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Estimation of Flood Risk Zone of Godavari Watershed using Remote Sensing and Geographic Information System

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ABSTRACT: Floods are amongst the most prevalent natural disasters. The frequency with which floods occur, their magnitude, extent and the cost of damage are escalating all around the globe. Past studies demonstrated that remote sensing (RS) and geographic information system (GIS) are very useful and effective tools in flood risk assessment and management. The study was undertaken to demarcate flood risk areas and create a map for the Godavari watershed, Nasik using remote sensing and geographic information system. In this study a standard methodology and software was used to demarcate flood risk zones using integration of RS and GIS technique. The composite map was generated using GIS tools. The accurate information to obtain the parameters for identifying the flood risk zone such as, slope, drainage density, rainfall units and land use and land cover were generated using the satellite data and survey of India (SOI) toposheets of scale 1:50000. It was integrated with weighted overlay in ArcGIS. Suitable ranks were assigned for each category of these parameters. For the various geomorphic units, weight factors are decided based on their capability to hold runoff and speed of water flow. The flood risk zone analysed map indicates little area of Eastern and Southern parts of the study area has show very high risk of flooding. The Eastern and North Eastern parts of the study area reflects very low risk of flooding.

KEYWORDS: remote sensing, geographic information system, flood risk zone

I. INTRODUCTION

Floods are the natural hazard with the highest frequency and the widest geographical distribution worldwide. Although most floods are small events, monster floods are not infrequent. Various climatic and non-climatic processes can result in different types of floods viz. riverine floods, flash floods, urban floods, glacial lake outburst floods and coastal flood. Flood magnitude depends on precipitation intensity, volume, timing, and phase, from the antecedent conditions of rivers and the drainage basins (frozen or not or saturated soil moisture or unsaturated) and status. Climatological parameters that are likely to be affected by climate change are precipitation, windstorms, storm surges and sea-level rise. The most common causes of flooding, both natural and human-induced are heavy rains, overflowing rivers, broken dams, urban drainage basins, storm surges and tsunamis, channels with steep sides, a lack of vegetation, melting snow and ice [9]. Flooding occurs most commonly from heavy rainfall when natural watercourses lack the capacity to convey excess water. It can also result from other phenomena, particularly in coastal areas, by a storm surge associated with a tropical cyclone, a tsunami or a high tide[1].

Using GIS mapping, analytical, and visualization capabilities allows the identification of vulnerable areas and helps create visual products for analysing that risk. When combined with existing geospatial information such as roads, population, built structures, property values, critical infrastructure, and hazardous materials in a GIS environment, it is possible to identify structures and population at risk, help route supplies and personnel, aid decision making with regard to where to pre-position temporary shelters and distribution points, give early estimates of likely flood losses,



and more[7]. Remote sensing and Geographic information system (GIS) are very useful and effective tools in flood risk assessment and management. Remote sensing captures information over large areas at short time intervals. Remotely sensed images can be used in delineating flood plains, mapping flood prone areas, land use mapping, flood detection and forecasting, rainfall mapping, evacuation planning and damage assessment. Remotely sensed data, such as satellite imageries, have large synoptic overview which can be used for several applications which include the mapping of a variability of terrain properties needed for flood analysis.

Over the years, the number of reported natural disasters such as flood has steadily been on the rise and the severity and impact of these natural disasters to the global economy and environment has increased noticeably. In developed countries, the impact of natural disasters is significantly reduced due to the existence of a comprehensive strategy for disaster management[5]. In underdeveloped and developing countries this is a novelty. GIS is a computer-based system that offers a wide range of tools for modelling flood affected areas and for determining or forecasting flood prone areas. Considering these applications of RS and GIS generated images for warning and monitoring natural disasters and developing disaster risk maps enabling preparedness and later to plan flood disaster management effectively the study of Godavari watershed of Nasik district in Maharashtra State, India. The objectives of the study were to create a flood risk zone analysed map for the Godavari watershed using remote sensing and geographic information system, and to examine rainfall, drainage and land use for the flood risk assessment.

II. RELATED WORK

Various scientist all over the world have been working on RS and GIS techniques using different software for identifying flood risk zone or hazard areas and plan remedial measure to control for better crop production as well as design of hydraulic structures of required capacity in various watersheds. In India, Sinha, *et. al* (2008) studied flood risk in the Kosi river basin in North Bihar India and used Analytical Hierarchy Process (a multi-parametric approach) to integrate geomorphological, geographic, and topographic and social (population density) parameters to propose a Flood Risk Index (FRI) in a GIS environment. The data used for this included district level maps, topographic maps and census data of 1991, digital elevation data (GTOPO30) and digital remote sensing images LISS-IV, LISS-III.

Sinha, *et. al*. (2011) studied on make flood risk zone map for Jagatsinghpur and Puri districts of Orissa State, India so as to help planning dissemination of the flood tolerant rice varieties in these districts. Flood inundated area maps prepared using Radarsat-2 data for different dates of the three years (2008, 2009 and 2010) collected from the NRSC website were digitized and analysed for flood risk assessment and zoning. The spatial variation of the flood affected areas in the lower Ajay river basin and the major causes for this situation was studied by Roy (2012). He observed that, the hydro-geological characters in terms of underlying geology, hydraulic gradient, porosity, permeability, groundwater movements, depth of aquifers, lithology, all of these, influence very much for the frequent floods.

The peak flood discharge of the Kunur river basin, a major tributary of the Ajay River in the lower Gangetic plain was estimated by Mistri and Roy (2013). Field measurements, GIS technique, and several channel geometry equations were adopted. The hydrological models suggested were adequate for the planning and design of various hydraulic structures and for flood frequency analysis. Shanwad U.K. *et. al*. (2012) prepared action plan and impact assessment of watersheds in Gulbarga district of Northern Karnataka using IRS 1D for two seasons. LISS-III and PAN merged data (sharpened) representing rabi (December 8 and 10, 2000) and summer (March 15, 2001) data were used for preparation of various thematic maps and resource action plans for the watershed. They revealed that, RS and GIS technologies provides an excellent opportunity to monitor the land resources and evaluate the land cover changes through on comparison of images acquired for the watershed at different periods. Samanta *et. al*. (2018) claimed that, the FR model in GIS is useful in geographical area to develop a food risk map which could help planners and decision makers to perform proper flood management.

III. METHODOLOGY

For developing a flood hazard map for the Godavari watershed area of Nasik district remotely sensed data in ArcGIS environment was used. First stage of work included development of spatial data base by using survey of India (SOI) toposheet on a 1: 50000 scale. GIS and remote sensing technology was applied to prepare various thematic maps with reference to flood hazard like drainage density, contour, and stream length. The second stage involved preparation of digital elevation model (DEM) by interpolating contour map that is digitized from SOI toposheet. DEM was used to prepare slope, aspect, flow accumulation and stream order. In the third stage, digital image processing of the satellite data was done for geo-referencing and geometric correction. This was followed by creation of different thematic layers



using supervised classification technique. In the fourth stage all above themes are further processed and analysed in overlay and ranking is given to evaluate suitable flood risk zone. All the thematic layers will overlay by using GIS to find the final integrated output of flood risk zones. In the present study, slope, drainage density, land use and land cover, rainfall and soil were considered for the identification of flood hazard.

The flood risk zones were obtained by overlaying all the thematic maps in terms of weighted overlay method using the spatial analysis tool in ArcGIS 10.8. The ranks had given for each individual parameter of each thematic map and the weightage was assigned according to the influence of the different parameters. All the thematic maps were converted into raster format and superimposed by weighted overlay method (rank and weight wise thematic maps and integrated with one another through GIS (Arc/Info grid environment).

For assigning the weightage, the land cover and rainfall were assigned higher weightage, whereas the soil was assigned lower weightage. The maximum value was given to the feature with highest flood capacity and the minimum given to the lowest capacity feature. For land cover highest rank was given to the residential area whereas high rank given to the barren land because it does not hold water. Forest land assigned as low rank as it can hold the water and lower to the water bodies. For Rainfall, the highest rank was given to high rainfall value and low rank to the low rainfall value. For high drainage density highest rank, followed by more drainage density was given. For slope high rank to low slope because of water is more stable at lower slope areas and low rank given to the higher slope. For DEM high rank to the less elevation and low rank to the high elevation was considered as it causes quick runoff. For soil high rank to the number 3818 as it covered maximum area.

IV. EXPERIMENTAL RESULTS

The accurate information to obtain the parameters for identifying the flood risk zone such as, slope, drainage density, rainfall units and land use and land cover were generated using the satellite data and survey of India (SOI) toposheets. It was integrated with weighted overlay in ArcGIS.

Digital Elevation Model (DEM) of study area:

The elevation and slope were determined from the ASTER DEM using surface analysis tools under the spatial analyst tool bar in ArcGIS. Contours of the study area were extracted from DEM and it was used to generate the slope and elevation maps. Low-lying areas with gentle slope angles have the tendency to be inundated first as compared to areas with steep slope angles during flooding. Most of the area is under very low and low DEM ranking (Fig. 1).

Slope :

Slope plays essential role in the flood vulnerability of a terrain. The slope influences the amount of surface runoff or subsurface drainage, infiltration and the direction of flow. Slopes with low gradients are extremely susceptible to flood occurrences since flat terrains allows for waterlogging conditions. The slope was classified using natural breaks. From Fig. 2 it was noticed that maximum part of study area has very low slope while some part has very high slope. Area with low slope tends to high risk of hazard.

Drainage Density:

Drainage density is the ratio of total stream length of all the orders per unit basin area. The stream network is derived from the ASTER DEM. For watershed delineation, the sink tool in ArcGIS hydrology was used to locate sinks in the DEM and the fill tool was used to fill the identified sinks. Flow direction tool was applied to compute the direction that water would flow for every cell and flow accumulation calculates the number of cells flowing into each cell of the filled DEM. The Basin tool is then used to create watersheds. Low drainage density was observed in regions of highly resistant or permeable soil material under dense vegetation cover and low relief (Fig.3). High drainage density was observed in the regions of weak and impermeable subsurface material and sparse vegetation.

Soil :

Soil texture and depth have a major impact on the flooding of an area. It was seen that study area has almost same soil type i.e. course shallow soil to the maximum extent and some amount of deep soil along the river side. Flood causing capacity is based on the soil's infiltration ability of study area. The course shallow soil leads to quick infiltration and have least flood risk.



Rainfall :

A rainfall interpolation surface was created for the study area. The rainfall interpolation surface was created based on Inverse distance weighted (IDW) method. IDW interpolation determines cell values using a linearly weighted combination of a set of sample points. From June to September, monsoon rain occurs in Godavari watershed, Nasik district and the rainfall starts decreasing gradually from the October month of the year. Almost no rainfall occurs for the period of January to May and December. The study area was found in various rainfall area starting from very low to vary high. The reclassified rainfall map is shown in Fig. 5.

Analysis of data

The various parameters such as digital elevation model, slope, drainage density, soil and rainfall were considered. The weightage was given to each factor for flood risk assessment. The overall analysis was prepared and tabulated in Table 1. The ranking was also given to each sub parameters. The flood hazard map which resulted from the weightage overlay process is shown in Fig. 6. The resulted map indicates some level of flooding experienced in all locations areas under the study.

Fig. 6 illustrates the flood risk zones map of the Godavari watershed through influencing factor technique. By implementing influencing factor, the area falling under very low risk, low risk, moderate risk, high risk, and very high risk of flood zones was demarcated. The little area of Eastern and Southern parts of the study area has show very high risk of flooding as this region shows very gentle slope, high rainfall, high drainage density which influence rapid flooding process. The Eastern and North Eastern parts of the study area reflects very low risk of flooding as the region is having very steep slope.

Table.1 Rank and Weightage for Different Parameters of Flood Risk Zones

Sr. No.	Parameters	Classes	Hazard prospect	Weightage	Ranking
1	Digital elevation model (m)	280-438	Very Low Risk	20%	1
		438.01-545	Low Risk		2
		545.01-657	Moderate Risk		3
		657.01-794	High Risk		4
		794.01-1177	Very High Risk		5
2	Slope (°)	0- 3.035	Very low risk	15	1
		3.035-7.73	Low risk		2
3	Drainage density (km/km ²)	7.73-13.80	Moderate risk	25 %	3
		13.80-22.08	High risk		4
		22.08-70.37	Very high risk		5
		0.20-1.33	Very low risk		1
		1.33-2.47	Low risk		2
		2.47-3.60	Moderate risk		3
		3.60-4.73	High risk		4
		4.73-5.86	Very high risk		5
4	Rainfall (mm)	2,683.77- 2,866.50	Very low risk	20 %	1
		2,866.50- 2,991.96	Low risk		2
		2,991.96- 3,114.69	Moderate risk		3
		3,114.69- 3,234.69	High risk		4
		3,234.69- 4,000	Very high risk		5
5	Soil	3818	Low risk	8%	1
		3820	High risk		2

V. CONCLUSION

The basic notion of flood risk mapping undertaken under this study was to efficiently delineate flood prone areas in Godavari watershed, Nasik. It is achieved through a multi criteria evaluation method within a GIS environment-based overlay analysis. The resulting map of weightage overlay analysis can be used as a guide for decision makers and city planners and administrators for better land use planning, flood risk management and also to prioritize their mitigation or relief response if required.



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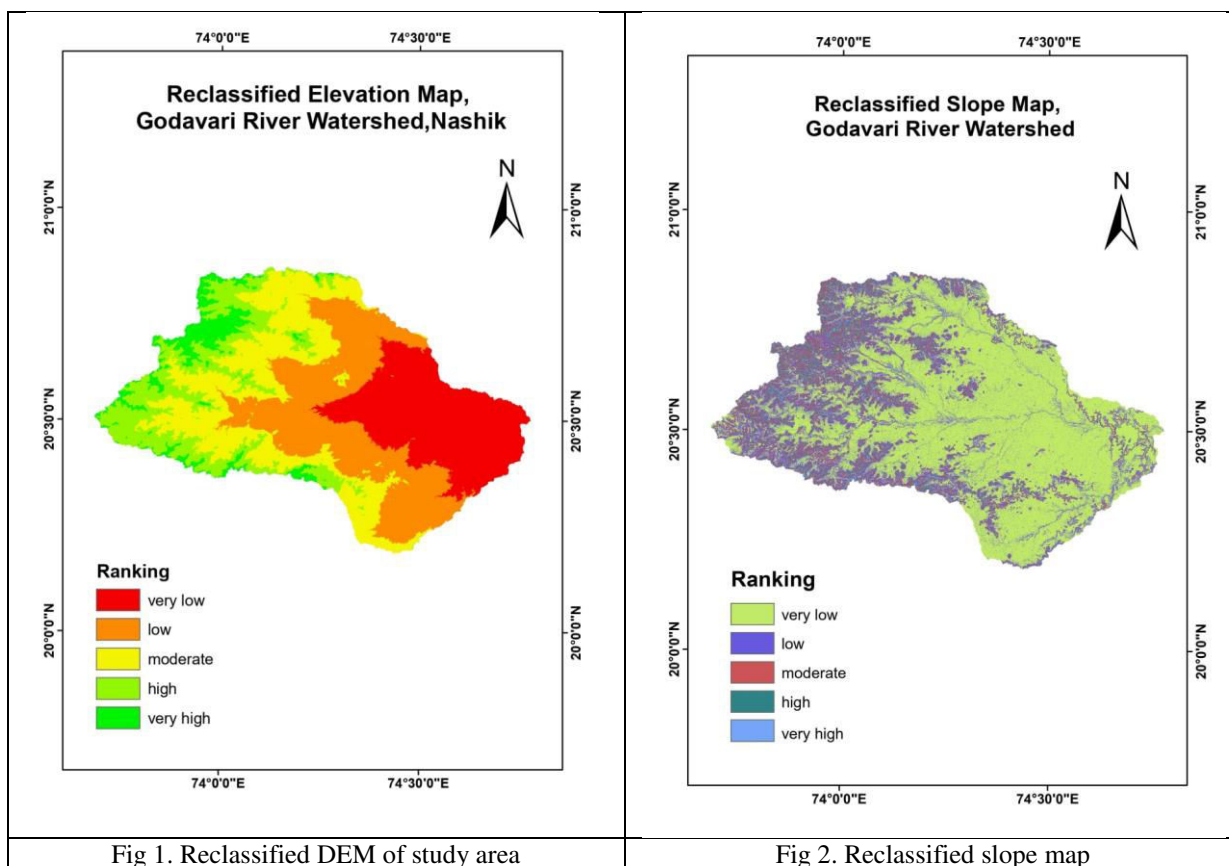
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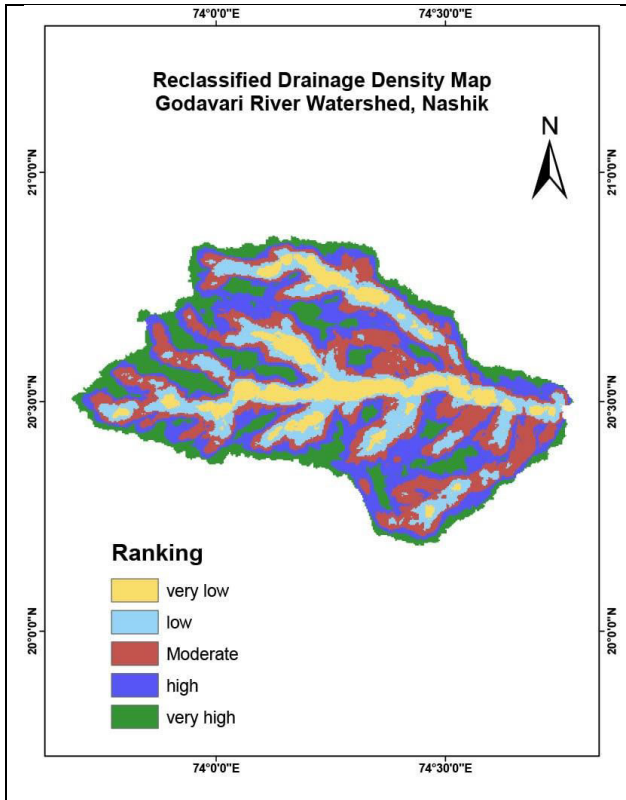


Fig 3. Reclassified drainage density

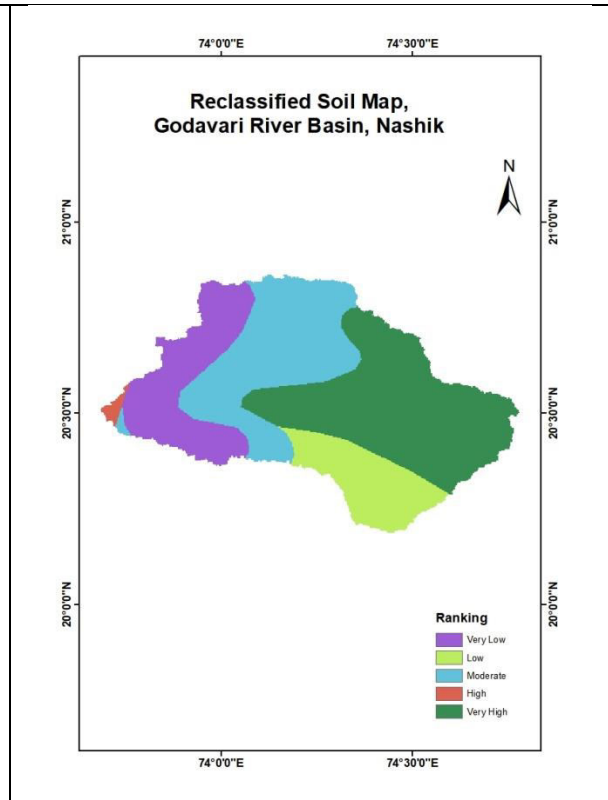


Fig. 4. Reclassified soil map

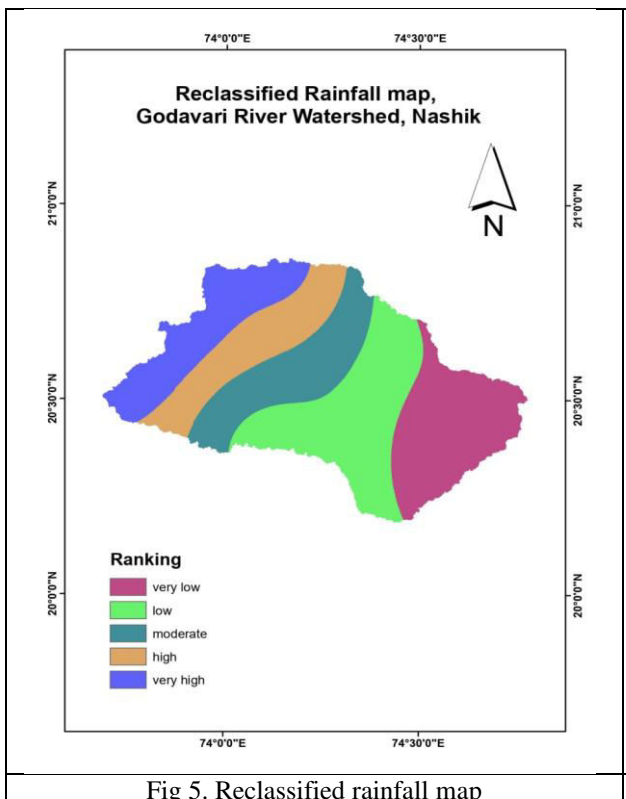


Fig 5. Reclassified rainfall map

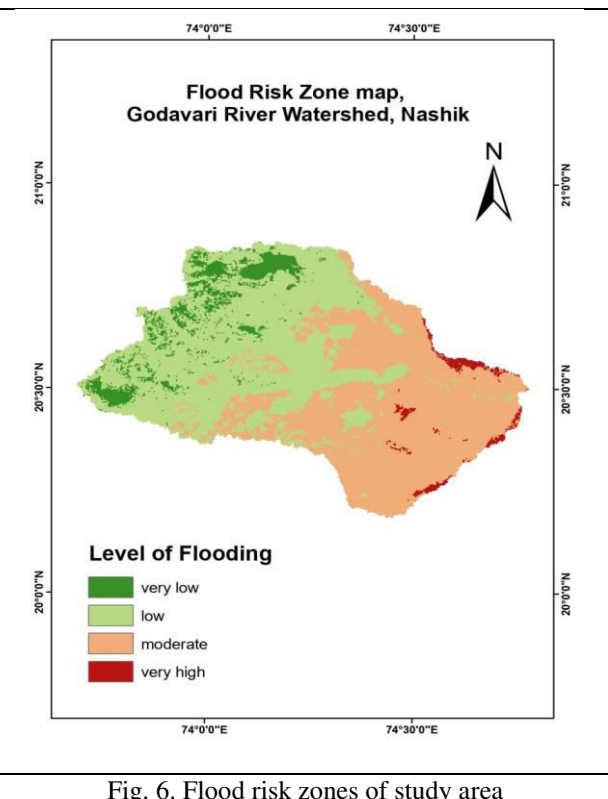


Fig. 6. Flood risk zones of study area



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