RESEARCH ARTICLE OPEN ACCESS

Flood Management And Flood Control Measures For Region In Bennihalla Basin

Mr. Raghavendra K *, Prof. Dimple Bahri *
*(Department of Civil Engineering, JAIN (Deemed-to-be University), Banaglore, 562112, India
Email: raghucivil43@gmail.com)

--************************----------------------------------

Abstract:

Floods are unpredictable natural disasters that cause damage to lives, resources, and the economy. To manage and understand flood hazards, modern Geoinformatics technology—including Remote Sensing (RS), Geographic Information System (GIS), and Global Positioning System (GPS)—is utilized.In this study, flood-prone areas in the Bennihalla Basin (Gadag and Dharwad districts of Karnataka) were mapped using various thematic layers, such as lithology, drainage density, soil, land slope, and surface water bodies, prepared using satellite data and conventional sources. These layers were assigned weights based on their role in flood occurrence, incorporating factors like annual rainfall, basin size, river gradient, drainage density, and population density.By integrating these factors using AutoDesk MAP and MapInfo GIS software, flood hazard zones were categorized into high, moderate, and low-risk areas. The findings highlight that Geoinformatics technology is an essential tool for flood hazard mapping and management.

Keywords — **Flood; Geoinformatics; Drainage; Basin; Rainfall, Model, HEC-RAS, prediction.**

--************************----------------------------------

I. INTRODUCTION

Floods are a recurring natural disaster in India, affecting 12-18% of the country's land annually. They cause extensive damage to property, the economy, human life, and nature. Karnataka is frequently impacted, with the Bennihalla River basin in Dharwad and Gadag districts being a significant flood-prone area.To analyze flood hazards, the Analytical Hierarchical Process (AHP) method in ArcGIS software is utilized, along with HEC-RAS software for flood modeling and prediction. Data spanning 2009-2023 has been collected to map hazard zones. The Bennihalla River, a tributary of the Malaprabha River, has a flat gradient, making it susceptible to flooding. The river's catchment area experiences significant erosion and siltation during monsoon rains, worsening flood risks.Tuparihalla, a major tributary of Bennihalla, further contributes to flood intensity. The upstream section consists of sandy loam soils, which have poor water retention, leading to erosion and silting. Floods affect both rural and urban areas, impacting agriculture, infrastructure, and daily life.

II. STUDY AREA

Investigated area lies in between north latitudes 15°04‟27” and 15°50‟23” and east longitudes between 74°58‟43” to 75°38‟44”. The study area is surrounded by Rona, Gadag and Shirhatti taluks in the east, Dharwad and Hubli taluks in the west. Shiggaon taluka in the south west and Nargund and Parasgad taluk in the north. Navalgund taluk in the Center. The study area falls in the semi-arid region. The physiographical of the study area is characterized by gently undulating terrain with alternating ridges and slope elevation ranges from 600 m above MSL. The climate of the study area is generally pleasant in the entire basin area. April and May are hottest months with average daily maximum temperature of about 38°C and average daily minimum temperature of about 20°C. The southwest monsoon sets in by June and ends by the middle of October. During this period the basin receives above 50% of the annual rainfall and the climate will be generally humid. Geologically, the study area is underlain by Dharwar schistose rocks and granitic gneiss.

The northeastern part of the study area is occupied by granitic gneiss, which are mainly covered by thick black cotton soil, shales, phyllites and altered grey wackes of schistose rock are covered the rest of the area. The schistose formations strike in NNW-SSE direction and are dip varying from 35° to nearly vertical. Granitic gneiss strike in NNW- SSE direction and is highly weathered.

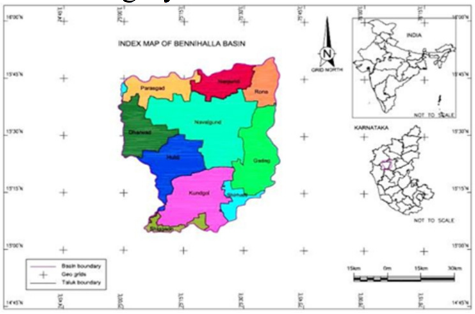

Fig.1: The Index Map of the Bennihalla Basin

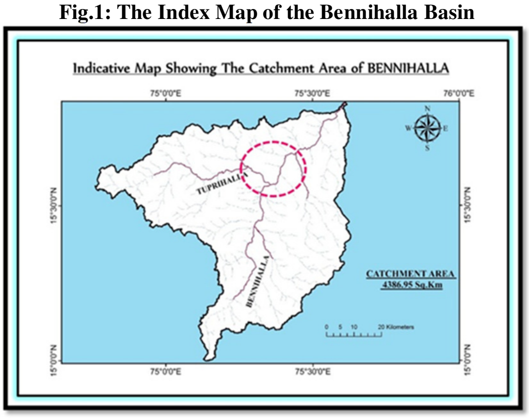

Fig.2: Catchment Area Zone Map of Bennihalla

III. OBJECTIVES

- To analyse and understand the reasons for the occurrence of flood.
- To map the flood hazard zone using the AHP method. (Analytical Hierarchical Process)
- To create model for previous flood situations of the study area.
- To develop a flood prediction model.

IV. MATERIALS AND METHODOLOGY

A. The following materials are used in study area

- Satellite images (IRS-1D, LISS-III)
- Google Earth images
- Topographic (map scale)
- Thematic maps (soil, LU/LC, geology, drainage network, slop, DEM, contours, etc.)
- Hydrogeological data and maps
- Geoinformatics software's (QGIS, AutoCAD, Google Earth,)).

The detailed methodology flow chart to be adopted for the study is given below at 3.

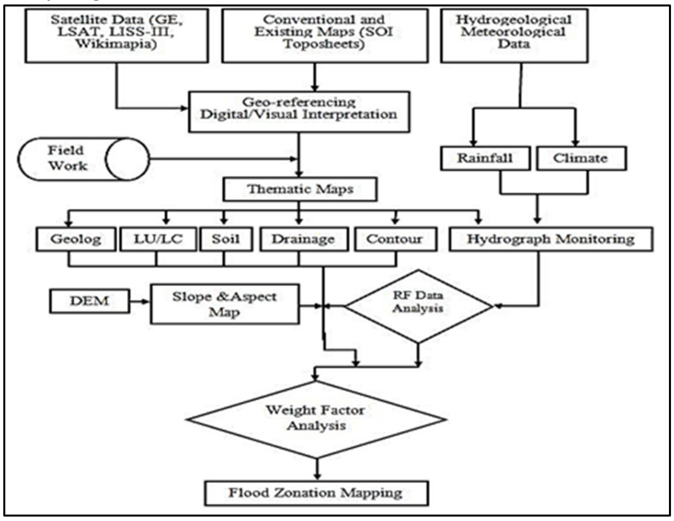

Fig.3: Research Methodology Flow Chart

B. Materials

The following materials are adopted while planning:

- Satellite
- Images (IRS-1D, LISS-III): Provide high-resolution spatial data for mapping and analysis.
- Google Earth Images: Useful for visualizing terrain and identifying flood-prone areas.
- Topographic Maps: Offer detailed elevation and terrain information critical for flood modelling.
- Thematic Maps: Include layers such as soil, land use/land cover (LU/LC), geology, drainage networks, slope, DEM (Digital Elevation Model), and contours for comprehensive analysis.
- Hydrogeological Data and Maps: Essential for understanding water flow, groundwater dynamics, and flood behaviour.
- Geoinformatics Software: Tools like MapInfo, AutoCAD, Google Earth, and ERDAS are employed for data processing, analysis, and creating flood hazard maps

C. Methodology

- Data Collection: Gather spatial, hydrological, and meteorological data from satellite images, topographic maps, and field surveys.
- Data Integration: Combine thematic maps (soil, LU/LC, geology, etc.) with hydrogeological data to create a comprehensive database.
- Flood Hazard Zonation: Use GIS and HEC-RAS software to analyze flood-prone areas and predict flood behavior.

- Modeling and Prediction: Develop flood models for specific years (e.g., 2009, 2013, 2019, 2023) using rainfall data and DEM layers.
- Analysis and Mapping: Generate flood hazard maps to identify high, moderate, and low-risk zones.
- Implementation: Use the findings to design structural measures (e.g., embankments, reservoirs) and non-structural measures (e.g., early warning systems, community awareness programs).

V. DATA ANALYSIS AND COMPILATION

A. *Generation of Thematic layers*

The flooding hazard zones were identified by interpreting in the study area, a multipara metric dataset comprising satellite data, google Earth data and conventional maps including survey of India (SOI) topographic sheets was used. IRS-1D LISS-III data collected from the national remote sensing center (NRSC), Hyderabad, India has been used for the preparation of thematic maps of drainage density and surface water body etc. All the 11 SOI toposheets (D43D1, D43D2, D43D3, D43D4, D43D5, D43D6, D43D8, D43D9,D43D10, D43D11, 48M5 and 48M7) covering the study area at 1:50,000 scales were scanned separately and all the scanned images were rectified and geometrically corrected. These images were then mosaicked to form a single image and transferred into MapInfo software to prepare thematic layers, namely study area boundary and slope. Further the thematic layers of geology and geomorphology were prepared from existing maps obtained from the natural resources data management system (NRDMS) center. The soil layer was prepared by digitizing the soil map obtained from the Karnataka state remote sensing application center (KSRSAC). Considering the data availability in the study area in the process the Bennihalla basin of each stream networks and river was firstly identified from the topographic map and delineated. After that flood plain lower terrace plain in each sub-basin were identified and delineated by considering both soil map and LU/LC map. Finally each flooding hazard zone was transferred and digitized coverages were spatially organized in the Geoinformatics environment with the same resolution and coordinate system. The checking of these spatial maps was done with respect to other database layers by the overlaying technique and refined mutually as part of standardization of the database. The errors due to digitization and miss mapping were removed in this process. In the present study, the cloud free digital image of IRS-1D LISS-III (linear imaging self-scanner) sensor having 23.5m spatial resolution was classified using ERDAS IMAGINE v8.6 digital image processing software. Initially the satellite image was registered with the base map after matching some of the identifiable features such as crossing of roads, railways, canals, bridges, etc., on both the base map as well as on the satellite image and topographic map of the same scale and stored in the Geoinformatics database of the computer system.

B. REASONS FOR THE OCCURRENCE OF FLOOD

Floods occur due to a combination of natural and human-induced factors. Heavy rainfall, poor drainage systems, deforestation, urbanization, and geographical features contribute to flooding. Understanding these causes helps in effective flood management and risk reduction.
Flooding is a complex environmental hazard caused by various interconnected factors.

Natural Causes:

- Heavy Rainfall – Excessive precipitation leads to increased runoff and overwhelmed drainage systems.
- River Overflow – When rivers exceed their capacity due to continuous rainfall, water spills into surrounding areas.
- Topography and Soil Composition – Low-lying regions and clay-heavy soils retain water, increasing flood risks.
- Climate Change – Rising temperatures lead to erratic weather patterns, increasing the frequency and severity of floods.
- Storm Surges & Cyclones – Coastal areas are vulnerable to high tides and storm-driven water intrusion.

Human-Induced Causes:

- Deforestation – Removal of vegetation reduces water absorption, leading to rapid runoff and soil erosion.
- Urbanization – Expanding cities with concrete surfaces prevent natural water infiltration, causing excessive surface runoff.
- Poor Drainage Systems – Blocked or inefficient drainage networks exacerbate flooding.
- Unplanned Land Use – Settlements in flood-prone areas increase vulnerability.
- Dam Failure – Structural failures or improper water release from reservoirs can lead to downstream flooding.

C. Assessment of the Flood Hazard Zone

Assessment of flooding in each hazard zone in Bennihalla basin was done by considering certain relevant factors. Their significance was indicated by weighting. The causative factors taken into account for this study include;

- Size of the Bennihalla basin
- Annual rainfall sum
- Slopes and aspect ratio of the basin
- Gradient of stream networks in the Bennihalla basin
- Drainage density of the basin
- Soil type in the basin
- Land use and land cover of the basin,
- Infrastructure and communication lines impacts of the basin.
- Theoretically, there are still more causative factors, for example daily rainfall, the hydrograph of the main stream networks of the basin, etc.

According to Pramojanee et al. [10], the weight of each factor was given on the basis of its estimated significance in causing flooding. The weight of each factor is as shown in Table 1.

Table.1 Assigned Weight Factor Classes

No.	Weight of factor	Assigned weight
1.	Annual rainfall	10
2.	Size of basin	9
3.	Slopes and aspect ratio of the basin	8
4.	Gradient of stream networks in the	7
5.	Drainage density	6
6.	Land use and land cover	3
7.	Soil type	2
8.	Infrastructure and communication	1
9.	Annual rainfall	10

Further each factor was divided into a number of classes and each class, weighted according to the estimated significance for causing flooding. The maximum weight for each class of every factor is 10 whilst the minimum is 2 and the total weight used for considering the rate of probability of flooding is:

$$T_w = W_f * W_c \quad (1)$$

Where, Tw is total weight of each factor, Wf is factor weight and Wc is weight of factor class.

D. Rainfall and Climate.

The Bennihalla basin falls under semi-arid region of the state and it is categorized as draught prone and flood hazard area. The normal rainfall is 613 mm. The north-east monsoon contributes nearly 24.8% and prevails from October to early December, and about 54.7% precipitation takes place during south – west monsoon period from June to September. Remaining 20.5% takes place during rest of the year. In the Bennihalla basin from December to February month is winter season, during April to May temperature reaches up to 42°C and December and January temperature will go down up to 16°C. The standard deviation of rainfall in the Bennihalla basin varies from 1.3 to 263.5mm from west to east. The average standard deviation for the Bennihalla basin is about 146 mm. South west monsoons is dominant followed by north east monsoon. The classes distinguished for annual rainfall factor as shown in.Table .

Table 2 Rainfall of Basin

Class.	Rainfall (mm)	Weight
1.	> 600	10
2.	500 – 600	8
3.	300 – 500	6
4.	< 300	2

E. Size of Basin

Shiggaon, Hubli, Dharwad and Parasgad) with total of 389 villages. The Bennihalla sub basin is a part of Malaprabha basin, The total area of Bennihalla basin 4,417 km2 covers and the total perimeter is 320.1 km. A Bennihalla river flowing parallel to the Malaprabha river and joins the Malapraba river at Ron taluk which is located north eastern part of the Bennihalla basin. The size of basin factor is classified as shown.

Table Error! No text of specified style in document.**.2 Size of Basin**

Class.	Size (Sq.km)	Weight
1.	> 4000	10
2.	2500 – 4000	8
3.	1000 – 2500	6
4.	500 – 1000	4
5.	< 500	2

F. Land Slope and Aspect Ration of the Basin

the study area. The area of the basin is plain to gently undulating terrain varies in altitude from 508 m – 740 m MSL. Bennihalla river sub basin is sloping towards north east direction. Master slope is 1.10 m per km where as Bennihalla river has 0.4 m per km slope. The Bennihalla river shows a seasonal regime varying from lean sluggish flow during summer to torrential muddy flow during the monsoon. The slope percentage in the area varies from 0 to 25%.On the basis of the slope the study area can be divided into five slope classes. The area with 0 to 1% slope falls in the „very high" category due to the nearly flat terrain and relatively high infiltration rate. The eastern portion of the study area (65% of the total area) falls under this category. The area with 1–2% slope is considered as „high" for floods due to slightly undulating topography with some run- off. Apart from a small portion in the extreme western portion of the basin, the entire central portion and the southern portion (35% of the total area) fall under this category. The area with a slope of 3–5% causes relatively high run-off and low infiltration, and hence is categorized as „moderate". The fourth (5–10%) and fifth (10–25%) category are considered as „very low" due to higher slope and run-off.

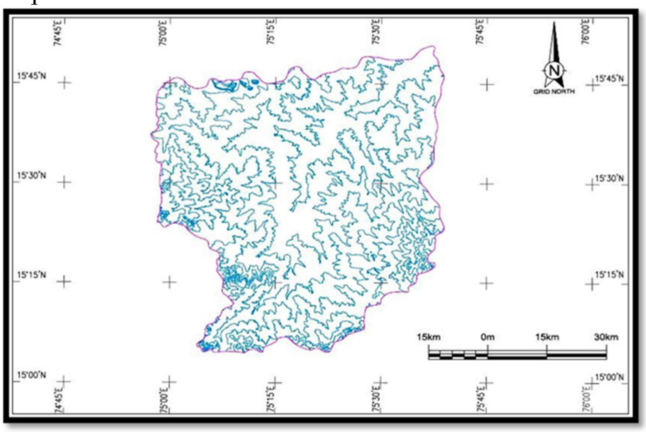

Fig.4: Land-Aspect Ratio Map of Bennihalla Basin

Table 4 Land Slope

Class.	Slope (%)	Weight
1.	10-25	10
2.	5-10	8
3.	3-5	6
4.	2-3	4
5.	1-2	2

G. Gradient of Stream Networks in the Basin

Calculating the gradient of the mainstream of basin:
River and stream gradient = (H2 - H1) * 100 D (2)
H1 = altitude of the highest point of the slope at the upper river or stream channel (in meters), H2 = the altitude of

Table 5 Gradient of Stream Network

Class.	Slope (%)	Weight
1.	> 5	10
2.	4 – 5	8
3.	3 – 4	6
4.	2 – 3	5
5.	1 – 2	4
6.	< 1	2

H. Drainage Density

In the present study, since the drainage density can indirectly indicate the overflow of an area due to its relation to surface run-off, it was considered as one of the indicators of flood occurrence. Drainage density measurements have been made for all the micro watersheds in the area and range from 1st to 5th orders. The drainage density map for the study area is shown in "Figure 17". Based on the drainage density of the micro basins, it can be grouped into four classes. Accordingly, these classes have been assigned „high", „moderate" and „low" categories, respectively. Most of the study areas (70%) has a drainage density of 1st to 2nd orders. The drainage density of the basin is calculated as follows and shown in table 4.

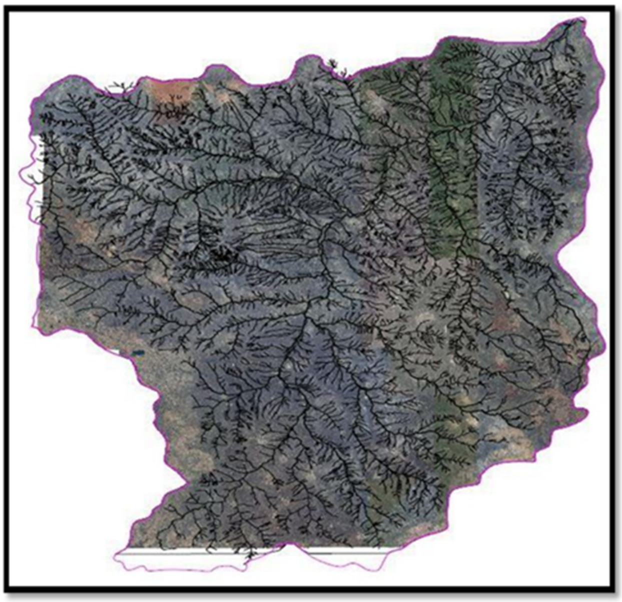

Fig.5: Drainage Density Map of Bennihalla Basin

Dd = Drainage density of basin, L = Total length of drainage channel in basin (km.), A = Total area of basin (km2)

Table 6 Drainage Density

Class.	*Dd*	Weight
1.	> 1	10
2.	1 – 3	8
3.	3 – 5	5
4.	< 5	2

I. Land Use and Land Cover

Considering the land use map complied from satellite imagery of the area the class and weight of each land use classes is shown in table VII. In the basin about 80% area is net irrigated, about 3% of the area is covered by forest and net sown area is about 87% of geographical area and the total LU/LC in the basin area is natural forest, cultivable waste, barren current, permanent pasture, net area sown, area sown.

Table 7 Land Use and Land Cover

Class.	*LU/LC*	Weight
1.	< 10%	10
2.	10 – 20%	8
3.	20 – 40%	6
4.	40 – 60%	4
5.	> 60%	2

J. Soil Type

1.80 MBGL (meters below ground level), average being 1.10 MBGL. The constant rate of infiltration in sandy to clayey residuum ranges between 0.5 to 4.5 cm/hr. Phyllitic soils are confined to hilly region, with other soil types covering relatively small areas. The soil description of the basin area is covers with shallow soil, sandy to clayey poorly.

Table 8 Soil Type

Class.	*Dd*	Weight
1.	> 60%	10
2.	40 – 60%	8
3.	20 – 40%	5
4.	< 20%	2

K. Infrastructure and Communication Lines

National highways, state highways, metal roads, black top roads, check dams, bridges, railway tracks and other infrastructure that obstruct the flow of the river and stream promote flooding has infrastructure obstructing the flow direction of stream and river within the flood hazard zone. The classes and weight of each class of this factor are shown in

Table 9 Gradient of Stream Network

Class.	Infrastructure	Weight
1.	> 10 locations	10
2.	6 – 10 locations	8
3.	3 – 5 locations	5
4.	< 3 locations	2

VI. RESULTS AND DISCUSSONS

The study area thematic maps are prepared based on assigned weight factors and classes in the above said, a map of every causative factor compiled, and the weight identified. The data sources used include satellite imagery, topographic map, basin map, soil map, LU/LC map, and climatic data. In the procedure, the occurrence of flooding in each flood hazard zone is estimated from the total sum of the weight of each causative factor considered. To obtain this total sum weight, all of causative factor maps were overlaid.

The total weight for estimating flooding in a particular flood hazard zone = the sum of every causative factor. All of these processes, the compilation of causative factor maps, the overlaying of all maps and the calculation of total weight were obtained by applying MapInfo, AutoCAD, and ERDAS.

Based on the weight of every factor and its class, the maximum total weight of each factor is the result of the multiplication of such factor weight with the weight of its dividing first class. Thus, maximum total weight of the factors rainfall, size of basin, land slope, gradient, drainage density, land use, soil type, and infrastructure are 100, 90, 80, 70, 60, 30, 20, and 10 respectively. The sum of these total maximum weights is 460.

For the total minimum weight of each factor, the same, it is the result of the multiplication of the factor weight with the weight of its lowest class. These are 20, 18, 16, 14, 12, 6, 4, and 2 respectively and the summed minimum total weight is 92. Considering this the total weight of the flood hazard zone with the highest to be flooded is 460 whilst the lowest is 92. Considering the statistic standard deviation values of the total weight data obtained for the research area, the weight of each class was given as Table 10:

Table 10: Weight of Each Class Range

Sl.No.	Class	Weight
1.	High	306 – 460
2.	Moderate	155 – 305
3.	Low	92 – 154

However, after fieldwork for checking the validity and reliability of the map these statistics were adjusted. When compiling the final flood hazard map the following statistics were considered for identifying the degree of flooding in the identifying flood hazard zone as shown in Fig.6.

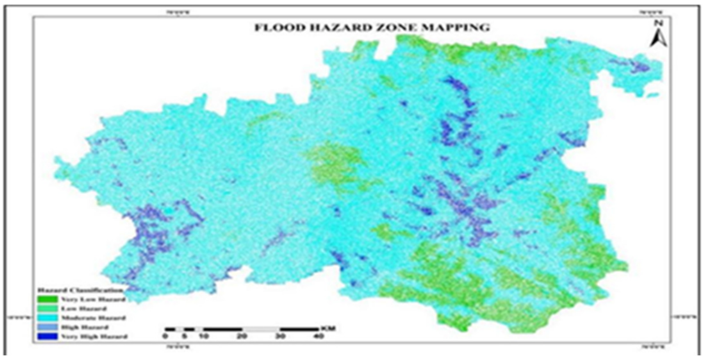

Fig. 6: Flood Hazard Zone

VII. CONCLUSION

This study was carried out with the aim of creating a flood hazard zonation map along the Bennihalla river basin, where it passes through the Gadag and Dharwad districts of Karnataka. Geoinformatics technology method was robust, using coordinate and elevation data of the study area and remotely sensed satellite IRS-1D, LISS – III imagery and SOI toposheets, analysis was carried out within MapInfo, ERDAS and AutoCAD. Digital elevation model was generated, reclassified and integrated with imagery of the area to show areas of different flood hazard zonation. Natural barriers exist between the river and the surrounding area, however urban explosion within the past decade and relocation after the Bennihalla basin in 2005 have led to settlement within flood prone areas like Navalgund, Byahatti, Hebsur, Amargol, Arhatti, Kongawad and Nargund have residential buildings, farms and industrial compounds within flood hazard zones. The primary purpose of producing these kinds of maps is for public dissemination of flood maps which will serve to increase public awareness. The study was to identify flood hazard zones and find out flood vulnerability to settlement, transportation network and risk to human life. Overall the results of this study demonstrated that the Geoinformatics technology is a powerful tool for assessment of flood hazard zone, based on which suitable locations for floods withdrawals could be identified. Consideration of an adequate number of thematic layers and proper assignment of weights are keys to the success of Geoinformatics techniques in identifying flood zonation maps. Based on the results of this study, concerned decision makers can formulate an efficient flood zonation plan for the study area so as to ensure as this methodology adopted in this study is based on logical conditions and reasoning, it can also be applied in other regions of India or abroad.

VIII. FUTURE SCOPE

- Advanced Flood Prediction Models: Using GIS and remote sensing technologies to improve flood hazard zonation mapping.
- Infrastructure Development: Constructing embankments, flood walls, and reservoirs to mitigate flood damage.
- Sustainable Land Use Planning: Implementing

floodplain zoning to prevent construction in high-risk areas.

- Community-Based Disaster Management: Enhancing local preparedness and response strategies.
- Eco-Friendly Solutions: Afforestation, reforestation, and soil conservation to reduce flood impact.

REFERENCES

[i]. Plan report, (2011), "Report of working group on flood management and region specific issues for XII Plan", government of India, planning commission, New Delhi, pp. 110.

[ii]. Amit Kumar, (2005), Application of GIS in flood hazard management: An alternative plan for the floods of north Indian plain, map India, New Delhi.

[iii]. Basavaraj, Hutti and Nijagunappa, R., (2012), "Geoinformatics based decision support system tools for water resources management in north Karnataka, India", International bimonthly, Indian journal of natural sciences, volume 2, issue 10, pp.779-791.

[iv]. Basavaraj, Hutti and Nijagunappa, R., (2011), "Geoinformatics technology application in north Karnataka for water resources management", Universal journal of environmental research and technology, Euresian publications, volume 1, issue 3, pp. 222-232.

[v]. Basavaraj, Hutti and Nijagunappa, R., (2011), "Applications of geoinformatics in water resources management of semi-arid region, north Karnataka, India", International journal of geomatics and geosciences, Integrated publications, volume 2, no 2, pp. 371-382.

[vi]. Basavaraj, Hutti and Nijagunappa, R., (2011), "Development of groundwater potential zone in north Karnataka semi-arid region using geoinformatics technology", Universal journal of environmental research and technology, Euresian publications, volume 1, issue 4, pp. 500-514.

[vii]. Bhadra, A., Choudhury, S. and Kar, D., (2011), "Flood hazard mapping in Dikrong basin of Arunachal Pradesh (India)", World academy of science, engineering and technology 60, India.

[viii]. Goel, N. K., Than, H. H. and Arya, D. S., (2005), "Flood hazard mapping in the lower part of Chindwin river basin, Myanmar", International conference on innovation advances and implementation of flood forecasting technology, Tromsø, Norway.

[ix]. Pramojanee, P., Tanavud, C., Yongchalermchai, Navanugraha, C., (2013), "An application of GIS for mapping of flood hazard and risk area in Nakorn Sri Thammarat province, south of Thailand", pp 9.

[x]. [10] Venkata Bapalu, G., Rajiv Sinha, (2005), "GIS in flood hazard mapping: a case study of Kosi river basin, India", Conference proceedings of map Middle East, UAE.

[xi]. For flood hazard zonation mapping, IRC:SP:113-2018 provides guidelines on flood disaster mitigation for highway engineers, including flood hazard zonation and risk assessment.

[xii]. The National Remote Sensing Centre (NRSC) has developed flood hazard zonation maps using satellite data for disaster risk reduction