1 **Land use and land cover change analysis of District Charsadda,**

2 **Pakistan along Kabul River in 2010 flood: using an advance**

3 **geographic information system and remote sensing techniques**

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8 **Abstract.** The objective of this research study was to quantify land use and land cover changes before and after

9 the 2010 flood at District Charsadda, Pakistan. The land use and land cover changes were evaluated with the help

10 of advanced geographic information systems (GIS) and remote sensing techniques (RST). Moreover, some

11 remedial measures were taken to develop land use/land cover of the area to overcome future problems. Land use

12 and land cover changes were measured by using satellite images. Two instances were compared, i.e. pre-flood

13 and post-flood, to analyze the change in land use/land cover of District Charsadda within 5Km along the Kabul

14 River. Comparative analysis of pre and post-flood imageries shows drastic changes over the water body, built-up

15 area, agriculture land, and bare land during flood instances. The study area is rural and agricultural land is

16 dominant in the area. We evaluated the percentage of different land uses/land covers within our study area, as

17 agricultural land was about 68.5%, barren land was about 22.5 %, and the water body was 8.8 % before the flood.

18 After inundation, the water body raised to 16.4 %, bare soil increased to 26.30 %, agriculture land degraded up to

19 57 %, and settlements (villages) along River Kabul were badly damaged and finished by this flood. Approximately,

20 four villages of District Nowshera, six villages of District Peshawar, and twenty-seven villages of Charsadda

21 District were badly damaged during the 2010 flood.

22 **Keywords:** Land Use and Land Cover Change; Change Detection; Supervised Classification; Geographic

23 Information System; Remote Sensing; Flood Mapping

24 **1   Introduction**

25 Flood mostly occurs in the flood plain area of Reverie's body. It is the overflow of water in the flood plain area

26 (Thomaz et al., 2007). The flood occurs when the land has no more capacity to absorb rainwater, and rivers and

27 lakes rise over their banks. Thus, overflow of water occurs in the surrounding area which ultimately affects the

28 ecosystem of the target area (Amoateng et al., 2018; Devi et al., 2019; Perry and Nawaz, 2008). A flood is a

29 natural event that occurs as a result of heavy and prolongs rainfall, coastal hazards, tsunami, and earthquake (Kron,

30 2005). Floods are predominantly associated with severe hydro-meteorological behavior, geomorphic agent's viz.

31 permeability, soil stabilization, vegetation cover, and river basin geometry. Urbanization, changing demographic

32 features within flood plains, changes in flood regime, climate change, mismanagement of dam, deforestation,

33 changes in land-use, and disturbance of ecological system due to anthropogenic actions considered the major

34 factors which increase the flood risk (Khattak et al., 2016). Global warming leads to huge rainfall, overflow of
35 water, climate change, and land cover infrastructure (Hunter, 2003; Patz et al., 2008).

36   Pakistan is a flood-prone country, renowned for its summer floods due to physical, geochemical, and climatic
37 features, which pose an adverse effect on the ecology of the surrounding area. Many flash floods occurred before
38 2010 but the flood of 2010 is known to be the worst in the history of Pakistan. In the context of discharge,
39 destruction, and volume of rainfall, it has broken all the prior records. The main causes of flooding in Pakistan
40 include the affected area near the river, heavy monsoon rain, snowfall and glaciers melting. Most of the weather
41 stations had observed rainfall above average. It shows that heavy and prolonged rainfall was a major cause of the
42 2010 flood for successive four days from 27–30, July. It has been observed that severe flood takes place in all
43 flood plain areas of the Riverine environment of Pakistan due to the global warming phenomenon. As a result of
44 flooding social, and economical loss occurs. Furthermore, primarily precious live forms such as humans, plants,
45 animals, residential, industrial, commercial, and recreational zone were destroyed within no time. Overpopulation,
46 ecosystem degradation, abrupt changes in climatic condition, further added new insights to the risk
47 management system (Harper and Snowden, 2017).

48   Pakistan is adversely affected during the 2010 flood, about 11239 people died and around 1985 people were
49 affected in the history of Pakistan. About 20 lac individuals in Pakistan were suffered due to the worst flood of
50 2010. So different people make an effort to make building resilience such as flood reduction approaches (Sardar
51 et al., 2016). Some researchers believed that climate change is the dominant factor responsible for the prolonged
52 rainfall in 2010. These factors were responsible for the disastrous flood in the country. In the KPK districts, a high
53 flow rate has been estimated at Kabul, Indus, and Swat Rivers (Khan, 2013). There are two wet spells in a year,
54 the winter and summer. Winter rainfall is caused by western fluctuations, high rainfall recorded in March and
55 April every year. While the highest summer rainfall records in July and August. But comparatively, the winter
56 rainfall is higher than summer (Bookhagen and Burbank, 2010).

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

64   Remote sensing is a worthwhile and accurate tool for mapping natural disasters such as land sliding, floods,
65 and earthquake, covers large areas. Remote sensing data are pertinent for related hazards due to wide-area
66 coverage, accessibility, and temporal frequency. Satellite imageries are useful data sources for detecting,
67 evaluating, and estimating flood density, damage, and its consequences. However, timely acquisition and
68 accessibility of images are crucial. Besides, mapping the actual flood extent required previous flood images
69 collected at the same season or proximity to the flood period. Using this approach, the extent of the water bodies
70 at their normal flow can be identified. The discharge of normal water during flood images gives the flood extent
71 (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

110   of snowmelt in Hindu Kush Range. In late February, both the rivers start rising and reach the highest level of
111   discharge in June and July due to snow melting is accompanied by summer rainfall. The discharge lasts until the
112   end of October to January, disrupted by irregular flooding caused by erratic rainfall. The climate of the study area
113   is extreme. Monsoon and Western disturbances are the two key factors responsible for the highest rainfall. The
114   average rainfall fluctuates between 300 to 625 mm. There are two wet spells in a year, highest winter rainfall in a
115   semi-arid zone, and summer rainfall in the sub-humid zone, according to climatic data (Bibi et al., 2018).

2.2   Image acquisition

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

2.3   Image processing

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

2.4   Software used

136   In the present study following software's were used;

137   1.   Arc GIS 10.2.2
138   2.   Microsoft Office Word
139   3.   Microsoft Excel
140   4.   Erdas Imagine
141   5.   Google Earth

2.5   Supervised image classification

143   The supervised classification is applied in ArcGIS to rectify satellite images to observe the spatial variation
144   features of the imageries (see Fig. 3). In this process, we assign a representative sample (pixel) to each land cover
145   class. During classification, we have classified the images into four major classes such as settlements, bare soil,
146   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

184   floods in time. Upstream localities did not receive any pre-flood warning. Downstream people were warned by
185   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

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

3.3   Mitigation measures

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

3.3.1   Evacuation and relocation

201   It has been strongly suggested that people of the higher risk areas should migrate to a safe allocated zone
202   recommended by the government authorities. Thus, people leave the flood-prone zone during flood instead of
203   staying over there and crossing of red hotspot areas declared by local and governmental authorities. At the same
204   time awareness among the people of the red zone should be created and give some protection strategies. The best
205   protection towards flood at the most primitive level is to seek higher ground level to overcome the potential risks
206   of the flood. Areas at most risk for flooding could be temporarily abandoned to shift the people to safer areas
207   when a flood is imminent. Approximately four villages of District Nowshera such as Banda Shaikh Ismail and
208   Zangal Kalle, six villages of District Peshawar such as Garhi Afridi and Shagar Qala, and twenty-seven villages
209   of Charsadda District includes Mian Qala, Dogar, Faqirabad, Tarnab, Tangi, etc., were severely damaged during
210   2010 flood. Governmental and non-governmental organizations and local communities are equally involved in
211   the evacuation process. During the flood, local people were found to help the troubled people to evacuate from
212   the flooded area to some extent. Although many people leave the flooded area by themselves (Kurosaki et al.,
213   2011).

3.3.2   Modify infrastructures to control/withstand floods

215   Design and construct such type of structures that can control or withstand floods like dams, levees, reservoirs.
216   Structures, such as bridges, which must inevitably be in flash flood zones, should be built to withstand the
217   inundation. Flood control infrastructures, such as dams, should be constructed and managed over time to minimize
218   the severity and consequences of floods. Large numbers of spurs and some reservoirs were also constructed on
219   the Rivers Swat, Kurrum, and Kabul, including their tributaries, which accounts for the erosion. Construction of
220   dams to reduce the flood discharge, water diversions to the side channels, or watersheds, levees can prevent flood

221 spreading in the vulnerable reaches to reduce flood damages, storage reservoirs, and to build storm channels to

222 carry flood water towards the protected areas (Heidari, 2009).

3.3.3 Flood proof buildings

224 Construction in the flood plain should be flood-proofed to mitigate future risks. Shift existing buildings and

225 structures to the safer areas is also an alternative but it is not desirable and easy to shift buildings from the high-

226 risk areas to a safe flood zone. This study area is very densely populated with intensive agricultural activity. It is

227 difficult for such a large number of communities to shift their property and belongings. Thus, it is suggested that

228 flood-proof buildings should be built in the study area to resist flood water to minimize the consequences of the

229 flood. From now onwards while constructing new buildings should be built one or two meters above from the

230 ground level to prevent flood damage in the study area.

3.3.4 Rehabilitation of flood affectees

232 Rehabilitation for community safety, emergency infrastructures should be constructed in the study area to

233 overcome the risk of flooding, like hospitals, emergency operations centers, police, fire, and rescue service. The

234 affected people need food, shelter, clothes, and reintegration for their normal life. Floods displace the people,

235 affect their socio-economic life, and damage their properties. They need rehab on an immediate basis. During the

236 flood, it was observed that the government, non-government organizations, and residents were equally involved

237 in the rehabilitation process of victims. Food, medicine, shelters, and money were distributed among the flood

238 victims to help them in fast recovery (Davies, 2011). During the 2010 flood, the Pakistan Army plays an important

239 role in flood management and rehabilitation, provides emergency rescue and relief services to the affectees of the

240 floods.

3.3.5 Flood protection embankments

242 Embankments are effective for minimizing the flood risk in a study area. Some specific measures should be taken

243 to reduce losses to villages, property, and agricultural fields by making flood embankment and raising of village

244 site through landfilling. Embankments are considered to be the most cost-effective and popular method for flood

245 control, only suggested for some critical localities. Major flood-protective infrastructures in Pakistan comprises

246 flood protection embankments 6,807 km, and 1,410 spurs, under control of Provincial Irrigation Departments

247 (Aslam, 2018). During the flood 2010, a barrier occurred at the joining point of River Swat and Kabul, termed as

248 Doaaba, due to which overflow in the River increase and water entered into the city. Islamic relief, a private

249 organization developed an embankment at a small level but proper embankments still needed to control the risks

250 of the flood (Akhter et al., 2017).

3.3.6 Re-meandering and channelization

252 River channelization is an effective technique to minimize the intensity of water in the water body during the

253 flood. River swat is channelized properly so if a flood generates in River Swat excess amount of water can store

254 in a channel but on the other hand, River Kabul is not channelized, so if a flood occurs in Kabul River, difficult

255 to handle stormwater, that's why the channeling of the River Kabul might be an effective strategy to prevent flood-

256 damaged in the flood plain zone of the area. Channelization of River Kabul can effectively increase water recharge

257 of the surrounding wells which further increases the chances of water availability for agricultural and irrigation

258 purposes (Akhter et al., 2017).

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

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

3.3.7   Flood forecast and warning systems

273

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

3.3.8   Land-use planning

285

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

3.3.9   Importance of land cover and tree plantation

291

292   Vegetation plays an important role in checking runoff and soil erosion and degradation. Farmers of the catchment
293   area may be advised to grow more and more plants, and trees to check and control surface runoff and provide a
294   maximum time gap between rainfall and flood occurrence. Reforestation could significantly reduce the impact of
295   climate change on flooding. Loss of vegetation cover (deforestation) will lead to an increase in the risk of flooding.
296   Natural forest cover compacts the soil so flood duration should be decreased. Deforestation magnifies the

297   incidents and severity of floods. While afforestation helps to prevent mass wasting which reduces the amount of

298   soil entering into the river and maintains the capacity of rivers, to reduce soil erosion. The degradation of soil

299   increases the sediment deposition in the river bed which reduces the water carrying/bearing capacity of the rivers.

4   Conclusion

301   This study provides useful information on the land-cover change, the trends, and impacts of land-cover change.

302   Remote Sensing and GIS techniques have proved useful to demarcate the flood-prone areas. It has become very

303   easy to delineate the severity of the floodwater and estimated cost of rehabilitation using these innovative

304   technologies. It allowed us to assess areas that were not physically accessible. These techniques have increased

305   high spatial resolution. The comparative analysis of pre and post-flood classified images of agriculture land was

306   decreased from 68.55 % to 55.10 %, water body increased from 8.81 % to 16.4 %, and construction build-up area

307   was also decreased. Approximately 4 villages of District Nowshera, 6 villages of District Peshawar, and 27

308   villages of Charsadda District were damaged during the 2010 flood. Therefore, the barren land increased from

309   23 % to 26.30 % due to a decrease in vegetation cover. Moreover, heavier damage to agricultural land and

310   settlements was observed along the rivers and nullahs of District Charsadda. This research will be helpful to

311   develop a quick response strategy and move quickly to take necessary remedial measures. The effectiveness of

312   remote sensing images for flood mapping has been extensively demonstrated in many recent flood events. It is

313   strongly recommended that the government should take appropriate measures to mitigate and manage floods at

314   the district level. All government bodies should prepare flood control plans and frameworks annually and ensure

315   the timely spread of early warnings through modern means of communication. If appropriate flood mitigation

316   measures have not been carried out and the pattern of land-use change continuously, it is suspected that future

317   generations might not be able to watch the same beauty of the District Charsadda. This information will help to

318   select, plan, and implement land-use strategies to address the challenges of land-use change.

319

320

321   *Data availability.* Satellites Images were downloaded from Earth Explorer website which is freely available

322   (https://earthexplorer.usgs.gov/) and the population data were obtained from (Statistics, P.B.o., 2017. Province

323   wise provisional results of census–2017. Pakistan Bureau of Statistics Islamabad.)

324   *Authors Contribution.* All authors discussed and conceptualized the whole article, leaded by MF, who conducted

325   and prepared all the data, mapping and finished initial draft. IH had a leading role on Mitigation measures

326   perspective and flow chart. SA contributed to data visualization and plagiarism check. WT reviewed the paper

327   and suggest some changes. AR critically reviewed the paper and conducted the publication stages.

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396 **Highlights**

397 • Land use and land cover change were investigated by using GIS and RS techniques.

398 • Two instances pre-flood and post-flood were compared to analyze the change.

399 • Comparative analysis of pre and post-flood analysis shows drastic changes.

400 • Waterbody change (9-16.4 %), cropland (69-57 %), and bare land (23-26 %).

401 • The high rate of damage to agricultural land and settlements along the Kabul River.

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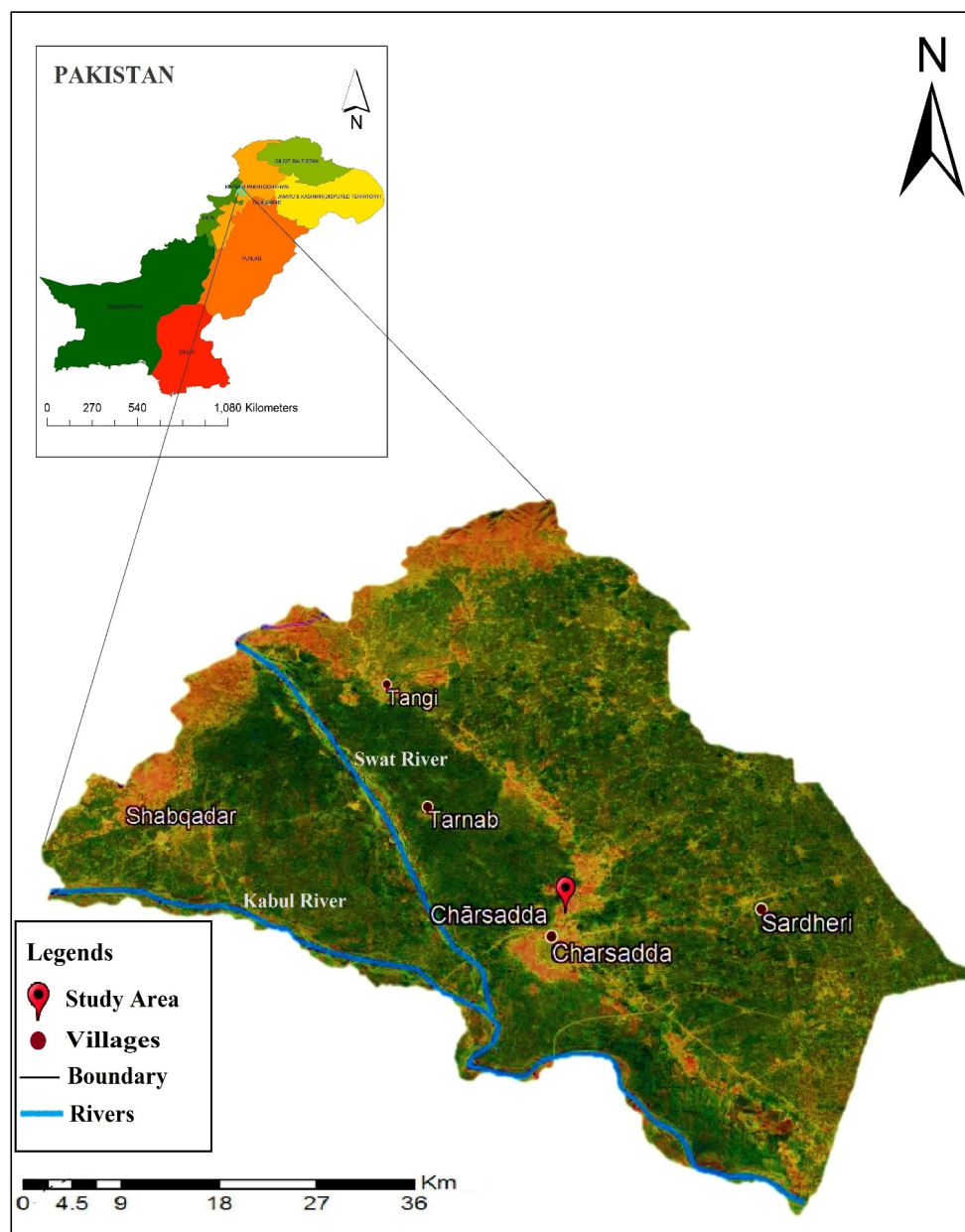
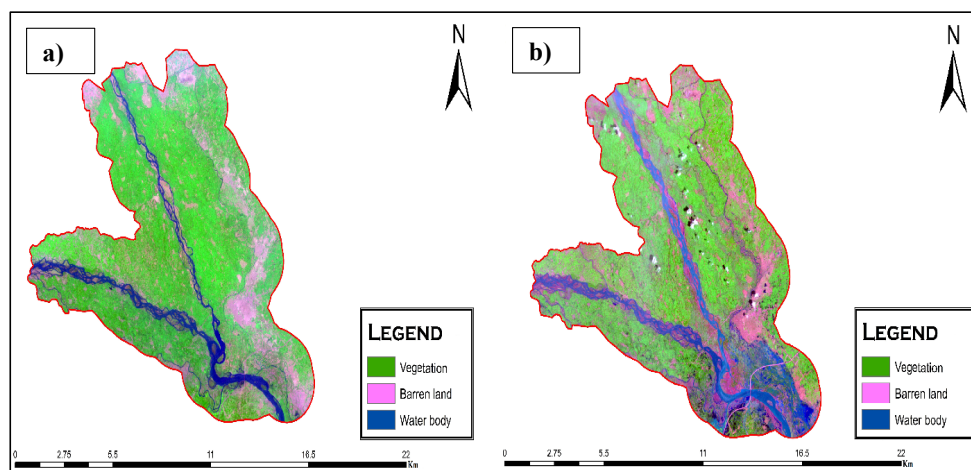
Table 1 Represents land covers distribution for each class before and after 2010 flood occurred in the flood plain zone of District Charsadda, Pakistan.

Land Cover Classes	22 July 2010, Before Flood		10 August 2010, After Flood	
	Area (km²)	percentage	Area (km²)	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).

407

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

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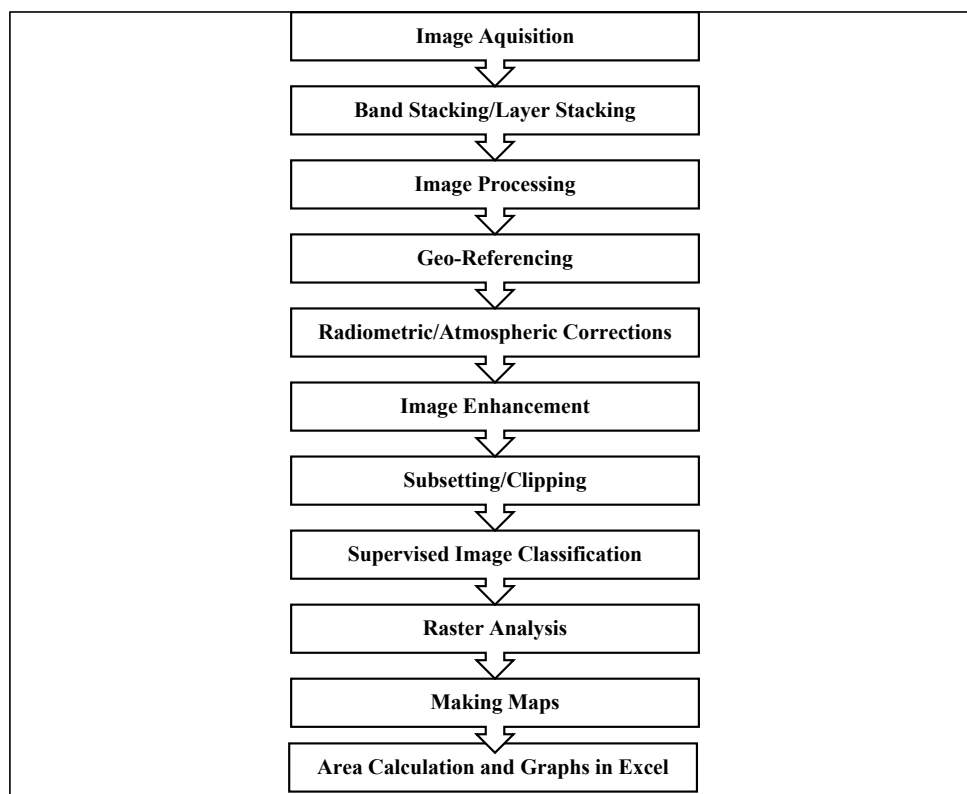
410 **Figure 3.** Shows a thematic workflow diagram for assessment of land use/cover changes in the study area.
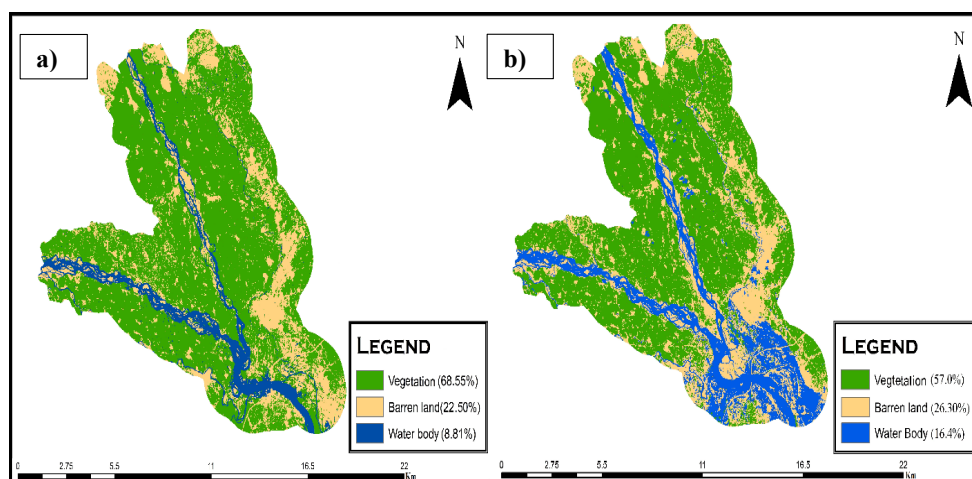
Figure 4. (a) Showing classified map of study area before flood, while, (b), reveal classified map of study area after flood.
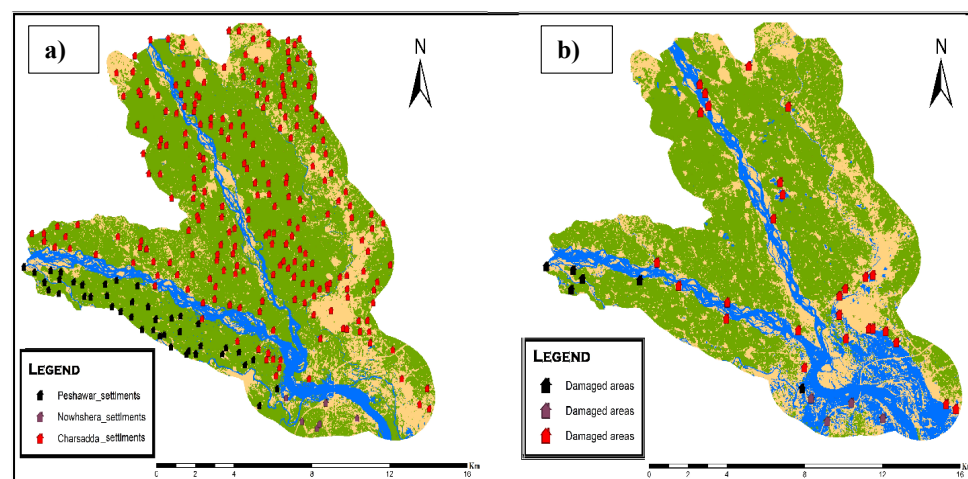
Figure 5. (a) Represent pre-flood classified map of settlements, (b) shows post-flood classified map of settlements of the study area.
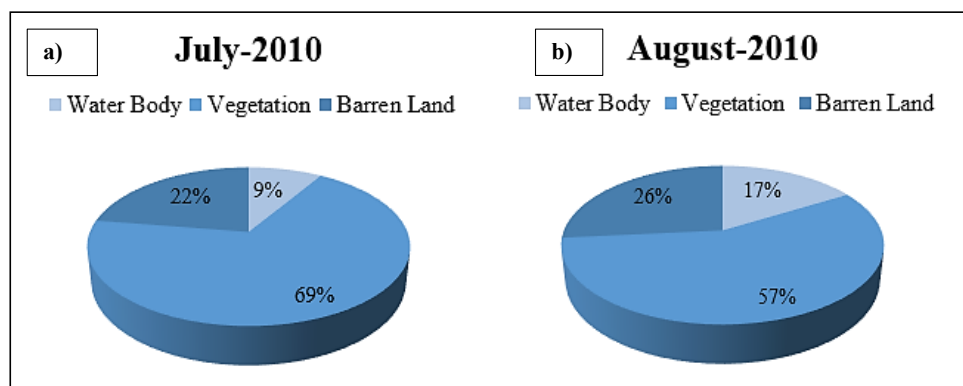
Figure 6. (a) identify pre-flood percentage changes in different land cover and, (b) determine post-flood percentage changes in different land cover of the study area.
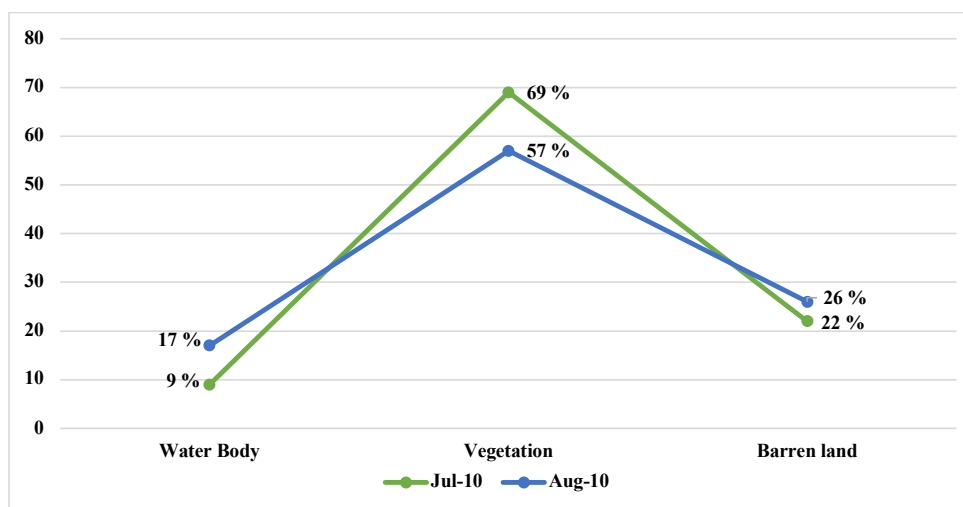
Figure 7. Showing percentage change in land use/land covers.