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Flood Hazard Mapping of North-Western Part of Bangladesh Using Geographic Information Tools

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ABSTRACT

Bangladesh is a country prone to flooding. Each and every year flood has occurred during rainy season in Bangladesh at some district mainly coastal area, haor basin, Ganges river basin, Brahmaputra river basin, Jamuna river basin, Meghna river basin etc. One of the famous districts of Bangladesh is Rajshahi district, because of the bad impact of the river flood. River floods carry sediment which deposits over the bed of the river and decrease the depth of the flow water. A flood hazard map will be developed in this study to help the peoples of Rajshahi district during the river flood to keep them safe from the disaster. This study will compile the factors for flood vulnerability, predicting the future flood scenario along with a list of recommendations for good institutional arrangements in the study area, so that disadvantaged people can receive assistance in a timely and effective manner during the flood. Geographic Information System (GIS) tool of version 10.8 is used in this study. To do as such, use SPOT and SRTM DEMs information for which precision evaluation is accomplished by utilizing actually take a look at focuses. The significant findings of this study demonstrate that river flooding occurs every year, especially 15 to 20 days before harvesting, as well as it is a highly dangerous event in the lives of the inhabitants in this area. Finally, in ArcMap, all of the data is integrated to provide a final flood hazard map for the research area.

1. Introduction

Bangladesh is a reverie country. So, during the rainy season flood is a normal scenario in this country, because in rainy season the rainfall amount is very high. The normal yearly precipitation changes from a limit of 5,690 mm in the upper east to at least 1,110 mm in the west. Quite possibly the most genuine normal peril happening everywhere on the world is known as flood (Seyedehet et al., 2008), what's more, hence passing of individuals on the planet is 40% which is brought about by characteristic risks, with the vast majority of flood danger happening in tropical areas (Ohlc and Tapsel, 2000). There are several types of flood mainly flash flooding (Elkhrachy, 2015; Da-wei et al., 2015; Gruntfest and Handmer, 2001), flooding caused by ground water rising (Burt et al., 2002; Forkuo and Tsawo, 2013; Fosu et al., 2012), coastal flooding (Nicholls, 2005) what's more, flood happening as a result of opening or breaking of a dam or a supply (Forkuo, 2011). Floods are the most frequent natural disaster which affect the society all over the world. According to (Dilley et al., 2005), more than 33% of land area of world is vulnerable to floods, which affect 82% of the world's population. Natural hazards are the possibilities of a real damaging occurrence occurring at a specific time and place, where the risk is defined as the actual exposure of a human value, and are frequently

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an integration of chances and harm within a specific area (Bhuiyan, 2014). For producing a flood risk map of a certain inundation affected area now a day's GIS is used frequently. They offer a practical solution to gather data from various maps and digital heights (Sanyal and Lu, 2004). With the help of land cover, physiographic, height and geographical data and drainage system data flood threat map can be developed. The hazard index should be allocated according to the depth of the flood. But additional features such as flood occurrence, flood period etc. ought to be measured (Islam and Sado, 2000). The stream water overflow in case of heavy rain for a certain amount of time in the reverie area for this reason the river cannot contain the all rain water into it. So that the excess quantity of river water overflow through the embankment of river and it results into flood in dry land area. The excess water also be flow because of the melting of ice glaciers at the upstream of the river, which causes serious damages to the environment, embankment of the river, health of human and animals etc.

There is a risk of global flooding, especially in the last thirty years. Environment transformation and man-made using of land interventions are defined as significant factors that causing flood risk (Atay et al., 2012). The Interventions, both normal and artificial including as a consequence of urbanization, flood hazards are mentioned, costal delta pains, building on waterlines and waterways deviations, stream beds under invalid rules, improper land use decisions in slopped areas, resulting in deformation and soil erosion, and construction on waterlines and waterways. Municipal growth, beachside delta pain, river beds in illegal regulation, inappropriate land in sloping areas our decision, so distortion and soil erosion, building of waterways and waterways deviations are all examples of natural and man-made interventions that include flood danger. It is impossible to overwhelmed hazards of flood without future replication, assessments and supervision of flood (Kourgiala and Karatzas, 2011; Eimers et al., 2000; Shaban et al., 2002; Serkerandkabdasli,2002; Yahaya et al., 2010; Hutchinson, 1998). River inundation hazard mapping is the procedure of significant flood levels and depth by relating stream water levels with groundwater levels. Producing of inundation hazard map may consist of water depth, current speed flood range and flood period. It is a primary as well as significant pointer for downpour plain terrestrial use progress scheduling and guidelines (Walesh, 1989). The Hydrological Engineering Center (HEC) of the United States Army Corps of Engineers began mapping river overflow floods in 1988 (Smith, 2003; Feldman and Owen, 1997). That is why we need to prepare a map of flood risk zone. It is a significant step to make an inundation risk zone map in the suitable administration of upcoming measures of flooding and to build up a satisfactory indication dealing (Elmira, 2016). Flood susceptibility maps are very advantageous tools to identify the in habitants and fundamentals at high hazard and to lead initial threatening system and precautionary procedures.

Bangladesh is a country of deltaic which situated on the confluence of three key rivers, the Ganges, the Meghna, and the Brahmaputra. Bangladesh is bounded by many mountains on three margins and it has a unique geographical setting and it is enormously flat and low and valley geography, has a low land shoreline and the environment of this country is very extreme which is very much vulnerable to highly ordinary dangers such as inundation (Islam et al., 2010; Hoque et al., 2011; Chowdhury et al., 1997). Due to these floods a lot of damages happen in the physical health of the agricultural crops, social disruptions in vulnerable groups, infrastructures and other buildings, livelihoods and home-grown organizations as well as straight and subsidiary financial losses (Bhuiyan and Dutta, 2012; Baky et al., 2012; Bhuiyan and Dutta, 2012; Mirza, 2011; Baky et al., 2012). Working with GIS for overflow organization has a significant advantage in that it not only creates an image of flooding but also generates effective further analysis of this sort of creation to predict possible mutilation due to inundation (Hausmann and Weber, 1998). For this advance in GIS it is additional competent and an extra accurate substitute to ancient techniques for reviewing watersheds (Johnson et al., 2001). Another useful technique to get a great inundation risk map is Digital Elevation Model (DEM). At present many techniques such as GIS and other spatial techniques provide some offers which are capable of extracting drainage systems and basins that have possible to effect of gathering of run-off. Due to analysis of the risk of flash flooding, drainage movement can be combined into GIS database to categorize the zones (Youssef and Pradhan, 2011).

In current years, exertion sewer completed to combine hydrologic representations and GIS with perfect output management, a new outlet of hydraulics and hydrology, specifically hydro-information (Karimi and Houston, 1996; Winterbottom and Gilvear, 2000; Yang, et al., 2002). Flood zoning research has converted more resourceful and a reduced amount of monotonous due to the practice of GIS technology, and has become extra perfect due to the convenience of remote sensing methods to verify outcomes with satellite imagery (Donnelly and Maidment, 2001; Bapalu and Shina, 2003; Yang and Rystedt, 2002; Sanyal and Lu, 2006; Chandran and Joisy, 2009; Punithavathi et al., 2011). GISs are well-defined like computer program worthy of

storing; accumulating, operating and presenting geologically referred statistics (USGS, 1998). GIS was once mostly used by topographers, but it is now widely used in engineering projects and investigations, especially in the area of water superiority, hydraulics, as well as hydrology. GIS offers a backdrop for intersecting data sheets and conducting spatial queries, resulting in the generation of new data. The results can be tabulated and numerically plotted, allowing for more in-depth study and better cement construction. Therefore, in this study, the flood hazard condition of Rajshahi district is mapping by the help of ArcGIS tools. This zone was preferred as study zone as of this district is in the area of Ganges floodplain which is a very important floodplain of Bangladesh. The created map tries to categorize high-hazard areas created on administrative parts (Upzilla) and several flood-related parameters. This, in turn, can assist key decision-makers in defining particular policies and mitigation procedures to support any decision-making changes that lead to the proper implementation of a long-term flood supervision strategy in Rajshahi.

2. Study area and data collection

Rajshahi is very well-known district of Bangladesh, chosen as the subject of this study as shown in Figure 1. It is located in the north-western part of Bangladesh. This district is located between the longitudes of 88017'E and 88058'E, and the latitudes of 24007'N and 24043'N. This region experiences both riverine and flash floods due to its proximity to major rivers like the Ganges (Padma) and its tributaries. Mapping flood hazards in this area can provide valuable information for disaster preparedness and mitigation. It has a history of significant flood events. Studying past floods in the region can help in understanding the patterns, impacts, and vulnerabilities associated with flooding. This information can be utilized to prepare more precise flood hazard maps. The district is home to a substantial population and critical infrastructure, including residential areas, agriculture, and transportation networks. Assessing flood hazards in this context is crucial for protecting lives and livelihoods. This District is known for its agricultural activities, and flooding can have severe consequences for crops and food production. Mapping flood hazards can assist in agricultural planning and disaster risk mitigation. Total area of this district is 2,407sq km. Total population of this district is 2,909,622. Rajshahi District's vulnerability to floods makes it a pertinent area for developing policies and plans for disaster risk reduction and response (Rouf, 2015). The choice of Rajshahi district for flood hazard mapping using ArcGIS is justified by its geographical, historical, and socio-economic significance in the context of flood vulnerability assessment and management in Bangladesh.

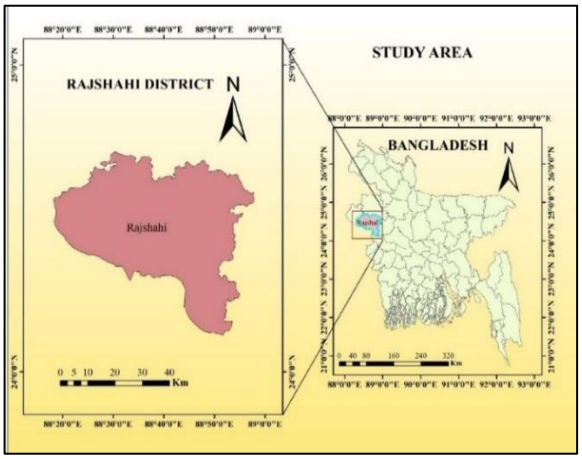

Figure 1. Location of study area

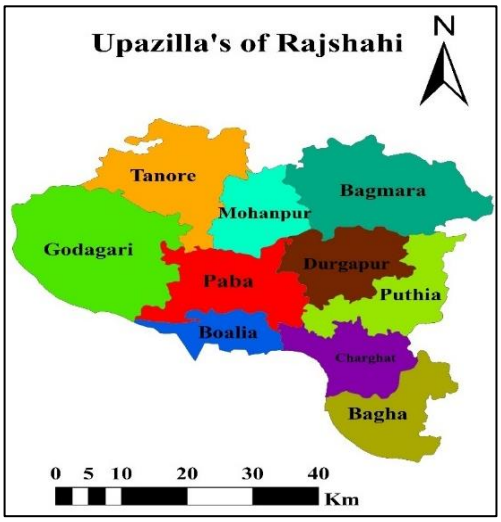

Figure 2. Upazilla wise map of study area

To build a mathematical flood hazard map, a large number of different types of data were collected and assembled from recent and past years. This information also served as the foundation for additional analysis and interpolation of the model's results, which resulted in an accurate estimate of the Ganges river flood plain's hydrological state. To build this model, discharge of water and water level of Ganges (Padma) river were collected from Bangladesh Water Development Board (BWDB) of Rajshahi District. The Administrative Upazilla boundary were acquired from DIVA-GIS. USGS (United States Geological Survey) Provides high-quality DEM data for the United States and also for the whole world. NASA SRTM (Shuttle Radar Topography Mission) Offers global coverage with a resolution of 30 meters which was downloaded from website. The collected information is demonstrated in Table 1.

Table 1. Collection of Data

Type of data	Source of data	Station ID	Periods (Year)
Data of discharge in (cusec)	BWDB	SW88	2004-2019
Water Level in (m)	BWDB	SW88	2004-2019
DEM	OPEN TOPOGRAPHY	---	2020
SRTM	WEBSITE	---	2020

3. Methodology

The technique of this study begins with the selection of the research area. The Bangladesh Water Development Board collects data on the Ganges River's maximum and minimum flood depth (BWDB). First, the components that contribute to flooding are identified, and the rates of mutual interaction are estimated. Elevation, surface discharge, soil patterns, slope, annual precipitation and distances from streams are used to determine the flood hazard map. Also, using Digital Elevation Model (DEM) files, their GIS-based were created. ArcGIS 10.8 modules are the GIS program used in this investigation.

For numerical modeling and analysis in GIS for flood hazard mapping, there are varieties of commercial and non-commercial software programs available. GIS was created by the Environmental Systems Research Institute (ESRI) and allows users to view, control, generate, and analyze geographic data. The TIN is typically the preferred GIS data for three-dimensional surface visualization and display. The following are some of the reasons for TIN shape, in order to portray the outside terrain with equal balance, it needs a far lower number of dots than a network. It can be changed to adjustable difficulty of topography that supports the different characteristics such as points, polygons, and lines etc. Also, the unique contribution data is sustained in the prototypical and flattered in investigation.

3.1 Factors considered for flood mapping

The factors should be considered for the flood hazard mapping are annual precipitation, slope of the area, surface drainage of the area, soil pattern, land use and land cover form of this area, distance from the river and elevation of the area. These seven factors are very useful to prepare a flood hazard map.

3.2 Annual precipitation

Annual precipitation is very much vulnerable for flood. If the precipitation rate is very high than the intensity and frequency of flood is also high. If in any area the precipitation rate is very low than the frequency and intensity rate of flood is also very low. Other hazards can emerge after a storm has gone, in addition to the immediate health risks connected with extreme precipitation events when flooding occurs.

3.3 Slope of study area

Low-elevation locations typically have a flat/moderate slope, making them further vulnerable to water logging and flooding. A vertical slope produces more speed than a flatter or moderate slope, allowing runoff to be disposed of faster. Runoff is held over an area and then released progressively over time on a flat to gentle slope (Kumar and Tehrany, 2018). So that, the rain water can easily fell into the Ganges River and fills the river so quickly and created flood in this research area. Figure 3(a) depicts the slope of this study area.

3.4 Surface drainage

As an ever-increasing number of individuals occupy the Earth, and as greater turn of events and urbanization happen, a greater amount of the normal scene is supplanted by impenetrable surfaces, like streets, houses, parking garages, and structures that diminish invasion of water into the ground and speed up overflow to trenches and streams. This factor is shown in the Figure 3(b).

3.5 Soil pattern

Because soil features, particularly those that are more prone to eroding, have a significant impact on flooding, and penetration rate is also influenced by soil features in a given location, soil category was chosen as a conditioning/influencing aspect (Mojaddadi et al., 2017). As a result, runoff from heavy rains in clay soils is expected to be faster and more efficient than in sand. Figure 3(c) depicts the study's soil pattern.

3.6 Distances from streams

The flood hazard has a significant impact on the storage distance from the stream network. Distance, on the other hand, is inversely related to flood spread and magnitude (Fernández and Lutz, 2010). In most cases, a flood happens adjacent to a river's bank and overwhelms low-lying zones nearby river (Samanta et al., 2018). For this study a 2 km buffer area is considered, to analysis the effect of flood. Distances from stream is shown in Figure 3(d).

3.7 Elevation

In general floods are less probable to happen in higher elevation areas, such as mountains, and more probable in lower height places, such as flat plains (Das and Pardeshi, 2018). According to this study this study area

is flat place which means it is very much vulnerable to flood. This is represented in Figure 3(e).

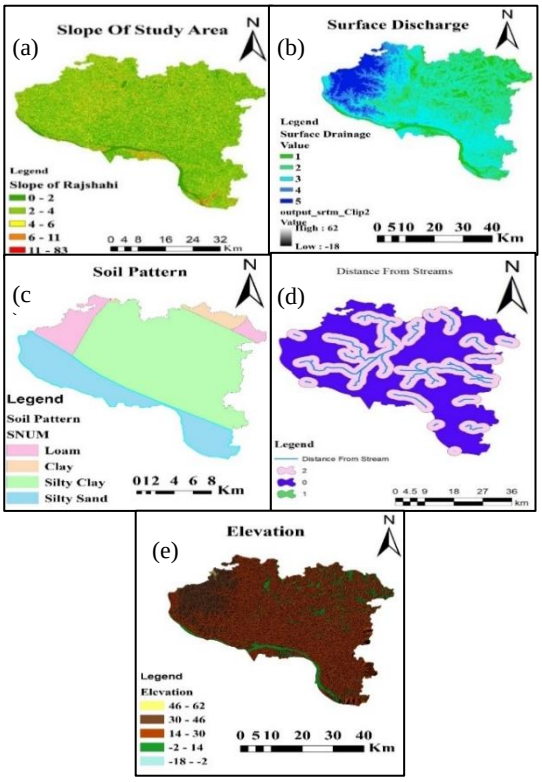

Figure 3. (a) Slope (b) Surface Drainage, (c) Soil Pattern, (d) Distance from Streams, (e) Elevation of study area (Obtained from Arc GIS 10.8)

3.8 Flow chart of methodology

The methodology used in this study to prepare a flood hazard map for the district of Rajshahi was mainly deepened on GIS. At first the main influencing factors of flood hazard in this study area were identified based on the best available datasets at national level. As a result, six factors were identified and compiled into a GIS-based database. Than the Digital Elevation Model (DEM) which was collected from United States Geological Survey (USGS) was input into the Arc-GIS software. Than the study area was clipped from the Reclassified DEM file. As the purpose of developing a Flood Hazard Map this reclassified DEM need to turn into a Triangular Irregular Network (TIN) because of this file gives the actual scenario of the land pattern of a particular area. Then set the boundary condition for Flood Hazard Mapping which is mainly flood depth. Then it will produce a unique Flood Hazard Map. The whole description is summarized by a flow chart in figure 4, which is given below.

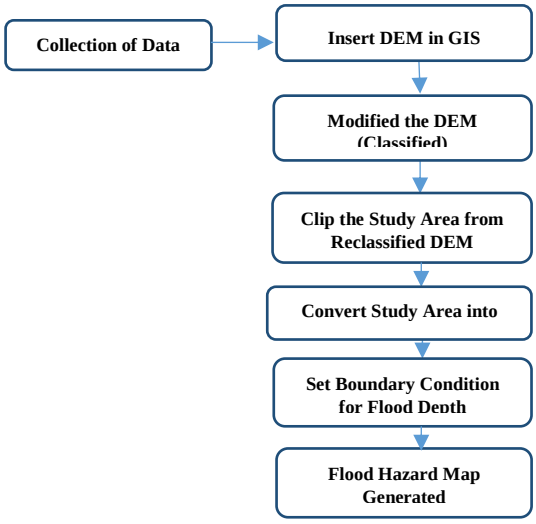

Figure 4. Flow Chart of the overall methodology

These are progressively used for photographic and statistical investigation of geography, land use and landforms and displaying of surface progressions. Bangladesh DEM obtained from NASA's Shuttle Radar Topographic Mission (SRTM) FTP service. It is a version of (GCS_WGS_1984). When predictable synchronizes method usage X and Y created level, GCS indicate position by latitude and longitude based on the globe. Forecasting controls change, which is unavoidable when looking at the globe from an aircraft (Masood, 2011).

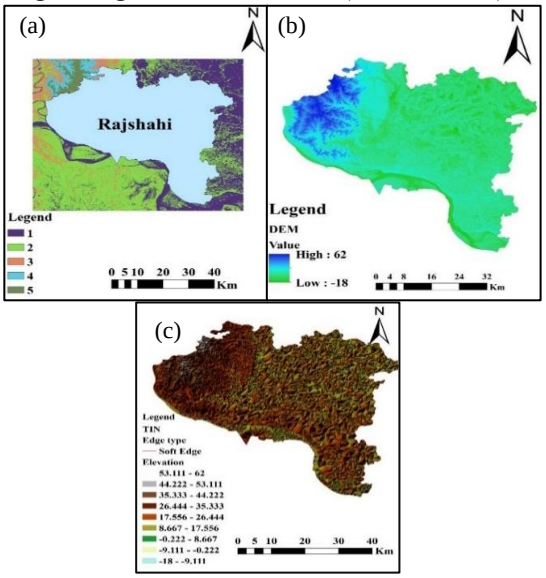

Figure 5. (a) Superimposed shape file on reclassified DEM, (b) Clipped DEM of shape file of study area, (c) Raster to TIN Generation of the study Area (Obtained from Arc GIS 10.8)

Later taking the improved DEM of collected DEM, the shape file of the Ganges River-adjacent Rajshahi area was superimposed, this is shown in Figure 5(a). By the help of the clipping tool in Arc toolbox, DEM of this

district was clipped from the modified Digital Elevation Model. The clipped Dem of study area is shown in Figure 5 (b). Aim of raster to TIN generated Triangulated Irregular Network (TIN) which exterior don't diverge as of involvement of raster a quantified Z acceptance. It converts raster data from a DEM to a TIN surface model. It's done in order to use the Arc toolbox's Raster to TIN tool. Figure 5(c) shows the TIN creation of the study region.

4. Results and discussion

From the whole research of flood hazard mapping different types of land use, land use of various flood vulnerabilities and existing infrastructure as potential flood shelters are available during disasters. In the following sections they are briefly discussed. From study it shows that about 3.64% of area is most floodable area and the rest of the area is less floodable area. Since mighty Ganges River flow through Rajshahi district this area is not affected by flood. Because of the embankment of the Ganges River the water cannot enter into this area. For this reason, a vast area is not affected by flood. But two upazilla which are affected by flood water are Mohonpur and Bagmara each and every year because of the water of Ganges River somehow enter into this area. The inundation map of flood affected areas is given below, in Figure 6.

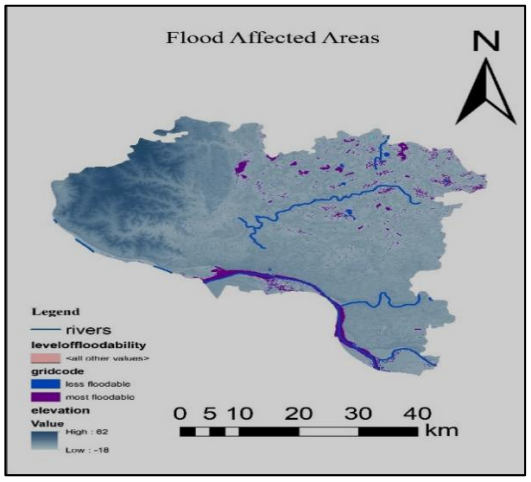

Figure 6. Flood affected areas of the study area (Analysis by Arc GIS 10.8)

Total population of Rajshahi district is 2286874. Flood affected people in this district are about 23383. We can also rank these floods affected zones by Free Flood area (FF) which is in the range of flood depth of 0.03-0.09 m, low Flood area which is in the range of 0.09-1.18 m of flood depth, high flood area which ranging from 1.18-3.6 m of flood height and very high flood area which is in the range of above 3.6 m of flood depth. This analysis is given below Figure 7.

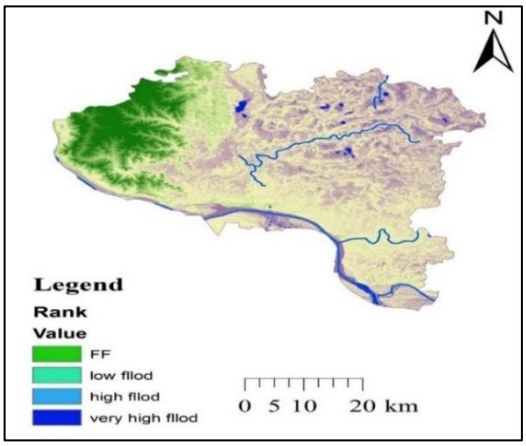

Figure 7. Ranking of inundation areas

The Ganges River is a very big river and it is very much dangerous at the monsoon season. Almost every year it flows with its highest peak and can submerged a vast area of land. In Bangladesh the Ganges causes a lot of damages at downstream area but in the area of Rajshahi district it doesn't cause a very vulnerable situation.

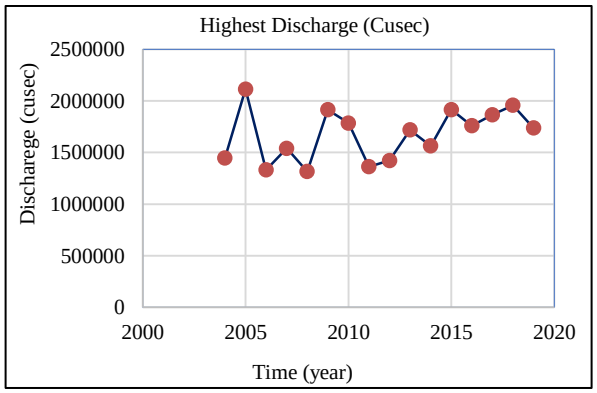

Figure 8. Annual highest discharge of Ganges river

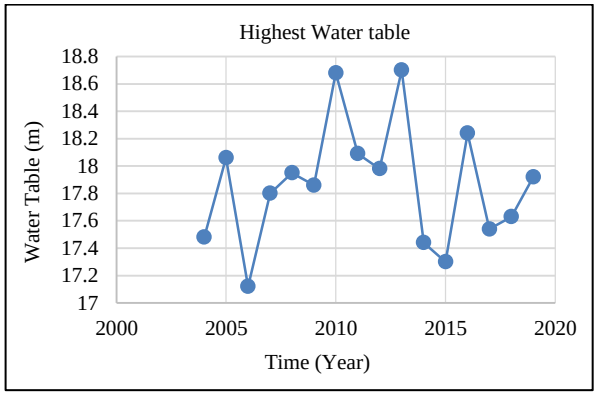

Figure 9. Highest water table of Ganges river

In Figure 8 and 9 shows the annual highest discharge in cusec and annual highest water table in meter of Ganges River. From these figures we observed that the highest

discharge of Ganges River is found in year 2005 and the highest water table is found in year 2013. If we change the flood type as Free Flood as F4, Low Flood as F3, High Flood as F2 and Very High Flood as F1 than the graphical representation of flood hazard areas will be shown like as following figures.

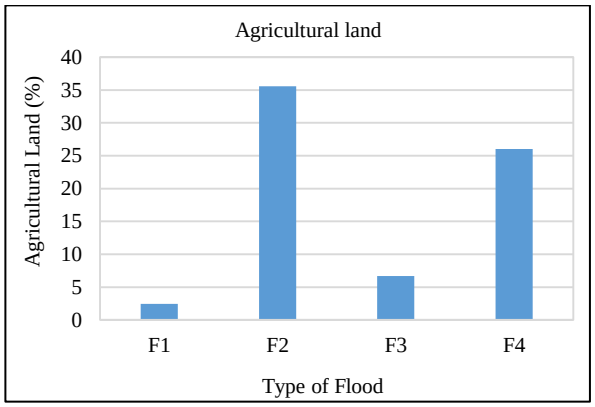

Figure 10. Flood Hazard for agricutural land

In figure 10 it shows that for flood type F2 covers the maximum area of agricultural land and a minimum area is affected by very high flood. From this analysis we can say that a huge number of agricultural lands are vulnerable for flood hazard. As a large number of agricultural lands is affected by high flood, it is dare need to enhance and upgrade the existing hydraulic infrastructure in these areas to safely handle expected flood amounts and accordingly mitigate its catastrophic consequences.

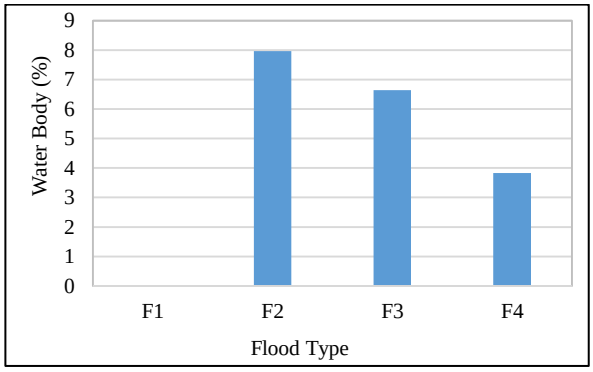

Figure 11. Flood Hazard for water body

Figure 11 shows the location of high-risk flood zone, and the maximum water body is flooded by high flood type. From this analysis it is clear that water bodies like canal, pond etc. are highly affected by High flood type. As ponds are used for firming fishes so there need to take proper action to protect these water bodies not to flood by flood water.

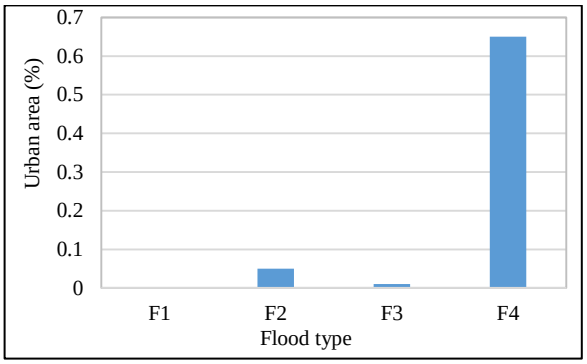

Figure 12. Flood hazard for Urban area

From Figure 12 it shows that maximum number of urban areas is in the free flood zone. That means urban areas of Rajshahi district is not so much affected by river flood. Also, we can see that there is no urban area in the very high flood zone. We can also see from the figure 10 of this study that agricultural land is highly affected by High flood category. This river carries a huge amount of water during the rainy season. This is around 40 to 45% of the dry season. For this reason, it can't hold this huge amount of water and overflow the banks of the river and causes flooding in the adjacent area of this river. If we consider the highest discharge of water and highest water table data and consider a buffer area around 3 km then the flood scenario of this area will be like Figure 13 (a). But this flood cannot cause any damage to the area of Rajshahi City Corporation because there is a very strong embankment of this river. But it can cause serious damages where this embankment is weak. If Rajshahi City Corporation is affected by flood than the people can take shelters in the areas, these are showing in the figure 13 (b). These places are highly elevated places which elevation is greater than 5m. But each and every year Bagmara and Mohonpur Upazilla are affected by flood. This is due to the overflow of the Ganges River water.

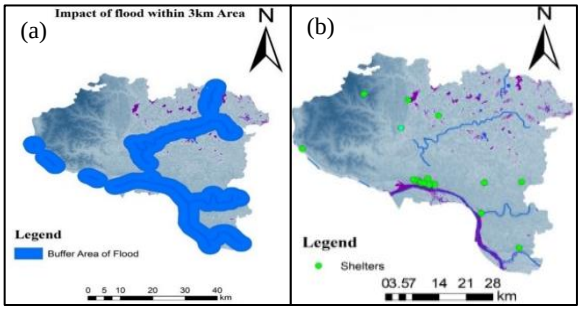

Figure 13. (a) Impact of flood due to high discharge of water, (b) Future shelter places for flood affected area.

Figure 13 depicts how shelter buildings for flood-affected communities can be constructed in the indicated areas where flooding will be minimal. The shelter structures will be constructed in such a way that

flood water will not be able to enter them. Separate sections for humans and domestic animals should be created.

Several Upazilla were found to have been submerged as a result of the flood inundation of the Ganges River and Jamuna River basin in 2004. Bagmara upazilla, one of the most dangerous upazilla that is flooded, was ranked 4 out of 4 of the ten upazilla.

5. Conclusions

A single model flood map and GIS technique were used to evaluate inundation hazard for the Ganges River floodplain. The findings of the study provide a method for measuring the prospect for flooding in the research area, which may be used to predict the damaging effects of impending floods. Flood hazard assessments were accepted, and flood hazard maps for the research region were created using a model simulated flood depth map from 2019. The inundation hazard maps generated for each administrative Upazilla. These categories of map support the appropriate persons for well realize the flood behaviour of the flood affected area.

The outcomes discussed of their search deliver very important evidence for inundation monitoring progress, and the formation and progress of flood measurement in the utmost flood hazardous zone in Ganges River floodplain. The most flood-prone Upazilla in the study region, according to map of flood hazard on the administrative unit map are Bagmara, Bagha, and Charghat due to the inundation of the Ganges river floodplain, whereas Tanore, Paba, Boalia, and Mohonpur are less flood-prone. For the flood affected areas several numbers of institutional building and other infrastructures are chosen that have potential to be used as shelter house during severe flood. A shelter was thought to be an existing school, hospital, or government building.

The Ganges River floodplain has a very high flood extent. As a result, early warning systems and mitigating measures must be implemented in these locations. As a result, policymakers and development planners can use the findings of this study to develop appropriate early warning systems and flood mitigation measures, reducing the effects of flooding on the livelihoods of rural small holder farmers in the study area by considering the area's spatial extent. This research provides crucial data that can help decision-makers prioritize development initiatives at the local government level. Based on the findings of this case study for the Rajshahi District, it is possible to draw the conclusion that geospatial technology offers the best potential for analysis and the provision of data necessary for efficient decision-making regarding floods. ArcGIS Model Builder's complete flood hazard and shelter model is simple enough for GIS beginners to use.

6. Limitations and future scopes of research

In our opinion, the results of the current study, along with other Rajshahi flood hazard maps already in existence, will considerably aid in the creation of a regional flood. Apart from the benefit and significance of this work, we want to draw attention to a few mapping-related constraints. The flood hazard modeling could be informed by distinct LULC classes. High resolution DEM may offer precise topographic parameters of the research location because the land is rather flat. If used, Mouza Wise Village statistics may have provided a true representation of the current population. Future study could employ the use of DEM and high-resolution satellite imagery to get around these limitations. Additionally, ground truth data could be included to assess the LULC's correctness. Assessment of the impact of flooding on inhabited areas (settlements and other infrastructure) may be advantageous for future planning in this area.

7. Acknowledgment

The Rajshahi University of Engineering & Technology deserves the authors' heartfelt thanks for allowing them to carry out this valuable research. We are also grateful to the Bangladesh Water Development Board (BWDB), US Geological Survey Department, Environmental Systems Research Institute (ESRI) for contributing us various important data and analysis of this study.

8. Conflict of interest

The authors declare no conflict of interest.

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