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Extent and Evaluation of Factors Causing Flash Floods in Watalai Khwar, District Bajaur, Pakistan

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ABSTRACT

This study was designed to identify the potential causes of flash floods in the Watalai watershed District of Bajaur, Khyber Pakhtunkhwa, Pakistan. The study used both primary and secondary data to achieve the study's main objectives. The five most frequently flood-affected villages were selected for the data collection. To investigate the anthropogenic causes of flash floods 310 carefully designed questionnaires were filled by the representatives of different sections of the local community. The study finds that in the opinion of 33% of the respondents' intense rainfall in the watershed mainly causes flash floods in the area. Similarly6% of the investigated people claim that flash floods in the area are due to heavy thunderstorms in the spring and summer seasons. About 33% of the inquired community is of the view that human encroachment and unplanned infrastructure are the main causes of flash floods in the Watalai floodplain. Likewise, 8% of the sample population reveals that flash floods are caused in the area due to an increase in population. However, in addition to the responses regarding the causes of flash floods from the community, other factors like the piped culverts and low height bridges are also causes of flash floods in the study area. The analysis of the study area's spatial images shows that the water channel's sharp angles, the low permeable mountainous region, steep slopes and the deposition of sediment load were the reason for high flow and flash floods.

1. INTRODUCTION

The contemporary world is prone to a number of catastrophes of different intensities and magnitudes. UNISDR 2015 estimated an annual economic loss of about US$ 300 billion globally due to disasters of different types. Apart from economic loss, disasters killed 26000 people per year during a span of ten years, i.e. 1995–2004. Data show that around 95% of all the deaths that occur in disasters are reported from poor nations of the world. Similarly, losses due to disasters in developing countries are twenty times greater than the developed countries. With each passing day, the vulnerability of the world population to these disasters is on the rise, as a result of climate change, rapid and unplanned urbanization, ecosystem degradation, and biodiversity loss (IPCC, 2018; Poljansek et al., 2017). According to the IFRC (2020), the number of disasters triggered by climate change has risen by 35% since 1990.

Flood is at the top of all the disasters faced by this world in terms of the devastation it caused (Rahman and Khan, 2013). For instance, floods alone have caused more than 40% of the total deaths that have occurs as a result of disasters (Khan, 2016). Among different types of floods, flash floods are the most frequently occurring disaster that affects

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people economically and socially. A flash flood is always swift and hits without any advance warning. It rises and falls rapidly, usually generated after six hours of intense rain over a catchment area. Recent data reveals an increased frequency and magnitude of floods due to factors induced by climate change and global warming (Lenderink & Meijgaard, 2008). Scientifically a significant increase in the frequency and magnitude of extreme precipitation events in different parts of the world is observed (Keiler et al., 2010) Moreover population growth and changes in land use land cover patterns have resulted in enhancing the frequency of occurrence of floods globally (Khan, 2016).

Flash flood accounts for 85% of the total floods in the world and it ranks first in term of deaths floods cause (AMS, 2000). The prediction is that due to climate change and global warming, the probability of the occurrence of floods is on the rise in the future years. Similarly, with the increase in the value of elements at risk, flood damages will also increase (Elmer et al., 2012). In the last 40 years, Pakistan has faced 76% climate-related disasters that affected 85% of the total population (Larsen et al., 2014). Pakistan is among the five South Asian countries with the highest numbers of people exposed to flash floods (GOP, 2007). Qaddafi 2018 stated that around 60% of the total land of Pakistan is vulnerable to floods. In 50 years from 1960 till 2011, floods in Pakistan have caused annual damages of about 1% of the Gross Domestic Product (Memon, 2019). Another statistics shows that during the span of 10 years (1991-2001) floods have caused damages of about 78000 million rupees to the properties of different types (Mirza, 2011).

History has shown that Pakistan has suffered from 67 different types of floods since 1900, among them the worth mentioning floods are that of the year 1929, 1955, 1959, 1973, 1976, 1988, 1992, 1996, 2005, and 2010 (Atta-ur-Rahman 2010). Back in 1950 floods affected a large number of rural villages in different parts of Pakistan as a result 3000 people lost their lives in the event. Similarly the flood of 1977 in some parts of Karachi killed around 300 people and affected thousands others. Another statistics shows that more than 5000 people were killed by the floods of 1992 and 1993 collectively in different parts of Pakistan. Those floods also washed away 12000 acres of agricultural land throughout the country (Rafiq & Blashke, 2012). In July 2007, a flash flood caused as a result of heavy rainfall in the provinces of Baluchistan and Sindh killed around 245 people and displaced thousands of others (USAID, 2008). In July 2013, a four-day rainfall event over the North-Western mountain system caused the country's most destructive flood (Rahman and Khan 2013). It had engulfed an area of around 38600 sq km around 1961 people lost their lives to the flood. It has also caused damage of 10 billion US$ to the economy (WB, 2010). Similarly in August 2013, floods in some parts of Afghanistan and Pakistan took the lives of 84 people and injured many more. Also, the flash flood of 2015 killed 36 people and brought destruction worth millions of rupees to the properties (GOKP, 2021). The super flood of the year 2022 killed 1730 people in Pakistan it brought a total of 14.9 Billion USD of damage to the properties and agriculture sector. An economic loss of One-third of the total area of Pakistan went under floodwater in 2022. An estimated 33 million people have been directly affected (GOP, 2022). Like all other parts of Pakistan, the district of Bajaur is also prone to recurrent flash floods that caused serious damage to the properties of the people living in the area. Literature shows that the study area is affected by significant flash flood events in the year 1973, 1992, 2000, 2010, 2012, 2017, and 2018 (FDMA, 2012; HUJRA, 2015). During the flash flood of the year 2017, six people have been killed and several others were injured, it also caused the damage of millions to the standing crops of maize and vegetables on hundreds of kilometers of area. Likewise, link roads, bridges, and electric supply were also damaged, leaving the people unconnected with the other parts of the district (Zubair, 2017).In 2018 a flash flood caused by intense rainfall and a thunderstorm killed seven people and injured another six in the Watalai floodplain (NEWS International, 2018).In 2019 heavy rainfall by the thunderstorm caused severe flash floods in the Watalai floodplain. Standing crops along with both public and private properties and infrastructures were damaged to a large extent(NEWS International, 2019).Very reciently in the year 2022 heavy rain in study area causes flash floods that resulted in deaths and other damages (GOP, 2022).Available literature lack any study concerning the causes of flash flood events in the studyarea. Thus, the current study is framed in a way to evaluate both physical and anthropogenic causative factors of the flash flood events in the Watalai floodplain of district Bajaur.

2. METHODS & MATERIALS

Study Area

The current study is conducted in Bajaur District, which is around 140 km in north of the provincial capital Peshawar. The districts of Dir, Malakand, and Mohmand surround the district. It also shares its North-Eastern border with the Kunar province of Afghanistan. The study area in the Hamalyan range has a large variation in the monsoon rains. Rabi crop reaches to full maturity; however, in some cases, the delay in rainfall halts the growth process.

The study area lies between 34° 30′ to 34° 58′ North Latitudes and 71° 11' to 71° 48' East Longitudes (GOP, 1998), having a total area of 1290 sq. km. The district is surrounded by mountains of different heights, some of which range higher than 3000m ASL. The land slopes down towards the South-Eastern direction. The Watalai Khwar has a catchment area of about 393 sq km. The upper mountainous region of the Northwest Mamund Valley constitutes the main catchment area of the Watalai Khwar.

A nearly 25 km long Watalai water course originates in the form of steep and narrow channels from the high mountains of Mukha, Kaga, Kharkai, Kitkot, and Gakhay. Several small channels originating from the plains and hills of the low-lying areas join the main channel at different sites. These add to the water flow during flash floods in Watalai Khwar. The channel flows from north to southeast and empties its water in the main Rud at Musa Kass near Government post graduate college Khar. The maximum elevation (3039) in the Watalai water shed is observed in the Northwest mountainous region where the Watalai Khwar originates. Likewise, the minimum elevation (772) is observed in the low-lying flat region near the outlet of the watercourse (Figure 1). Snowfall and rain in the upper watershed mainly contribute to the water in the Watalai Khwar. These rainfall events are mainly accompanied by the cloud burst and thunderstorms, generating thousands of tons of water in the upper mountainous region (USAID, 1991).

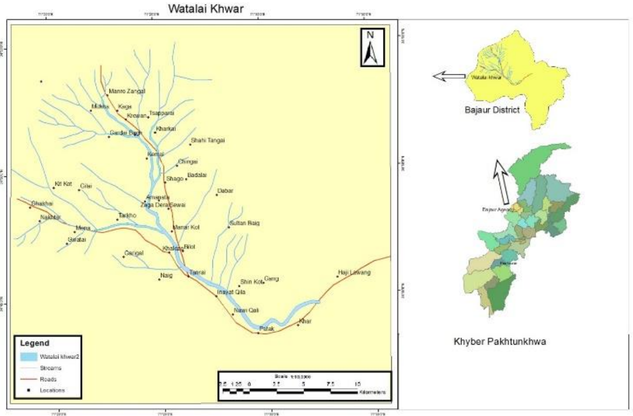

Figure 1. Location of the study area

Data Collection & Analysis

To achieve the objectives of the study, data was collected through both primary and secondary sources. A detailed questionnaire is designed to collect the primary data from the general respondents. A total of 310 questionnaires were filled by respondents. Similarly, another questionnaire was designed to record responses from the officials of different departments and non-government organizations (NGOs). Five focus group discussions (FGDs) were also conducted, one each with the community elders from each village. The study area is divided into two parts, i.e., the steep hilly potion and the plain down area. Field visits were conducted to collect the data and to observe the study area.

Around 35 villages are located along the banks of Watalai Khwar, out of which, 26 villages were located within the range of one kilometer. Through the purposive sampling technique, the five most frequently affected villages were selected for data collection. Among the five, three were selected from the plane area and two from the hilly area. The sample size was estimated by using the Sekaran (2003) tables. Similarly, the number of respondents from the selected villages was estimated through the proportionate sampling technique. Likewise, a random sampling technique was used for the selection of participants for the data collection. Various governmental departments were consulted for secondary data collection; for instance, the meteorological observatory Lower Dir was contacted for the average rainfall data of the area. The irrigation division Bajaur was approached for the data regarding drainage data. The Provincial Disaster Management Authority (PDMA), Khyber Pakhtunkhwa, the district administration, and the NGOs working in the area were approached for the impacts of the flood in the previous times. Topographic sheets and maps were taken from the survey of Pakistan and Google Earth. The population of the area was given in the census report.

The data obtained by questionnaire was analyzed with the help of SPSS and presented in tables designed in Excel-2016. Arc-Gis (10.2) and Google Earth Engine are used to produce different land use land cover maps of the study area. Slope with the help of digital elevation model (DEM) was obtained for the study area with the help of ALOS PALSAR DEM.

3. RESULTS & DISCUSSION

(Here you mentioned “Results and Discussion”; however, in the below text, I could not find any discussion, while you mentioned only your results. I suggest including a discussion part, which means you should discuss your results in light of the available literature. The discussion usually refers to justifying and comparing your results and findings with the published literature and finding out agreement and disagreements, and their possible reasons. Climatically, Bajaur lies in the semi-arid, subtropical continental highland region, with an average annual rainfall of 800 mm. The area gets the maximum of its share of rain in the monsoon and spring seasons. In the winter, snow covers most of the mountains in the upper region of the valley, which is also a source of running water in the Watalai Khwar. In the study area, the frequency and intensity of rains are becoming unpredictable (GOP, 1998).

Physical Causes

The DEMof the study area depicts that the area is mountainous in nature, having a huge variation in the height from the sea level. The maximum height recorded is 3039m ASL in the upper mountainous region. While, the minimum height (772m ASL) is observed in the outlet of the Watalai channel right at the junction, where it discharges to Bajaur Rud.The abrupt variations of channel angles clearly indicate that the flow will always be flashy in nature, especially in the mountainous region. This is also one of the reasons for high damageability of the flash floods in the upper region.Likewise,due to the mountainous nature of the upper portion of the watershed (Figure 2), the permeability is lower, and hence a greater flow is generated in this region. Thus a greater portion of the rainwater is drained to the Watalai Khwar contributing to flash floods. The channel also receives water from the adjacent barren lands and the built-up villages thus, contributing to the cause of flash floods.

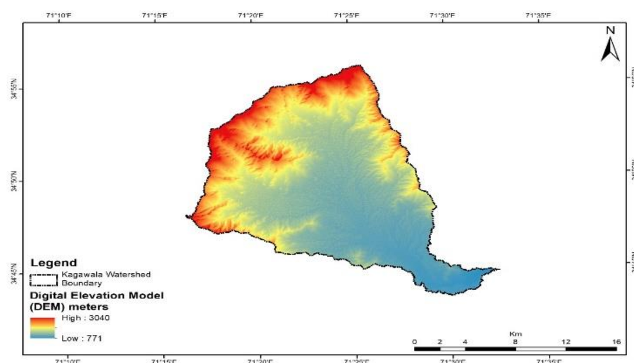

Figure 2. DEM of Watalai watershed

A greater flow of water will generate a higher sediment load transport. As depicted in Figure 3, the northern and western parts of the Watalai watershed contribute highly to the sediment load in the khwar. The deposition of these sediment loads then reduces the water-carrying capacity of the channel and hence causes floods in the adjacent areas. In advanced countries, such sediment deposition in the water channels is regulated by the relevant authorities; however, in the study area no such arrangements exist, hence the problems of flash floods intensify over the passage of time.

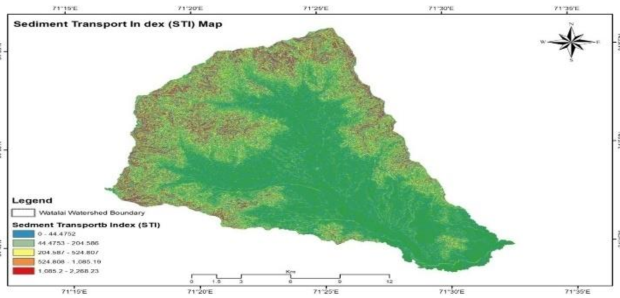

Figure 3. Sediment Transport Index

Every channel has its own slope the upper region dries up early than the lower region. The flow in the stream is always opposite to the direction of the slope. The spread of flood water depends on the height of the adjacent areas.Slope is an indication of the calculation of the run-up hence the higher the slope the more will be the run-up.The slope of Watalai Khwar ranges from 0–74.8 degrees (Figure 4). Overall, the slope of Watalai Khwar ranges from 25.9-74.8 degrees is considered to be a higher slope, and hence a high run-up generating flash flood is expected. A high slope is observed in the Northwest and Northeast sides of the Watalai watershed and hence a high flow with fast velocity is expected. Such high-speed water flow erodes the land and banks of the channels hence carrying high sediment load. Low slope is mainly observed in the low-lying areas, especially in the middle portion and at the outlet. Such low slopes mainly pave the way to the deposition of sediment load, which again limits the flow capacity of the water channel, and hence flash flood generates. Similarly, areas with low slopes are relatively flat, and less water is needed to inundate them.

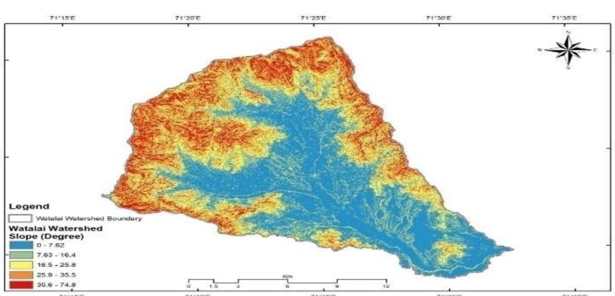

Figure 4. Slope of Watalai Watershed

Studies have found that a strong correlation exists between rainfall and flash floods in the area (Karymbalis et al. 2012, Loczy (2012). About 33% of the respondents confirmed that the flash flood in the study area is caused as a result of the intense rainfall (Field Survey, 2021). History shows that rainfall in the study area is intense during the monsoon and in the spring seasons hence flash floods mainly occur during these two seasons. The above-derived data is in line with the findings of Karymbalis et al. 2012 who concluded that flash floods in Corinth Greece occur as a result of heavy precipitation and human encroachment towards the active floodplain. Similarly, Loczy (2012) also established a correlation between rainfall and flood level.

Thunderstorm sometimes produces heavy rain in the upper portion of the watershed which may cause flash floods. Mir (2006) analyses that thunderstorms are becoming more frequent in the upper region of Pakistan. Similarly, during the FGDs it was reported by the participants, the strong wind accompanied by lighting is usually a part of the rains in monsoon season. Also during the current study, 26% of the surveyed people have termed thunderstorms as a cause of flash floods in the study area (Field Survey, 2021).

Human-Induced Causes

Population growth and the number of flash flood events are interlinked, an increase in population results in an increase in the frequency of occurrence of flash floods in a specific area (Gil-Guirado et al., 2019 & Mu et al., 2020). The same is observed in the study area according to the GOP 2017 the population of the study area almost increased three times since 1998. This clearly indicates the pressure of population increase on natural resources and the waterways. During field visits, the interactions of humans both directly and indirectly with the ecosystem were seen and observed (Figures 5 & 6). Similarly, during the FGDs and some interviews with the relevant departments, it was recorded that population increase has intensified deforestation and overgrazing, which indirectly lead to flooding in the study area. Field data shows that 8% of the recorded responses claim that flash floods in the study area are due to the increase in human population (Field Survey, 2021). Population growth has a direct impact on deforestation this again increases the run-up which in turn intensifies erosion that leads to increased sediment loads. This deposition of sediment load in the low-lying areas causes flash floods.

Figure 5. Aerial view of agriculture fields extended along Watalai Khwar

Figure 6. Extended protection wall for agriculture fields

Human encroachment into the floodplain is one of the leading causes of flash floods in the area. This was confirmed by 33% of the respondents through data derived from the questionnaires (Field Survey, 2021). In the case of the study area, agriculture fields are seen extended in the floodplain; however, these fields are then protected by gibbon walls along the channel thus narrowing the way for water to pass (Figure 5 & 6). Similarly, human settlements are present along the bank of the channel thus increasing the risk of damages from flash floods in the area (Figure 7). Hence both residential and agricultural sectors extended in the floodplain are causing flash floods in the study area.

Figure 7. Human settlements along the Watalai khwar

The relevant government authorities during interviews stated that no regulation pertaining to the prohibition of encroachments in the floodplain is applicable in the area. The participants of the FGDs and personal interviews with the community leaders showed distress over the extension of human activities in the flood plain. Then consider the plains around the channel as collective property and the construction of settlements over it is just a land-grabbing tactic. Some other activities, like the construction of pipe and box culverts at different places on the Watalai water channel, also cause flash floods in the study area. The diameter of the culvert pipes matters a lot during the flow of flood water. Pipes of small diameter cannot accommodate much of the flood water without obstructing it. Similarly, the debris contained in the flood water blocks the pipes and causes an overflow as shown in Figures 8 and 9.

Figure 8. Pipes culvert before flood

Figure 9. Pipes culvert after the flash flood

Low heighted box culverts also pose a reason for flash floods in the study area (Figures 10 and 11). During monsoon rain water brings huge bed rocks and tree trunks of different types, which result in blockage of such culverts thus causing increase in upstream water level. This results in an overflow of water in the adjacent areas thus causing flash floods.

Figure 10. Low-heightened bridge before a flood

Figure 11. Low-heightened bridge submerged during a flood

Due to water pressure and the non-standard construction material of the bridge most likely there is always a chance of collapsing the box culvert. This results in the sudden release of water at once thus a high-velocity flash flood emerges and washes away the agricultural fields and houses in the low-lying areas.

4. CONCLUSION

The Watalai Khwar floodplain of district Bajaur is exposed to horrific flash floods; some of the past flash floods in the study area were the flash floods of 1973, 1992, 2000, 2010, 2012, 2017, 2018, and 2019. The flash floods caused damages of billions of rupees to the properties and the lives of the local community in the mentioned years. The current study has identified the major causes of flash floods in the Watalai floodplain district of Bajaur. The study found that in the opinion of 33% of the respondents, intense rainfall in the watershed mainly causes flash floods in the area. Similarly, 26% of the investigated people claimed that flash floods in the area are due to heavy thunderstorms in the season of summer. About 33% of the inquired community believe that human encroachment and unplanned infrastructure are the main causes of flash floods in the Watalai floodplain. Likewise, 8% of the population investigated revealed that flash floods are caused in the area due to an increase in population. Low-diameter concrete piped culverts and low-heightened box culverts were also observed in the study area, which caused flash floods in the study area in the past.

In addition to the causes recorded from the community, the analysis of the spatial image showed that sharp angles and low permeability capacity of the upper mountainous region were the reason for the high flow and the flash floods. Similarly steep slopes and the deposition of sediment load were also identified as the causes of the flash floods. Relevant authorities should conduct detailed hydrological studies to estimate the extent of water coming from the valleys associated. Early warning system for the forecasting of flash flood should be installed in the area. All major engineering measures need to be taken so as to reduce the impacts to these flash floods events. To reduce the vulnerability of the local people laws concerning the prohibition of construction of new settlements along the main channel must be strictly implemented. Further studies related to flash flood hazards in different part of the district should be conducted.

Competing Interests

The author did not declare any competing interest.

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