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RESEARCH ARTICLE

CHANGE DETECTION IN LAND USE AND LAND COVER OF DISTRICT CHARSADDA PAKISTAN ALONG RIVER KABUL (2010 FLOOD): TAKING ADVANTAGE OF GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING

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ABSTRACT

This study aims to quantify land use and land cover changes before and after the 2010 flood in district Charsadda, Pakistan. Advanced geographic information systems (GIS) and remote sensing techniques (RST) evaluate land use and land cover changes. The purpose of this research is to estimate and compare the pre- and post-flood changes and their influences on land use and land cover changes. Land use land cover data studies are important for sustainable management of natural resources; they are becoming increasingly important for assessing the environmental impacts of economic development. Moreover, some remedial measures are adopted to develop the area's land cover to overcome future problems. Land use and land cover changes are measured using satellite images. Two instances, i.e., pre-flood and post-flood, are compared to analyze the change in land use and land cover of district Charsadda within 5 km along the Kabul River. Comparative analysis of pre-flood and post-flood imageries highlighted some drastic changes over the water body, built-up area, agricultural land, and bare land during flood instances. The study area is rural and agricultural land is dominant as compared to other land uses. We evaluated the percentage of different land use and land cover within our study area. The agricultural land found about 68.5%, barren land 22.5%, and the water body 8.8% before the flood. After inundation, the water body raised to 16.4%, bare soil increased to 26.3%, agricultural land degraded up to 57.0%, and settlements (villages) along the Kabul River were severely damaged and finished by this flood. 2010's flood heavily damaged approximately four villages in district Nowshera, six in district Peshawar, and twenty-seven Charsadda District villages.

KEYWORDS

Land Use and Land Cover Changes, Change Detection, Supervised Classification, Geographic Information System, Remote Sensing, Flood Mapping, Natural Hazards

1. INTRODUCTION

Flood events significantly impacted communities living in flood-prone areas, causing tremendous damage to human lives and economic losses (Ferrari et al., 2020; Masson et al., 2019). Flood mostly occurs in the flood plain area of the river's body. It is the overflow of water and usually occurs when the land has no more capacity to absorb rainwater, and rivers and lakes rise over their banks (Thomaz et al., 2007). This overflow of water occurs in the surrounding area, which ultimately affects the target area's ecosystems (Amoateng et al., 2018; Devi et al., 2019; Perry and Nawaz, 2008). A flood is a natural event resulting from massive and prolonged rainfall, coastal hazards, tsunami, and earthquake (Kron, 2005). Floods are predominantly associated with severe hydro-meteorological behavior; the 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 are significant factors that increase the flood risk (Khattak et al., 2016). Global warming leads to massive rainfall, water overflow, 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, adversely affecting the surrounding area's ecology. Many flash floods occurred before 2010, but the flood of 2010 is known to be the worst in Pakistan's history. In the context of discharge, destruction, and volume of rainfall, it has broken all the prior records. The leading causes of flooding in Pakistan include the affected area near the river, heavy monsoon rain, snowfall, and melting glaciers. Most of the weather stations had observed rainfall above average. It shows that heavy and prolonged rain was a significant cause of the 2010 flood for four successive days from 27–30 July. It has observed that severe flood occurs in all floodplain areas of Pakistan's riverine environment due to the global warming phenomenon. As a result of flooding social, and economic loss occurs. Furthermore, the 2010's flood destroyed precious live forms such as humans, plants, animals, the residential, industrial, commercial, and recreational zone within no time. Overpopulation, ecosystem degradation, abrupt changes in climatic conditions further added new insights into the risk management system (Harper and Snowden, 2017).

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Pakistan is adversely affected by the 2010 flood. About 11239 people died, and around 1985, people were involved in Pakistan's history. About 20 lakh individuals in Pakistan suffered due to the worst flood of 2010. Henceforth, people have initiated efforts to build resilience, such as flood reduction approaches (Sardar et al., 2016). Some researchers believed that climate change was the dominant factor responsible for the prolonged rainfall in 2010. These factors were responsible for the disastrous flood in the country. In the KPK (Khyber Pakhtunkhwa) districts, a high flow rate at Kabul, Indus, and Swat rivers was estimated (Khan, 2013).

There are two wet spells in a year, winter and summer. Western fluctuations cause winter rainfall, and high rainfall is recorded in March and April every year. While the highest summer rainfall records are in July and August. But comparatively, the winter rainfall is more elevated than in summer (Bookhagen and Burbank, 2010). Khyber Pakhtunkhwa province recorded approximately 200-280 millimeters of heavy rain at the end of July and August 2010, especially in Peshawar, Charsadda, and Nowshera. An average of around 280 mm (11 inches) of rainfall was reported consecutively for three days in the most affected areas. These rains are responsible for enormous flooding in the Indus, Swat, and Kabul Rivers, which stayed high to extreme flood levels. Many fatalities registered, thousands of buildings demolished, and millions have lost their homes. 2010's flash flood drowned many villages and towns and damaged most of the agricultural lands. Kilometers of road sections and many bridges washed away.

Remote sensing (RS) is a valuable and accurate tool for mapping natural disasters such as land sliding, floods, and earthquakes, covers large areas. RS 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 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 in proximity to the flood period. The size of the water bodies at their normal flow can be defined using this method. Normal water discharge 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 for change detection studies. A combination of GIS and RS recognize as an effective and efficient tool, extensively applied for detecting land cover changes in an area at different times. GIS and RS techniques have immeasurable advantages compared with previous methodologies, and these tools are handy and efficient for monitoring dynamic changes in land use and land cover (Ouedraogo, 2010).

Changes in land use and land covers are 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 and land cover change study requires a comprehensive interpretation and evaluation of all the factors that trigger these environmental changes. The conversion of rural land into urban land prospects rises in impervious regions (Rahman et al., 2012). Land use and land cover are often confusing as synonymous terms, but they may reflect different landscape aspects. The term land-use defines events, often including individuals, which take place on the ground and reflect existing property use. Examples include residential homes, shopping centers, row crops, tree nurseries, state parks, reservoirs, etc. In contrast, land-cover classification uses to demonstrate the type of physical land on the earth's surface include; water, snow, grassland, forest, and bare soil (Zafar and Zaidi, 2015).

Based on the above discussion, we studied the land use and land cover change due to flood hazards and its remedial measures using GIS and RS techniques to control and havoc of flood in the flood plain area of river Kabul in district Charsadda. Therefore, this research aims to give an idea and workflow of GIS and RS technology application for flood impacts and mention how GIS and RS technology can help evaluate land cover changes and make the appropriate decisions. The main objectives of this study are; 1) estimate and compare the pre-and post-flood changes and their influences on land use and land cover changes, 2) produce land use and land cover maps through GIS and remote sensing techniques to find out the flood impacts on land, and 3) suggest and recommend mitigation measures to reduce the impact of recurrent floods. However, many researchers have been working on the risk assessment and risk zonation of the 2010's flood. Still, no significant attention pays to the land-use and land-cover change analysis better to understand the impacts of flood hazards on land in the proposed study area. This study is the first comprehensive analysis to map and analyze the land-use and land-cover changes in the Charsadda District during the 2010's flood using advanced geographic information system (GIS) and remote sensing (RS) techniques. This research is vital in contributing to future city planning, flood management, preserving the aesthetic value of the area, and filling the gap in the existing research work.

2. Materials and Methods

2.1 Study area

The study area locates 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 bounds by Tangi, Mardan district on the East, Nowshera and Peshawar districts on the Southside, and Shabqadar 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 Charsadda district population is 1,616,198 (Statistics, 2017). Three main rivers flowing in Charsadda; Kabul, Jindi, and the Swat; these rivers are the primary irrigation source in district Charsadda and its surrounding areas. The area surrounded by river Swat and river Kabul is called Doaaba and has prime importance. 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 increases in the spring season because of snowmelt in Hindu Kush Range. In late February, both the rivers start rising and reach the highest discharge level in June and July due to snow melting accompanied by summer rainfall. The discharge lasts until the end of October to January, disrupted by periodic 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. According to climatic data, there are two wet spells in a year, the highest winter rainfall in a semi-arid zone and summer rainfall in the sub-humid zone (Bibi et al., 2018).

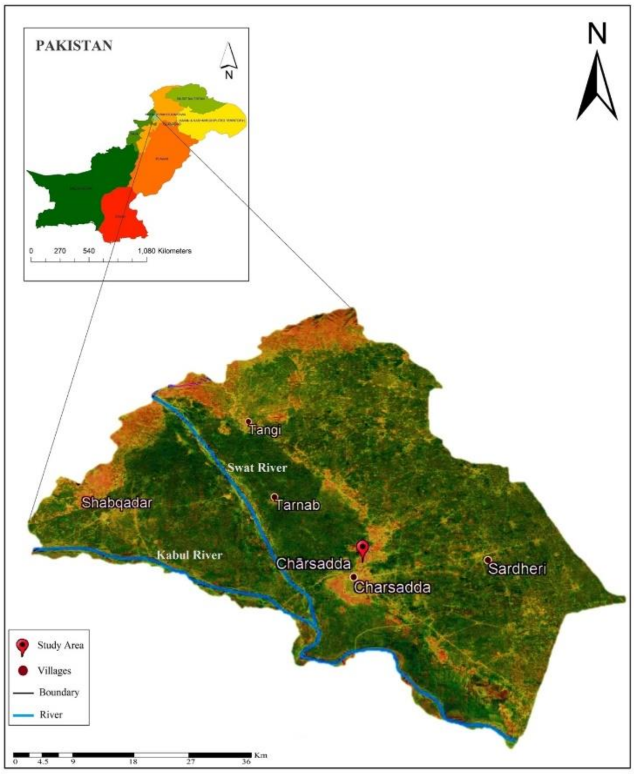

Figure 1: Location map of district Charsadda showing the extent of Kabul and Swat River. (The base map adapts from © Google Earth).

2.2 Image acquisition

Image acquisition used high-resolution remote sensing images for land degradation, precision farming, water, air pollution, and natural hazards (floods, earthquakes, landslides) (Ehlers et al., 2004). We acquired two high-resolution Landsat-7 images (pre-flood and post-flood) of the year 2010 of Charsadda District from the USGS website to estimate and compare the changes in land use and land cover before and after the flood. August 04, 2010, was the first Landsat post-event imagery available to map the flood's extent with an acquisition date close to the peak flood in Charsadda and Nowshera. Visually, we found that the North-West of Charsadda and the East side of Nowshera seem to be the most affected area. This image covered the positively flooded areas of Charsadda, Nowshera, and Peshawar, which helped visualize the flood 5 km and the river Kabul. Another 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 average monsoon rainfalls. The pre-flood and post-flood Landsat imageries demonstrate in Fig. 2. These satellite images are composed of 11 layers, tied by using a color composite algorithm in ArcGIS. We use bands 7, 4, and 2 (natural-like), respectively.

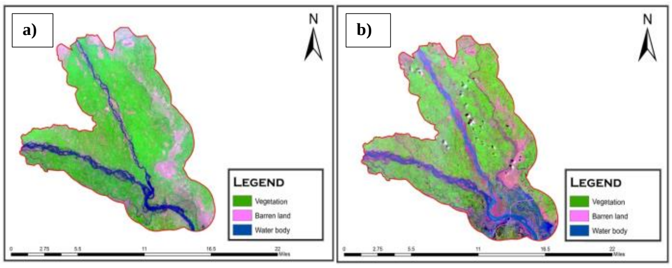

Figure 2: (a) Pre-flood Landsat-7 image of July 22, 2010 (b) Post-flood Landsat-7 image of August 04, 2010, clearly shows flood event.

2.3 Image processing

Satellite images have been processed step-wise with standard procedures. Firstly, we 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 (EI) using a focal spatial analysis tool to eliminate the data's noise to get error-free data (O'Melveny, 2004). Image restoration is a powerful tool to calibrate the images to achieve a faithful earth's representation in the meantime (see Fig. 3). Then we have done image enhancement for improving image quality for better classification. It is a modification of images to enhance their visual appearance. Image enhancement plays an important and substantial role in all aspects of remote sensing (Ehlers et al., 2004). After that, we clipped out our area of interest by using the extraction tool of ArcGIS with the help of the shapefile of the study area. A shapefile is an Esri vector data storage format to store geographic features' location, shape, and attributes. An extraction is a helpful tool for improving processing speed and time-consuming and improving the extracted data accuracy. Later on, a supervised image classification approach was applied to assess the pre-and post-flood changes between the two images to produce change maps to determine the flood impacts on land.

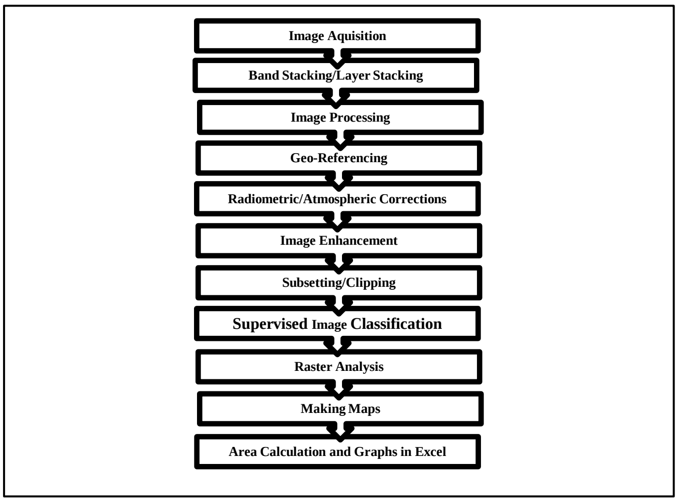

Figure 3. Displays a thematic workflow diagram for the evaluation of land use/cover changes in the study field.

2.3.1 Software used

In the present study following software programs are used;

- Arc GIS 10.2.2 (esri.com)
- Microsoft Office (Word & Excel) (microsoft.com)
- Erdas Imagine (hexagongeospatial.com)
- Google Earth (earth.google.com/)

Arc GIS software is used to map the study area's land use and land cover to detect changes before and after the flood. Arc GIS is used to compliment the display and processing of the data (Singh and Khanduri, 2011; Zubair, 2006).

Microsoft word utilizes for research presentation, and Microsoft Excel uses for producing graphs and percentages.

Erdas Imagine software checked radiometric correction/distortion for the satellite images (before and after the flood) using the image file's metadata (Zubair, 2006).

Google Earth Engine helps make a study area map and provides precise visualization of the land covers across the study area.

2.4 Supervised image classification

The supervised classification is applied in ArcGIS to rectify satellite images to observe the imageries' spatial variational features (see Fig. 3). In this process, we assign a representative sample (pixel) to each land cover class. Supervised image classification performed in three stages; to select training areas, creating a signature file, and classification. We classified Images into four major classes: settlements, bare soil, water bodies, and vegetative land.

2.5 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). A raster calculator is used to calculate the statistic of LULC both in terms of percentage and hectare. Then we export our results into Microsoft Excel and make graphs to see the actual changes in land covers of district Charsadda before and after the flood (2010).

2.6 Precision and accuracy

Once an image is classified, it is crucial to check the images' accuracy before processing and interpreting it. We have reviewed the classified imageries' precision and accuracy by following the swipe technique through the Geographic Information System and Remote Sensing. The supervised imageries' accuracy mostly depended on the spatial analyst tool to determine the differences in land use and land cover changes by examining different land features (see Fig. 3). All land use and land cover classes precisely overlaid on the original image during the overlying of images.

3. Results and Discussions

3.1 Pre-and post-flood analysis

Landsat images' classification categorizes into four significant classes: vegetative area, water bodies, bare soil, and settlements. The vegetative area included the agricultural fields (crops) across the study area and the bare ground, the soil not covered by vegetation, litter, or duff. Waterbodies include rivers, small tributaries, and nullahs that pass through the study area's settlements, consisting of all tehsil, towns, villages, and buildings. Pre- and Post-flood classified images of the district Charsadda along the 5 km river Kabul showed in Fig. 4. We used classified images to determine each class area and percentage before and after the flood for different land covers for 2010, as shown in Table 1. The results of Table 1 demonstrate the conversion among other land covers of the study area. After the classification, it was clear that the build-up area, waterbody, bare soil, and vegetation vanishes by the flooded water of 2010.

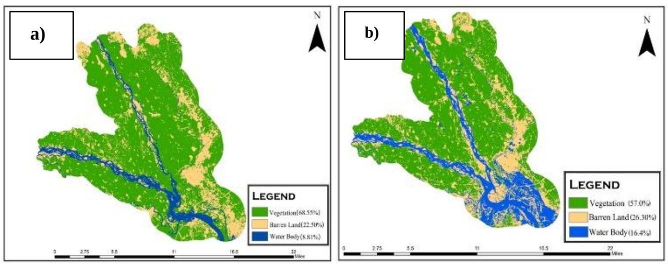

Figure 4: (a) Classified map of the study area shows the distribution of different land covers across the study area before the flood, while (b) reveals post classified map of study area showing land covers.

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

Land Cover Clsses	July 22, 2010, Before Flood		August 10, 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%

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 district Charsadda, Peshawar, and Nowshera illustrates 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 with high fertile lands and produces various crops and fruits. The spatial distribution mapping showed 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, melting glaciers, deforestation, and overgrazing in the catchment area. The flood of 2010 caused severe damages to settlements, agricultural land, standing crops, and other infrastructures. Most of the houses are of mud, which ultimately collapsed during flood occurrence in the study area. The houses were damaged during the flood and resulted in the displacement of 5500 families. 2010's flood completely damaged many governments, private health facilities, and water supply channels.

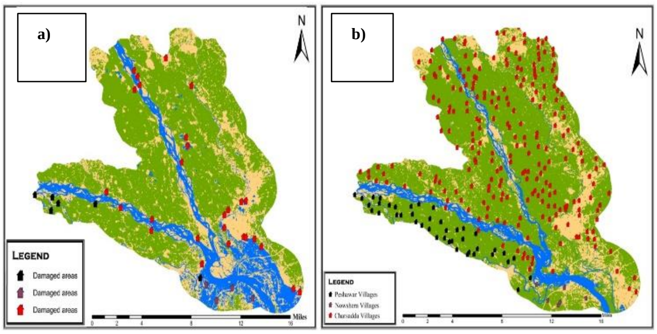

Figure 5: (a) Represent pre-flood classified map of settlements of district Charsadda, (b) shows a classified map of settlements damaged during the flood in the study area.

Research findings suggest that municipal and district authorities should improve flood channelization and embankments in flood-prone areas to minimize flood hazards (Yousaf and Naveed, 2013). A flood control room is installed at the district headquarters to collect and get preliminary information about floods but is 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, and upstream localities did not receive any pre-flood warning. Local people warned downstream 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: flash flood decreased the agricultural land from 68.5% to 55.1%, water body increased up to 16.4 % from 8.81%, build-up area was also reduced (see Fig. 6 and Fig. 7). 2010's flood-damaged approximately four villages of district Nowshera, six villages of district Peshawar, and 27 villages of Charsadda District. 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.

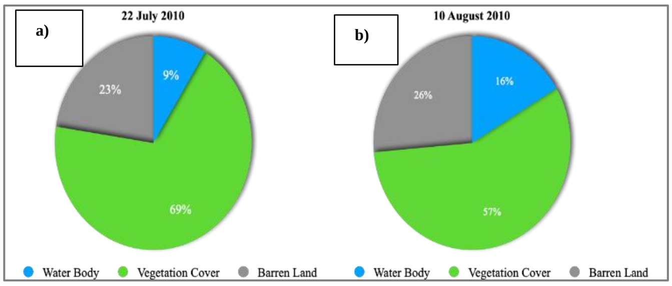

Figure 6: (a) identify pre-flood percentage changes in different land cover and (b) determine post-flood percentage changes in different land cover of the study area

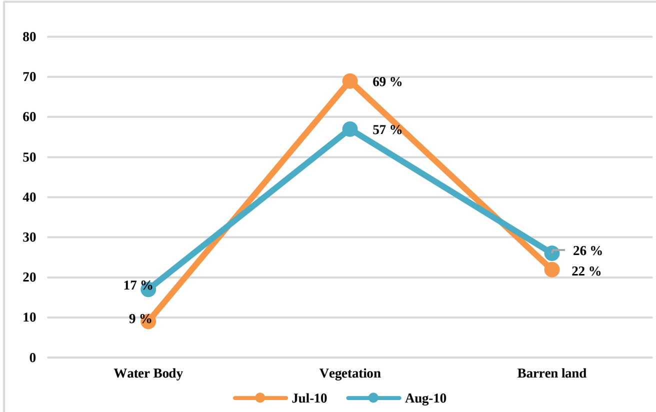

Figure 7: Showing percentage change in land covers of the study area before and after the flood, 2010

District Charsadda is always at flood risk because of Kabul and Swat rivers. The district is prone to both riverine floods as well as flash floods. Intensive agricultural activities and deforestation in the study area decrease the rivers' water carrying capacity and experience repeated overflow. Additionally, the growing population in flood plains is another threat to the district (Bibi et al., 2018). As the population of the district is 1,022,364 according to the 1998 census and 1,616,198 in 2017 (Statistics, 2017). Approximately 2.43% change occurred from 1998 to 2017 per year. All these factors contributed to land degradation and forced the rivers and tributaries to overflow from the watercourse, which caused flash floods.

3.3 Mitigation measures

The study area is at a high risk of flooding, especially in the monsoon season. Under such conditions, the essential 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 live in flood-prone areas. If we focus on flood resilience instead of defense, there is a possibility of reducing the damage. We must learn to live with the flooding and brace ourselves for the epidemic situation. The following mitigation measures suggest against flooding in the study area.

3.3.1 Evacuation and relocation of locals

It suggests 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 red hotspot areas declared by local and governmental authorities. Simultaneously, awareness among the red zone people should be created and give some protection strategies. The best protection towards flood at the most primitive level is to seek a higher ground level to overcome the potential risks of the flood. Areas at most risk of flooding could temporarily shift people to safer areas when a flood is imminent. Approximately four District Nowshera villages such as Banda Shaikh Ismail and Zangal Kalle, six villages of district Peshawar such as Garhi Afridi and Shagar Qala 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 up to some extent. However, 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 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 builds on rivers Swat, Kurrum, and Kabul, including their tributaries, account 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 minimize flood damages, storage reservoirs, and build storm channels 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 safer areas is also an alternative. Still, it is not desirable and comfortable to shift facilities from high-risk areas to safe flood zone. This study area is densely populated with intensive agricultural activity. It is difficult for such a large number of communities to shift their property and belongings. Thus, it suggests that flood-proof buildings should be built in the study area to resist flood water to minimize the flood's consequences. Constructing new buildings should be built one or two meters above the ground level to prevent flood damage in the study area.

3.3.4 Rehabilitation of flood-affected community

Rehabilitation for community safety, the government should construct emergency infrastructures 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 everyday life. Floods displace the people, affect their socio-economic life, and damage their properties. They need rehabilitation on an immediate basis. During the flood, government, non-government organizations, and residents were equally involved in the victims' rehabilitation process. For the rapid recovery of the flood victims, food, medicine, shelters, and money were distributed (Davies, 2011). During the 2010 flood, the Pakistan Army played an important role in flood management and rehabilitation, provided emergency rescue and relief services to the flood-affected persons.

3.3.5 Flood protection embankments

Embankments are effective in minimizing flood risks. Government and municipal agencies should take specific measures to reduce losses to villages, property, and agricultural fields by making flood embankments and raising village sites through landfilling. Embankments are considered the most cost-effective and popular method for flood control, only suggested for some critical localities. Major flood-protective infrastructures in Pakistan comprise flood protection embankments 6,807 km and 1,410 spurs under the supervision of Provincial Irrigation Departments (PID) (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 increases and water entered into the city. Islamic Relief, a private organization, developed an embankment at a small level, but proper barricades are still needed to control the flood risks (Akhter et al., 2017).

3.3.6 Re-meandering and channelization

River channelization is an effective technique to minimize water intensity in the water body during a flood. River Swat is channelized adequately, so if a flood generates in River Swat excess amount of water can store in a channel. Still, on the other hand, river Kabul is not channelized, so if a flood occurs in Kabul river, challenging 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, further increasing the chances of water availability for agricultural and irrigation purposes (Akhter et al., 2017).

The study area dominates fertile agricultural land, which necessitates the channelization of the drain. The path of the channel may be broadened and deepened so that floodwater may flow smoothly. Must design bridges across the drain at the highest level of rural flash floods. There should be an efficient system for storing excessive rainwater to prevent the overflow of water. One of the most important steps is to strengthen the drainage, avoid water logging to prevent floods. Sedimentation is another excellent 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 decreases the storage capacity of the rivers and streams and causes floods (Tariq and Van De Giesen, 2012).

Responsible authorities should take erosion control measurements 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 straightened river's length, which reduces the flow of transportation that can efficiently store water in the river. Consequently, Re-meandering can reduce the risk of flooding downstream by reducing the hydrological response times during extreme discharge periods.

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 people more time to take action before floods, potentially saving lives. Before the flooding, handle all necessary precautions and warn the community to be prepared in advance. Warnings and pre-planning can reduce the impacts of floods. Forecasting flood situations is essential to provide some relief to the community. A flood warning center may be installed upstream in the area to warn the downstream people at least an hour or two before the flood. It suggests designing a flood prediction framework based on the rainfall and runoff data, especially for the Charsadda District, to evaluate the flood severity and magnitude. In Pakistan, floods are witnessed every year in the monsoon season. The flood commission launches flood control plans every year in April, regulates water discharge at important dams and barrages, and regularly interacts and communicates with all provincial governments 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 precious and attractive for parks, recreation, and ecological reserves. Land use planning plays an essential role in reducing risks from floods, which leads to sustainability and improved resilience. Land-use planning can help flood mitigation and minimize risks by restricting construction activities in flood-prone areas (MS, 2010).

3.3.9 Importance of land cover and tree plantation

Vegetation plays a vital role in checking runoff and soil erosion and degradation. Farmers of the catchment area advise growing more and more plants and trees to prevent 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 it decreases flood duration. Deforestation magnifies the incidents and severity of floods. In contrast, afforestation helps prevent mass wasting, reducing the amount of soil entering the river and maintaining rivers' capacity to minimize soil erosion. The degradation of soil increases the sediment deposition in the river bed, which reduces the rivers' water carrying/bearing capacity.

4. Conclusion

This study provides useful information on the land cover change, the trends, and the impacts of land cover change. It is necessary to monitor the ongoing process of land use/land cover patterns over time to ensure sustainable development. GIS and RS techniques have proved useful to demarcate flood-prone areas. It has become effortless to delineate the severity of the floodwater and estimated rehabilitation cost 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 agricultural land images decreased from 68.5% to 55.1%, water bodies rose from 8.81% to 16.4%, and reduced construction build-up area. Approximately four Nowshera district villages, six villages of district Peshawar, and 27 villages of Charsadda District damage during the 2010 flood. Therefore, the barren land increased from 23% to 26.3% due to decreased vegetation cover.

Moreover, heavier damage to agricultural land and settlements observes along the rivers and nullahs of district Charsadda. This research will help 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 firmly recommends that the government 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 communication.

For the sake of human development and support, we must effectively manage the limited amount of usable land we still have. For the sake of human development and support, we must effectively manage the limited amount of usable land we still have. If concerned authorities will not take appropriate flood mitigation measures, the pattern of land-use changes continuously, and it is suspects that future generations might not be able to watch the same beauty of the district Charsadda. This information will help select, plan, and implement land-use strategies to address land-use change challenges.

Data Availability

Satellite images downloads from the Earth Explorer website, which is freely available (https://earthexplorer.usgs.gov/). The population data obtained from (Statistics, P.B.o., 2017. Province-wise provisional results of census–2017. Pakistan Bureau of Statistics Islamabad.)

Authors Contribution

Miss. Misbah Fida, Mr. Irshad Hussain, Dr. Abdur Rashid, Mr. Syed Amir Ali Shah, and Dr. Sardar Khan discussed and conceptualized the article. Miss. Misbah Fida organized all the data and prepared the initial draft for this research study. Mr. Irshad Hussain reviewed the initial draft and suggested some changes. Dr. Abdur Rashid critically examined the paper and conducted the publication stages. Mr. Syed Amir Ali Shah contributed to data visualization and plagiarism check. In the end, Prof. Sardar Khan helped reply to the comments section and did language correction of the entire manuscript.

Competing Interests

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

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