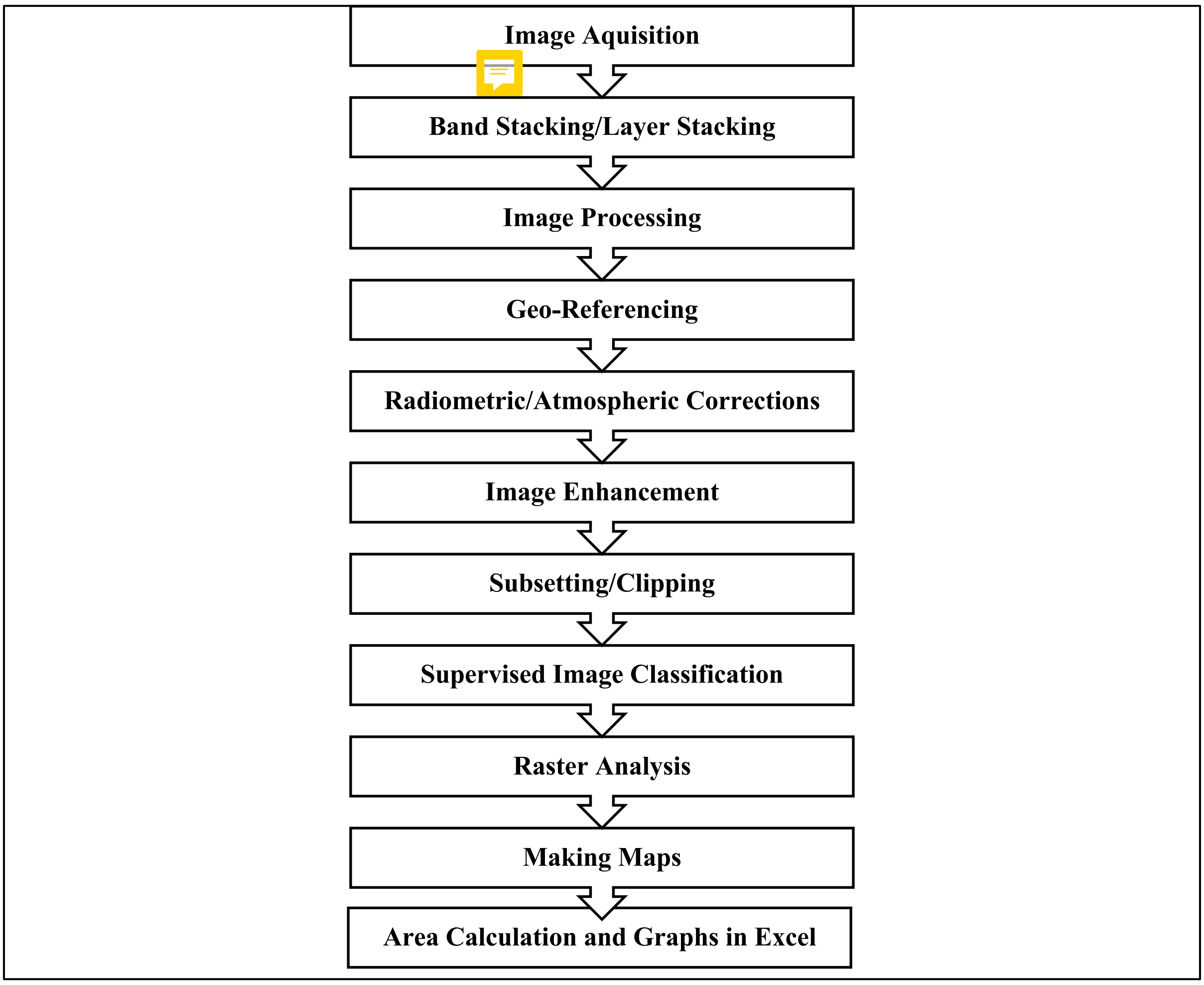

Figure 3. Shows a thematic workflow diagram for assessment of land use/cover changes in the study area.

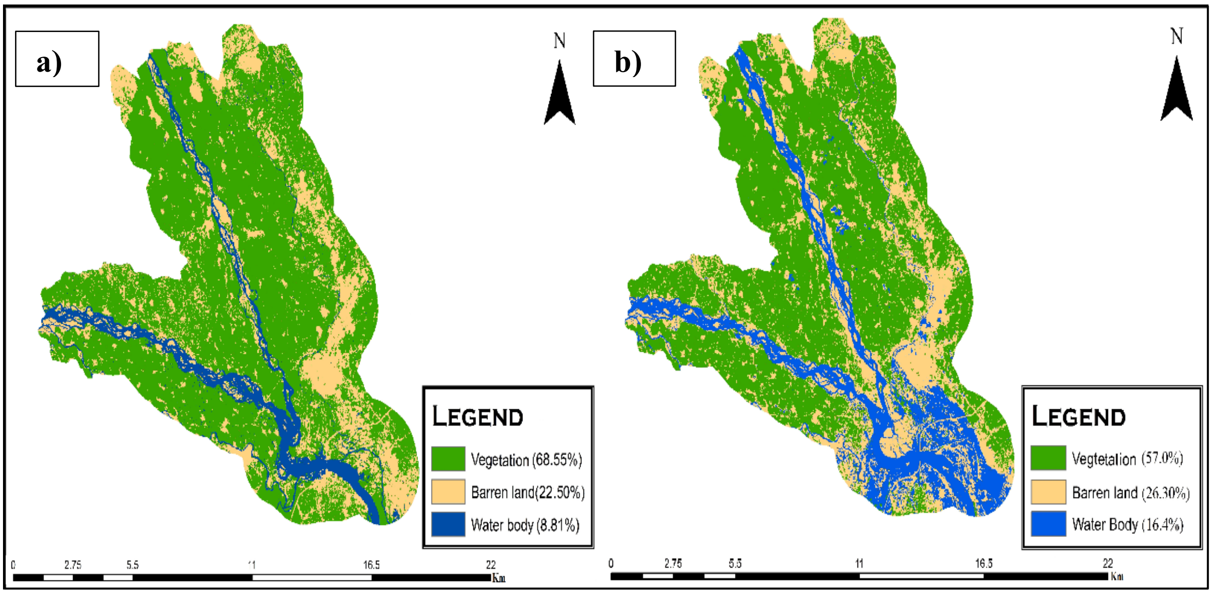

Figure 4. (a) Showing classified map of study area before flood, while, (b), reveal classified map of study area after flood.

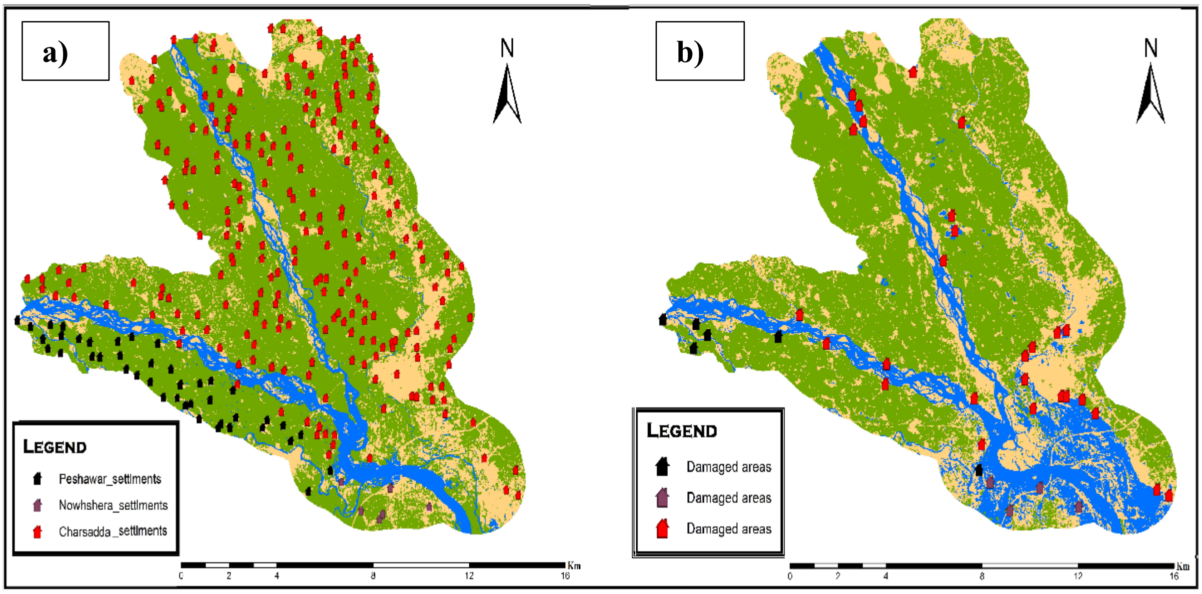

Figure 5. (a) Represent pre-flood classified map of settlements, (b) shows post-flood classified map of settlements of the study area.

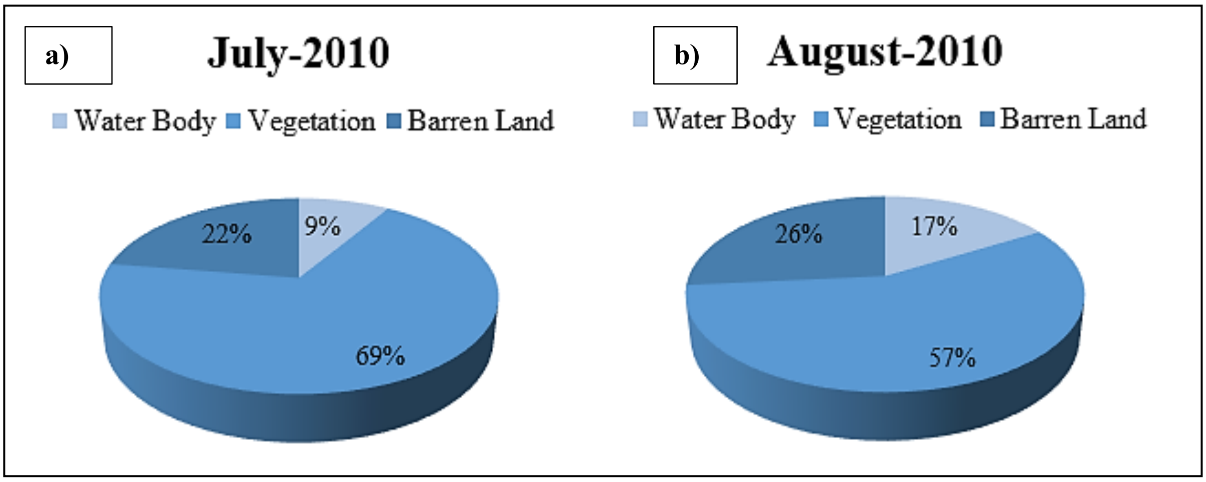

Figure 6. (a) identify pre-flood percentage changes in different land cover and, (b) determine post-flood percentage changes in different land cover of the study area.

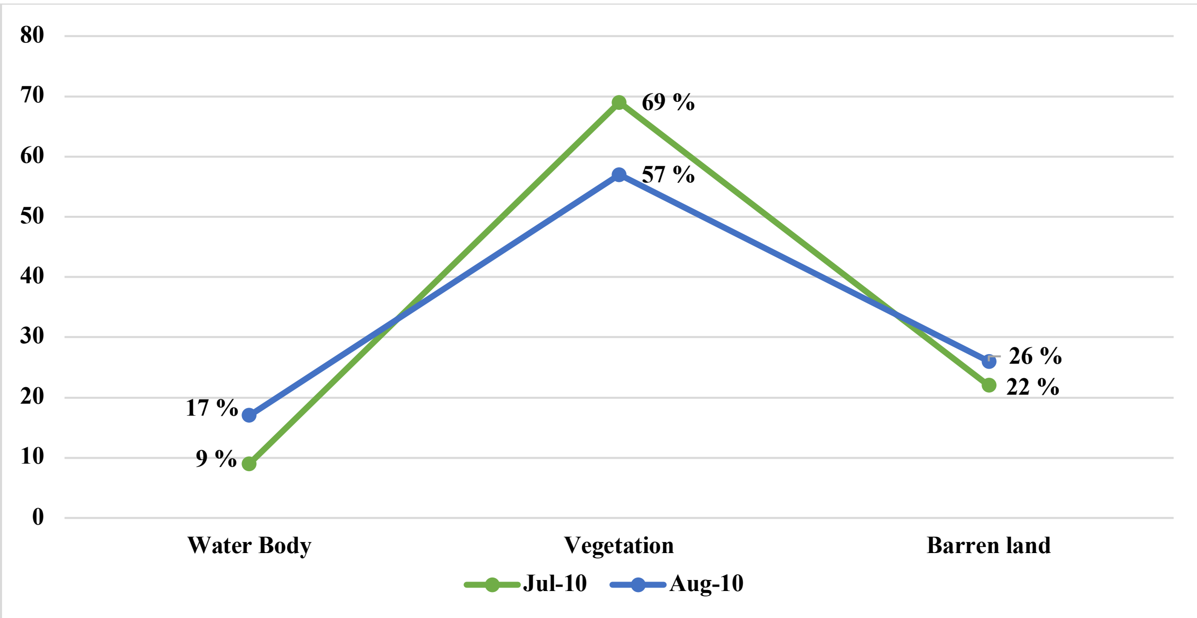

Figure 7. Showing percentage change in land use/land covers.