Flood hazard zonation of Bhima river basin (Haveli, Shirur, Khed and Daund taluka), Pune, India using Remote Sensing and GIS techniques

Ashwajit A. B¹, Sivakumar V², Chincholkar S¹, Thakare A¹, Ingole A¹
1- Department of Civil Engineering, College of Engineering, Pune-411 005, India.
2- Spatial Sciences and Disaster Management Group, Centre for Development of Advanced Computing (C-DAC), Pune-411007.
ashwajit3333@gmail.com
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ABSTRACT

Flood is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems, which not only damages the lives, natural resources and environment, but also causes the loss of economy and health. An attempt has been made in the project to prepare Flood Hazard Risk Zone maps of Bhima river basin (Part of Haveli, Shirur, Khed and Daund taluka) based on multi criteria assessment using remote sensing and Geographic Information System (GIS) techniques. Parameter considered for the flood are rainfall distribution, drainage density, land use/land cover, soil type, size of micro watershed, slope, and roads per micro watershed to prepare Flood hazard risk zone map. A final Flood Hazard Risk Zone map has been prepared showing three categories High, Moderate and Low Risk Zone. This identifies flood prone areas and will help in proper river management and appropriate planning of development works.

Keywords: Hazard risk zone map, multi criteria assessment, GIS, remote sensing, Bhima river basin.

1. Introduction

Flood is most common natural disasters in India. When rivers overflow their banks they cause damage to lives, property, infrastructure and crops. Floods usually are local, short-lived events that can happen suddenly and sometimes with little or no warning. They usually are caused by intense storms that produce more runoff than an area can store or a stream can carry within its normal channel. Rivers can also flood its surroundings when the dams fail, when ice or a landslide temporarily block the course of the river channel. Flood is the penalty human beings have to pay when they interfere in the rivers right of way.

While flood research and flood protection policy has ever since been dominated by a technical world view, the social and socio-economic aspects gained in importance in recent decades due to expansive and intensified land use, rising damage potentials in floodplain areas and, thus, increasing conflicts between socio-economic land use and flood protection policy (Schanze, 2002). Flooding in general and urban flooding in particular is not an unknown event in world and in India. The uneven distribution of rain fall coupled with Mindless urbanisation, encroaching upon and filling up natural drainage channels and urban lakes to use the high-value urban land for buildings are the cause of urban flooding. The flood hazard zonation for the study area identifies flood prone areas that will help in proper river management and appropriate planning of development works.
2. Literature review

Pramojanee, et al., (2012) have carried out a study for the flood hazard and risk areas mapping for the Nakhon Si Thammarat province is situated on the east coast of Peninsular Thailand. This paper discusses only the procedures that were applied for mapping flood hazard and risk areas in the provinces. The study includes the analysis and compilation of the flood hazard map and the flood risk map probability rating of flooding in each hazard zone in every watershed was done by considering certain causative factors such as size of watershed, annual rainfall sum, degree of both side slopes of the watershed, gradient of main river and stream of the watershed, drainage density of watershed, type of soil in watershed, land use type of watershed and, communication lines and other infrastructure that influences drainage of the watershed. The significance was indicated by weighting and causative factors and based this final maps were prepared.

Ajin, et al., (2011) has carried out a study to prepare Flood hazard risk zone maps of Vamanapuram River basin based on multi criteria assessment using remote sensing and GIS tools. The factors such as rainfall distribution, drainage density, land use, soil type, size of micro watershed, slope, and roads per micro watershed are studied to prepare Flood hazard risk zone map.

Muhammad and Saanyol, (2013) have carried out a study for the Flood vulnerability mapping in the river Kaduna which is a tributary of river Niger in Nigeria. Using High resolution imagery, a Digital Elevation Model was developed with ArcGIS to identify flood prone areas along the Middle Course of the river. A flow accumulation model was created using the DEM and the DEM was reclassified into high risk, moderate risk and low risk zones using equal interval of separation based on elevation. This was overlaid on the map of the area to produce a vulnerability map of the area. The study also conducted interviews with a sample of residents of certain areas that are at risk from flooding to identify elements-at risk of flood. Natural barriers exist between the river and the surrounding area, however urban explosion within the past decade and relocation after the Kaduna violence in 2000 have led to settlement within flood prone areas and finally they have discovered that a flood map can be used effectively in public enlightenment, disaster response planning and flood risk management.

Aditi, et al., (2011) have carried out a study Flood Hazard Mapping for the Dikrong river basin of Arunachal Pradesh India. In this paper flood inundated areas were mapped using GIS for the Dikrong river basin corresponding to different return periods (2, 5, 25, 50, and 100 years). In this paper at First the digital elevation model (DEM) of the entire basin and the water source grid were loaded into ArcGIS 9.3. Then a cost grid map was created for a particular return period and grid map and flood hazard map is created. The flood hazard maps were digitized to determine the inundation area and the developed inundation maps corresponding to 25, 50, and 100 year return period floods were compared to corresponding maps developed by conventional methods as reported in the Brahmaputra Board Master Plan for Dikrong basin. They have found that, the average deviation of modeled flood inundation areas from reported map inundation areas is below 5%. Hence, GIS techniques were proved to be successful in extracting the flood inundation extent of Dikrong basin in a time and cost effective manner.

Thilagavathi, et al., (2011) has carried out a study to demarcate the flood hazard prone areas in the papanasam taluk, northern part of Thanjavur District in Tamilnadu. In this paper the toposheets in a scale of 1:50,000 and 58 N/1, N/2, N/6, N/5, M/8, and satellite image that
cover the study area was collected. The base map of village boundary showing all the prominent geographic features of the basin was prepared by integrating toposheets and satellite image. Field visits to different parts of the basin made to observe the landforms. Based on the observations made from the field base map was prepared. The amount of rainfall in the study area for various seasons like pre-monsoon, monsoon and post-monsoon were collected from the metrological department and an annual average for each season were arrived at. Contour map already prepared through GIS with the field data by GPS. The parameters like Soil, Cropping pattern, Topography and Drainage have been observed and finally Causes of floods in study area are found out. Major problems like Rainfall, Huts Damages, and Agriculture Loss are studied.

3. Study area

The study area lies between latitude 18° 35'0'' to 18° 45’00’’ N and longitude 74° 00’ 00’’ to 74° 15’00’’ E in middle upper Bhima watershed basin in khed, Haveli, Shirur and Daund taluka, of Pune district in Maharashtra which covering an area of approximately 300 km² and perimeter 108 km. The study area is covered in one SOI 1:50000 scale toposheet. As shown in Figure1, the area was selected according to the watershed on both the sides of the river covering parts of Shirur Taluka on upper side and part of Haveli Taluka and small part of Khed and daund Taluka on top and bottom side respectively.

3.1 Material and methods

For the present studies the various maps were formed using ArcGIS and ERDAS imagine software. The study area delineated from survey of India Toposheet of scale 1:50000 numbered E43 I2. The Base map, micro-watershed, water bodies, Roads, drainage were digitized from SOI toposheet. The rainfall distribution map was prepared from Indian Metrological Department (IMD) data. The soil map was prepared by digitizing geographic profile of Pune division by Dr. D.V. phokharkar-2012. The land use/land cover map was extracted from LANDSAT ETM+ satellite image and the data was classified using ERDAS
Imagine 9.1 software. The slope map was prepared from ASTER DEM obtained from eartexplolar.usgs.gov. The google earth was used to modify road network.

For the present study Multi criteria evaluation method were used. A personal geodatabase was created in Arc Catalog and dataset was created for the Study area with the spatial reference of GCS_WGS_1984. Important features like streams, roads, water bodies, soil and micro watershed were digitized using ArcGIS tools. The thematic maps of rainfall distribution, slope, micro watershed size, drainage density, soil type, land use/land cover and roads per micro watershed were prepared using ArcGIS software and assigned weightage for each class. After assigning weightage all the thematic maps were integrated in ARCGIS Weighted Overlay Spatial Analysis tools and percentage was given for each factor on the basis of its estimated importance in causing flooding. Finally, integrated Flood Hazard Risk Zone map was prepared.

4. Results and discussions

4.1 Land use land cover

Land use land cover is most important factor that causes the flood hazard. The increase of human population and standards of living require more harvest and production from the earth resources, especially the land resources. The destruction of this steady state causes many problems such as soil erosion and increase of the surface run off decreases the soil moisture withholding capacity, resulting in more surfaces run off and hence more sudden heavy floods. For Agricultural land the presence of thick vegetation cover slows the journey of water from sky to soil and reduces amount of runoff. The vegetation cover of soils, weather it is permanent grassland or the cover of other crops, has a contact on the capacity of the soil to act as a water store. Barren land consists of soil in which plants cannot grow results in increasing runoff on the other side fallow land causes destruction to free flow of runoff. The land use /land cover classes of study area were prepared from LANDSAT 7 (ETM+) data. A supervised classification method was adopted using ERDAS Imagine 9.1 software and later analyzed using ArcGIS spatial analyst tools. The land use/land cover map is as shown in Figure2, the land use classes are agricultural land, fallow land, barren land, settlement, and water bodies.

Figure 2: Map showing the landuse landcover
4.2 Soil type

For flood hazard zonation soil type is a most important factor as the amount of water flow through soil is depends on infiltration capacity and the remaining results in to the surface runoff. Therefore for study soil present in the watershed classified on the basis of its infiltration capacity. The soil map available from geographic profile of Pune division was digitized in ArcGIS and the soil map of study area was extracted from it. It is shown from Figure 3, that the majority of the study area is consists of Coarse shallow soil and some part Medium black soil. Out of which the formal having high infiltration capacity than later. The chances of flood increase with decrease in infiltration capacity.

![Figure 3: Map showing soil type](image)

4.3 Size of Micro-watershed

Size of micro watershed have greater effect on flood if the area is larger it requires runoff of longer duration for major increase in water level to cause flood. Therefore chances of flood decreases with increase in size of micro-watershed and vice-versa. Micro-watersheds were trace from the toposheet on water divide basis. These were digitized and the size of each watershed was computed. The size of micro watershed ranges from 2 sq.km-38 sq.km. The micro-watershed size map is as shown in Figure 4.

4.4 Slope map

The nature of the landscape around a river will control how quickly rainwater reaches the river. Slope influences direction and amount of surface runoff reaching the site. A river channel surrounded by steep slope causes’ fast surface runoff. Therefore the slope map of the study area is most important for flood hazard zonation. ASTER DEM 30 meter spatial resolution data was downloaded from earthexplorar.usgs.gov. The slope map in degree was prepared using ArcGIS software. As shown in Figure 5, slope angles for study area ranges from 0-48 degrees. Steeper slopes are more susceptible to surface runoff on other hand flat terrain susceptible to water logging.
Figure 4: Map showing size of microwatershed

Figure 5: Map showing slope map

4.5 Roads per micro watershed

Road is one of the important factor induces flood hazards. The purpose of this map is to find the obstructions caused by the constructions of roads, which disturbs the free flow of water. Obstructions caused by the construction of structures in the ways of floodwaters, significantly obstruct the free flow of rivers (Valdiya, 2004). All roads were mapped initially from the toposheet and modified using Google Earth data then it is converted into shape file, and finally road network map was generated in ArcGIS. The road map was overlaid on micro watershed and Roads per micro watershed map was derived as shown in fig.6. The number of roads per micro watershed ranges from 0 to 20. Roads, bridges in the watershed restrict the passage of flood discharge. Roads and infrastructures which cover much of the land surface have less capacity to store rainfall (Konarad, 2003). Also due to construction of road pervious surface converted into impervious surface.
Rainfall distribution is an important factor for flood hazard zonation. High intensity rainfall results in heavy floods. As rainfall volume increases, it leads to an increase in surface runoff volume. Floods occur when the volume of water exceeds the ability of a stream and river to hold the water within its normal banks. Any stream, creek, lake, or river can flood. There is no rain gauge station present in the study area, therefore, we collected nearby rain gauge stations surrounding the study area (i.e., Shirur, Haveli, Daund, and Khed). The rainfall data of these stations were collected from IMD and the rainfall map was prepared using Inverse Distance Weighted method using ArcGIS spatial analyst tool. After preparing (interpolating) rainfall distribution maps of this region, we clipped for this study area and classified into five classes. The rainfall distribution map is as shown in Figure 7.
4.7 Drainage density

Drainage density is total length of all streams in the watershed divided by total area of watershed. It is a measure of how the watershed is drained by streams. Drainage density indicates well drainage and poor drainage conditions. A high drainage density value is favorable for runoff and hence indicates low chances of flood and vice-versa. Drainage density map is derived from the drainage map. Drainage map is overlaid on Watershed map to find out the ratio of total length of watershed to total area of watershed and it is categorized. The overall drainage density of area is 1.71/km. Fig.8 shows drainage density map.

![Weighted drainage density map](image)

**Figure 8**: Map showing drainage density. High -1.14 to 1.71, Moderate- 0.57 to 1.14, Low -0 to 0.57

4.8 Flood hazard risk zone map

After preparing all the maps weightage were assigning in each map and weighted map were prepared for each factor considered. Then the net probability of occurrence of flooding in each flood hazard zone was estimated from the total sum of weight of each contributing factor. To obtain this all the weighted maps were overlaid. GIS allows the decision maker to make out a list meeting a predefined set of criteria with the overlay process (Heywood, et al., 1993). The processes, like compilation of contributing factor maps, the overlaying of all maps and the calculation of hazard areas were obtained by using Raster Calculator in ArcGIS Spatial Analyst tool. The factors which contribute to the floods are given in the Table.1. The flood hazard map was prepared by giving suitable percentage to these contributing factors and the prepared map is shown in Figure 9.

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Contributing Factor</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land use land cover</td>
<td>20%</td>
</tr>
<tr>
<td>2</td>
<td>Soil type</td>
<td>10%</td>
</tr>
<tr>
<td>3</td>
<td>Size of micro-watershed</td>
<td>20%</td>
</tr>
<tr>
<td>4</td>
<td>Slope</td>
<td>15%</td>
</tr>
<tr>
<td>5</td>
<td>Roads per micro watershed</td>
<td>5%</td>
</tr>
<tr>
<td>6</td>
<td>Rainfall Distribution</td>
<td>20%</td>
</tr>
<tr>
<td>7</td>
<td>Drainage density</td>
<td>10%</td>
</tr>
</tbody>
</table>

**Table1**: Showing the contributing factors to flood
5. Conclusion

The study was carried out with the aim of creating a flood susceptibility map along the course of Bhima river basin region (Haveli, Shirur, Daund and Khed taluka). GIS is used for creating flood hazard map from the available database. The primary purpose of producing these kinds of maps is for public dissemination of flood map which will serve to increase public awareness. This will empower individuals and officials to take suitable preliminary and response measures, which will help them for taking decision. Further scope of the study would be validating prepared thematic maps and accuracy assessment; however, this study would encourage carrying out further analysis. This result would helpful to understand the overall flood scenario of the area.

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6. References


