GIS and Remote Sensing-Based Evaluation of Flood Hazard, Causes and Damages: Budni Nullah, Peshawar, Pakistan

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KEYWORDS	ABSTRACT
Remote Sensing GIS Catchment Flood Hazard Mapping Evaluation	Remote Sensing has made a substantial contribution in flood monitoring and damage assessment, which leads the disaster management authorities to contribute significantly. A recent study focuses on the application of GIS in Flood Hazard Mapping of Budni Nullah, Peshawar. The Nullah faced devastating floods in various periods of time, but the most catastrophic flood was in 2008 and 2013. Furthermore, in this research, different aspects of flood risk assessments were carried out in order to identify flood Hazard causes, damages and prone areas through the application of GIS and remote sensing.

1. Introduction

Flood is the abnormal rise of water from its mean level, which inundates the adjoining levees, flood plains and sometimes inundates areas far away from flood plains depending on the rain or melting of ice in the upper catchment areas. There are various types of floods depending on the tectonic activities like climatic condition, physiography and source of water. A flood occurs when land doesn't hold enough water from rain to absorb, so as a result, it overflows from the crest of rivers, and lakes and Nullah. This normally happens in the areas where we face heavy rain, because of the monsoon season, thunderstorm, hurricanes, typhoons, and cloud bursts too. (Rehman & Khan, 2015).

Flood is the abnormal rise of water from its mean level, which inundates the adjoining levees, flood plains and sometimes inundates area far away from flood plains, depending on the rain or melting of ice in the upper catchment areas. Flood is a rapid event which generates and reach to its peak level in less time. So, whenever we are trying to control the flood in case of encroachments on a flood plain, they become a problem. (Khan, 2009). Flash floods are rapid onset event, which rapidly rises along with an urban low-lying area. Flash floods are dangerous as it causes destruction on areas which lies near flood plains or on the flood plains. Such damages occur due to heavy rain, dam break, levee failure, rapidly melting snow, cloud bursting and ice jams. Furthermore, heavy rain weakens the soil as a result, water changes into mud, which is denser than ordinary water causes debris flow. This flow causes damage to buildings, roads, and other infrastructure. Flash floods are known by its fast occurrence, damages and muddy flow, these are in small scale but can cause damage to life and property (Gruntfest & Handmer, 2001).

Furthermore, Hazard mapping depicts those areas which are vulnerable to particular hazards like floods, earthquake, Tsunami, Cyclone and Glacial Lake outburst flood (GLOF) etc. Flood hazard mapping is a workable component for suitable land use in flood locations, which creates readable and less time-consuming maps thus helping in the identification of hazard risk areas to establish the effects of mitigation (Bapalu & Sinha, 2005).

Moreover, the aim of hazard mapping is to know the occurrence of an event and present it to

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stakeholders and the local community, while these maps cannot prevent flood hazard or any phenomena but they can reduce its losses up to a great extent. The main theme of hazard mapping is to provide a knowledge to residents; that what could be the range of a possible damage, the extent of a disaster that will occur and a roadmap for its prevention (Udono & Sah, 2002). The hazard map is divided into three categories or more depending on the level of vulnerability, the study will show medium, low and high, on the basis of the danger posed to an average human being as a result of flood water. For detailed flood mapping, a scale of 1:2500 is used to describe the extent of flood water at different rainfall locations, which is distinguished by different colors (Cooper & Opadeyi, 2006). The study has been conducted to create flood hazard maps, mainly in areas where the flood is in the danger range. After that, mitigation areas were marked based on their vulnerability levels.

This study in future can be improved by finding out flood inundation, flood depth and velocity (Forkuo, 2011). During floods, timely, detailed situation reports are required by the disaster management authorities to locate and identify the affected areas and to implement the corresponding damage mitigation; this is the most delicate management category since it involves rescue operations and the safety of people and property (Jeyaseelan, 2004).

The author prepared the hazard map of the 1988 flood with an elevation, geological and physio-graphic division. The different thematic maps were evaluated for making the best combination of flood hazard maps. These flood maps will be used for better planning and management of floods. Different levels of inundation data are taken from satellite images of different times. Flood depth and frequency acquired through NOAA-AHVRR Data, and flood damage through physiographic division, geologic division, and administrative districts. This study will be very

helpful for flood risk management and for the awareness of people, as it is found that 7.50% area is at very high risk and 16.34% are at high risk, in which the capital city also lies (Islam & Sado, 2009).

Multi-Criteria analysis and AHP techniques are also used for decision making. Depending on Qualitative and Quantitative information, Results were acquired for flood Depth, total flood area, flood inundation area, most of the affected area by the flood and Number of affected schools etc. (Duan, & Aekakkararungroj, 2010).

Besides, (Catani *et al.,* 2005) conducted research on mapping of Landslide Hazards and Risk at the catchment in the ARNO River Basin. They used already adopted methodologies and the main points about that catchment area. And on the basis of those points they made new methods, like conventional and non-conventional methods. They mapped Mass Movements due to different triggering events, what are the environmental roles in causing such Landslides. Giving Different Hazard values, vulnerabilities and Risk because of Hazards. Because of which they have found different unmapped hazard areas. The Final Results were made on the basis of Mapping these are land planning and risk prevention policies at practical, local and National Level (Catani *et al.,* 2005).

In recent study, author made two hazard maps, the detailed hazard map and island wide hazard map. The island-wide Hazard map was divided into three hazard zones which are medium, low and high zones, on the basis of severity of vulnerability posed to human life. The extent of flood water is represented by return period in different times. According to study, slope in some area is steep, flat and in some it is gentle slope. The level of flood is medium at the high catchment places and runoff quantity is also high. Well-developed Hydrologic database and updated maps are helpful for future forecasting. (Cooper & Opadeyi, 2006).

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1.1 Study Area

Geographical coordinates of Budni Nullah (Peshawar) are 34° 00′ 18″ to 34° 4′ 27″ North, 74° 24′ 18″ to 74°42′ 36″ and are located in the North-Eastern part of Peshawar (Khan *et al.,* 2010). This study was conducted on Budni Nullah and its surrounding areas in District Peshawar, Khyber Pakhtunkhwa, Pakistan. Based on the Census report of 1998, the population of this region is 158,467, with a number of households is 18,643 (GoP, 1999). The area surrounding Budni Nullah is divided into 11 Union councils. In which 35 out of 75 villages are in the exposure zone around Budni Nullah (GoKP, 2015). The area faced severe flooding in 2008 due to a large amount of precipitation and population density. Moreover, the area is also prone to flooding due to unplanned housing (Figure 1).

Like other provinces, Khyber Pakhtunkhwa also faced huge losses because of floods, especially in 2010. The number of severely affected districts in Khyber Pakhtunkhwa was ten, whereas fourteen districts were rendered moderately affected (NDMA, 2010). Agriculture is the primary source of revenue for Khyber Pakhtunkhwa. Khyber Pakhtunkhwa recorded huge losses of crops that stand up to 191020 hectares. The main crops affected were cotton, sugar cane, wheat, fodder crops and rice (GoKPK, 2010).

The mean maximum temperature in summer is over 40 °C (104 °F), and the mean minimum temperature is 25 °C (77 °F). The minimum temperature during winter is 4 °C (39 °F), and the maximum is 18.35 °C (65.03 °F). Peshawar is not situated in the monsoon region, unlike the other northern parts of Pakistan.
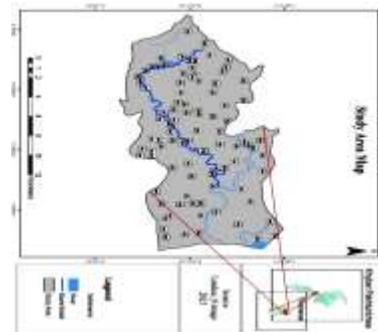

Figure 1: Study Area Map

2. Materials and Methods

Different Techniques were used in recent study for analysis of different aspects like,

- Terrain of area
- Frequency of events occurring
- Foot Prints of flood inundation
- Assessment of past or potential damages
- Land use map generation
- Prioritization of different hazardous area into low, medium and high hazard
- Assess the Settlements

A non-descriptive survey method was also used to achieve the purpose of the study. In this method, different processes are expressed in terms of one or more quantities. Quantitative data was found through a questionnaire to explain the phenomena. Moreover, the results are presented in the form of graphs and charts. The Qualitative Research Methodology was adopted; a questionnaire was filled out by the local people who had suffered from Flood Hazard. Other Data Regarding finding Hazards were obtained through Satellite Images i.e. Slope, Watershed, Land use, flood extent and flood hazard zones were generated through Satellite Images. Data was analysed through SPSS Statistical Software. ERDAS, ArcMap and Google Earth were also used. GPS was used for Slope Generation. The final map was obtained by Overlay analysis.

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3.   Results

3.1 Watershed Map

Budni Nullah is charged from upstream. On the basis of its discharge point, the watershed pattern of Budni Nullah has been generated. It shows the catchments areas from where water comes to the discharge point. Streams are identified through the Map Algebra tool. Watershed shows that Water is coming from Upper Catchment areas, which need to be managed properly (Figure 2).
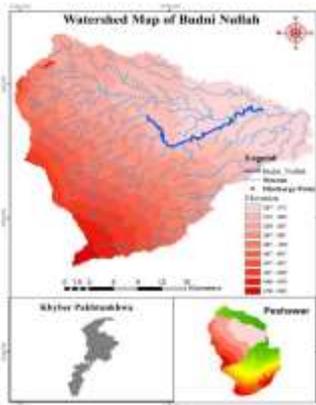
Figure 2: Watershed Map

3.2 Slope as a Hazard

Slope affect the constancy of terrain. It gives the direction and runoff of water. It also directly contributes to the intensity, speed, erosion and losses as a result of flood. A high slope will speed the velocity of floodwater. Normally, the water moves in narrow paths. If the speed of water is high, it will leads to more erosion of the soil layers and will flow away each and everything that comes in its path. The best practical example is flash and riverine floods. Flash floods usually cover a small area with huge economic and human losses. As the slope decreases, the flood starts becoming riverine, which means the water starts to spread out. Figure 3, demonstrates the slope of the study area with lower and higher slopes.   A change in slopes reflects more accumulation of water causes more damage. Different hazard prone areas through contours are also shown.
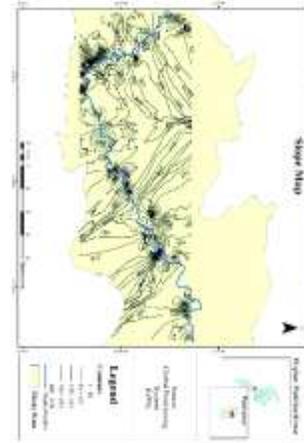
Figure 3: Slope as a cause of flooding

3.3. Settlements

There are more than 30 villages and towns, located on the flood plains of Budni Nullah. Despite the fact that the people are facing floods after every heavy rain in the summer season, the population of the area is increasing. Some villages are present even on the Budni Nullah. They are facing various diseases and damage. Also, the impact of those settlements on the environment is severe, as people are unaware of the mismanagement. Due to sedimentation and the uncleaning of water bodies, the level of normal flow has increased. Moreover, people living in such types of settlements are facing various diseases like tuberculosis, influenza, malaria, dengue, diarrhea and other intestinal diseases. Figure 4, shows the number of settlements on Nullah, which, after comparing it with other causes and maps show the peak of vulnerability in many areas.

Figure 4: Settlements Map

34

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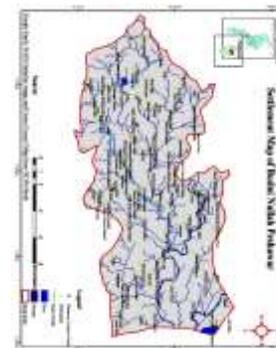
3.4. Foot Prints of flood inundation

The flood inundation means the rising of a water body from its normal flow, which can inundate the dry lands and other adjoining areas, the fields, houses, settlements roads, etc. Area inundated maps show different areas which are inundated. It is a source of showing damages. After conducting a field survey, it is found that severe flooding occurs in those areas in 2008 and 2013, which inundated an average 70% near budni Nullah. Furthermore, it gives us different level of inundation which depends on the area at different heights. Besides, areas of different heights will experience different levels of inundation. This helps the decision makers and stakeholders to define their routes to their settlements, which will be safe as compared to low-lying areas. On the basis of different area elevation inundated map is generated (Figure 5).
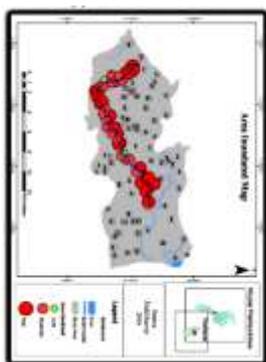

Figure 5: Area inundation

In addition, peak discharge of different floods is mentioned, which depicts how high the flood level was in 2008 at Darmangi G/Station (Figure 6).
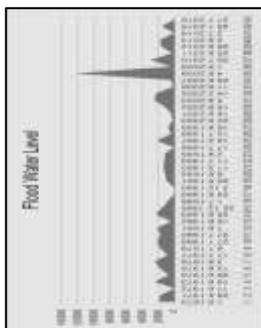

Figure 6: Peak Discharge Graph

3.5. Affected Buildings

Mainly in 2008, there were Kacha (Un-Cemented) houses which suffer much and complete loss as compared to cemented houses. On the basis of this damage, an effective map was made in which homes and other infrastructural buildings are selected. Different weightage was assigned and divided this weightage into three categories: low, moderate, and high-affected buildings (Figure 7).
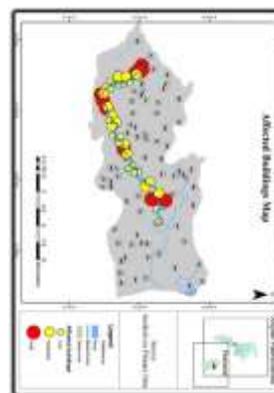

Figure 7: Affected Buildings

3.6. Losses

Mainly, people have faced Agricultural losses, because their main economic activity is to sow and reap crops. Due to a low level of education, people have less or no diversified economic sources. Losses map is based on both structural and Non-structural losses. On the basis of different types of losses, a weightage was assigned to different villages and towns that faced losses and a loss map was generated (Figure 8).
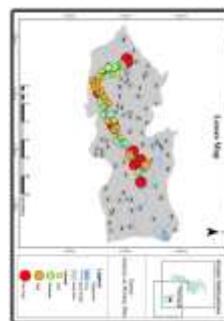

Figure 8: Losses map

35

3.7. Injuries and Sanitation

Injuries were high after the Catastrophic flood of 2008 and 2013, because many people evacuated, and some who were stuck or took time in evacuation got injured, but the death tolls were low. Moreover, People suffered from sanitation problems and their water is still not cleaned, which leads to the non-availability of clean drinking water. The people who are living in those settlements are facing various infectious problems, such as tuberculosis, malaria, diarrhoea and other mainly intestinal problems. A serious sanitation problem is also found in those settlements. The ground water and surface water gets unhealthy and dirty because of poor waste management, and the Budni Nullah receives toxic chemicals from other catchments areas. People living in these areas used different type of sanitation ways, like water motors, taking water from well and through hand pumps. The secondary hazard of floods is still residing in the locale even after many years. Also, there is a severe problem of Big Rats. Which killed many people. People say they are emerged after those floods of 2008 and 2013. The intensity of injuries and the impact on the sanitation system was assigned values and represented using Pie Chart symbology to better understand the severity of these issues (Figure 9).
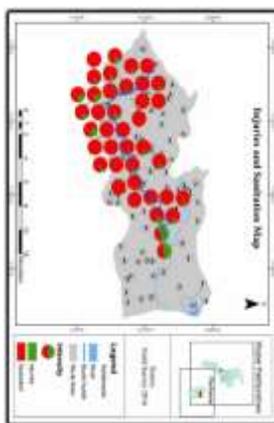

Figure 9: Injuries and Sanitation Map

3.8. Flood Extent

Flood extent refers to the extent of floodwater. It gives the prediction of the extent of the upcoming high flood event (Figure 10).
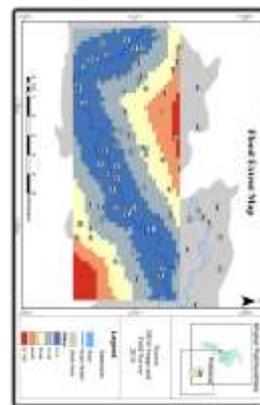

Figure 10: Flood Extent Map

3.9. Flood Hazard Zones

The chances of occurrence of flood hazards in different villages and colonies are calculated by overlaying all the hazard factors, which are discussed above, to identify hazard zones and create a flood hazard zonation based on those maps. During the field survey, noted the distance of each point i.e. village and colonies, from the flood watercourse, which suffer from floods almost every year after heavy rain at upper catchment areas.

The total weightage for finding the flood Hazard zones can be find out by the sum of every contributing hazard (Pramojanee, Tanavud, Yongchalermchai, & Navanugraha). In Figure 11, the final map layout shows a zone is generated and map shows different Hazard zones and it's a final resultant map in which the high hazard zone is in 300 meters and moderate hazard zone is in 500, and the low hazard zone is in 700.It was generated on the basis of the 2008 and 2013 flood which shows extremity in overflowing of flood water under this weightage.
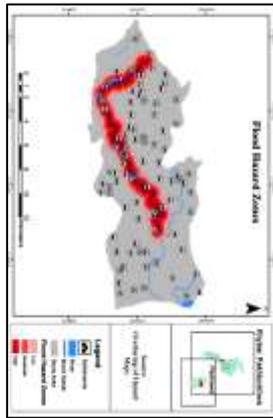
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Figure 11: Flood Hazard Zones

4. Conclusion

Analysis of Flood Hazard Causes and Damages is an important component in Land use planning for Hazardous areas. By creating easily readable maps, and Charts, it helps the government technical staff, planners, NGOs and Community people. The Study consists of a multi-criteria decision-making process. In which different techniques and tools were used both qualitative and quantitative to identify the flood hazards, flood risk and the consequences of severe flood in Past. Furthermore, GIS/RS software like ERDAS ArcMap, google earth and SPSS plays a vital role in assessing and integrating the required data.

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