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FLOOD VULNERABLE MAPPING IN LOWER TAPI RIVER BASIN, GUJARAT, INDIA USING REMOTE SENSING AND GIS

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Abstract *- Lower part of the Tapi River Basin is prone to flood hazard due to its location between coast and Ukai dam, metrological conditions, low lying topography, inadequate natural and manmade drainage and sudden occasional heavy release of flood water from Kakrapar weir. For this Multi-criteria Evaluation (MCE) methods have been adopted for identifying flood vulnerable areas using remote sensing and GIS technology. In this study Rank Sum method has been used to calculate the weights of factors contributing flood hazard such as hydrology, slope, soil type, drainage density, landform and land use/ land cover. This study will be helpful in proper planning, management and development of the flood vulnerable areas and for taking adequate flood control measures in time.*

Keywords *- GIS, Multi-criteria evaluation, Ranking sum method, Remote sensing, Vulnerable Mapping*

I. INTRODUCTION

Flood has always been a recurrent phenomenon in India with more than 12 percent of the total land area in India is prone to recurrent flood. India receives 75% of rains during the monsoon season (June – September). As a result almost all the rivers are flooded during this time resulting in to the intense and recurrent floods. Flood vulnerable mapping is a vital component for appropriate land use planning in flood prone areas. Lower Tapi area in the downstream of Ukai dam in Gujarat has been affected by a number of times by flood. Therefore, this area has been selected for the present flood assessment and visualization study using GIS. General Flood scenario of Surat is usually affected by two types of flood: (1) Tapi River Flood (2) Khadi Flood. Tapi river flood occur due to heavy inflow of rainfall in Tapi basin while Khadi flood occur due to heavy rainfall in city and tidal effect of sea.

II. STUDY AREA

The Tapi basin extends over an area of 65145 sq. km. which is nearly 2% of the total geographical area of the country. The basin lies in the States of Maharashtra, Madhya Pradesh and Gujarat. Tapi River originate in the Satpura Ranges near Multai Town (M.P) at elevation 752 meter (above M.S.L.) covering 724 km length. Major tributaries of Tapi river are Purna, Wagner, Girna, Bori , Anar, Panjara, Baray, Arunavati and Gomai. The study area lies between Longitude 72°33' & 78°17'E and Latitude 20°09' & 21°50'N. River Tapi flows through the city and meets the Arabian sea at about 16 km from Surat. Surat is 90 km in downstream of Ukai Dam over river Tapi.

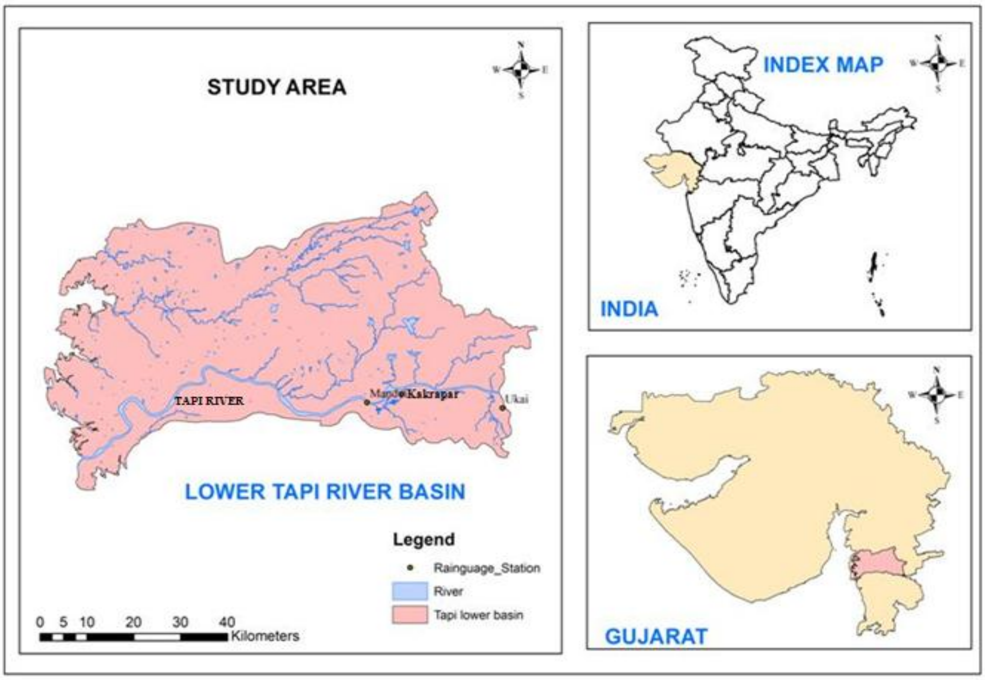

Figure 1. Location Map of the Study area

III. DATA USED

In the present study a combination of different data sets such as Metrological data, Satellite imagery, Administrative data and Thematic map obtained from concerned government agencies **(Table 1)** have been used to compute flood vulnerability areas based on multi criteria evaluation through ranking sum method.

Table 1. Collateral Data

Type of data	Name of Organization	Details of Data
Rainfall Data	State water data centre, Gandhinagar.	Tapi lower basin, daily rainfall data (Ukai, Mandvi & Kakrapar stations from year 1990 to 2013)
Administrative map	BISAG, Ghandhinagar	Village boundary map

IV. METHODOLOGY

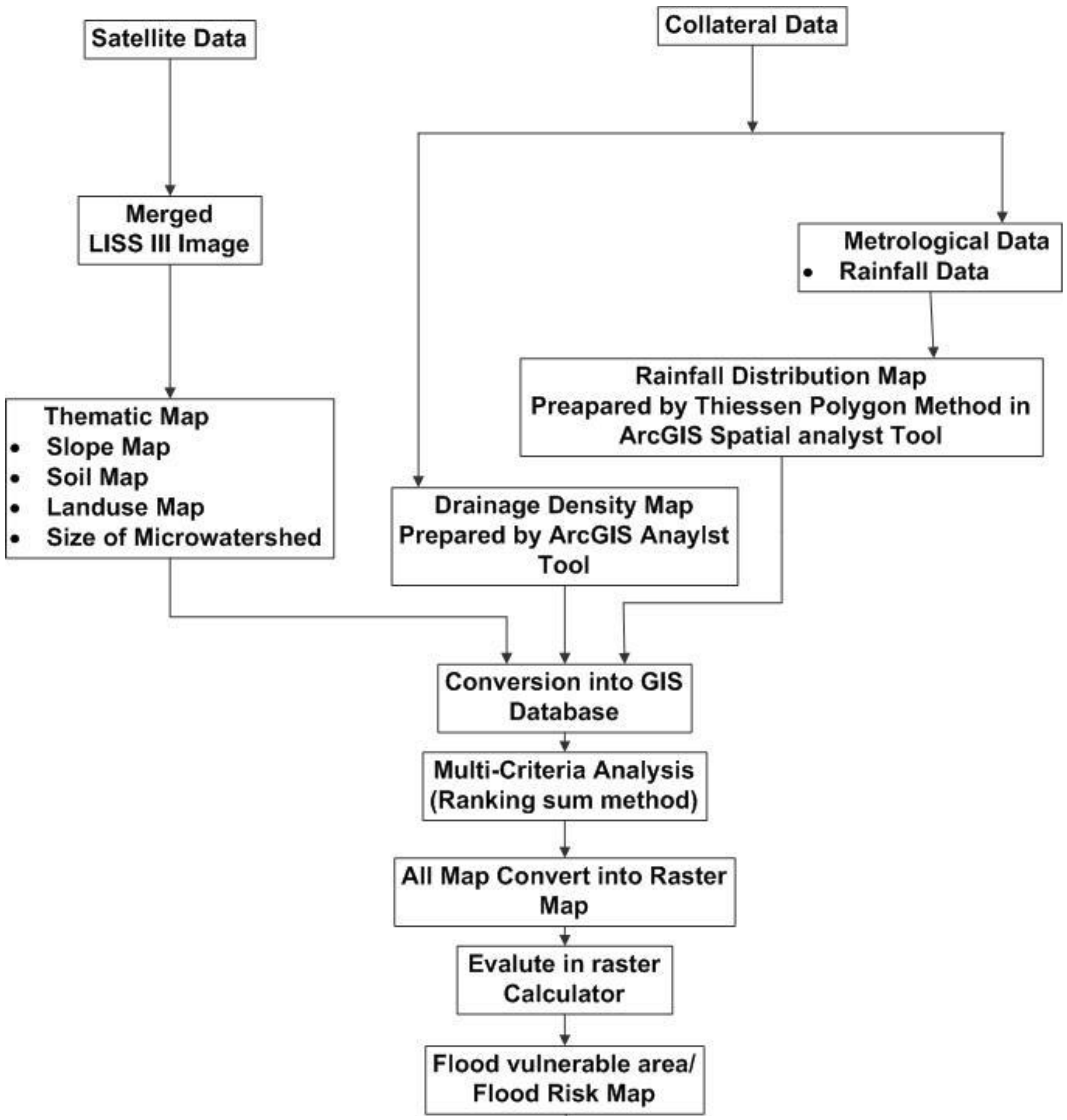

Figure 2. Flow chart of Methodology

V. FLOOD VULNERABILITY PARAMETERS AND DEELOPMENT OF MAPS

The major factors affecting the flood and flood vulnerability for any basin and for Tapi river basin are identified as follows:

A. Average annual rainfall

Rainfall distribution map has been prepared using Thiessen Polygon method in Spatial Analyst Tool in ArcGIS software by incorporating the rainfall data of various stations in Lower Tapi basin **(Fig 2).** These parameter classified into three categories **(Table 2).**

Table 2. Criteria and Weights of Rainfall Distribution map

Criteria	Weight Variables	Sub class of criteria	Rating level
Rainfall	3	High	1
		Moderate	2
		Low	3

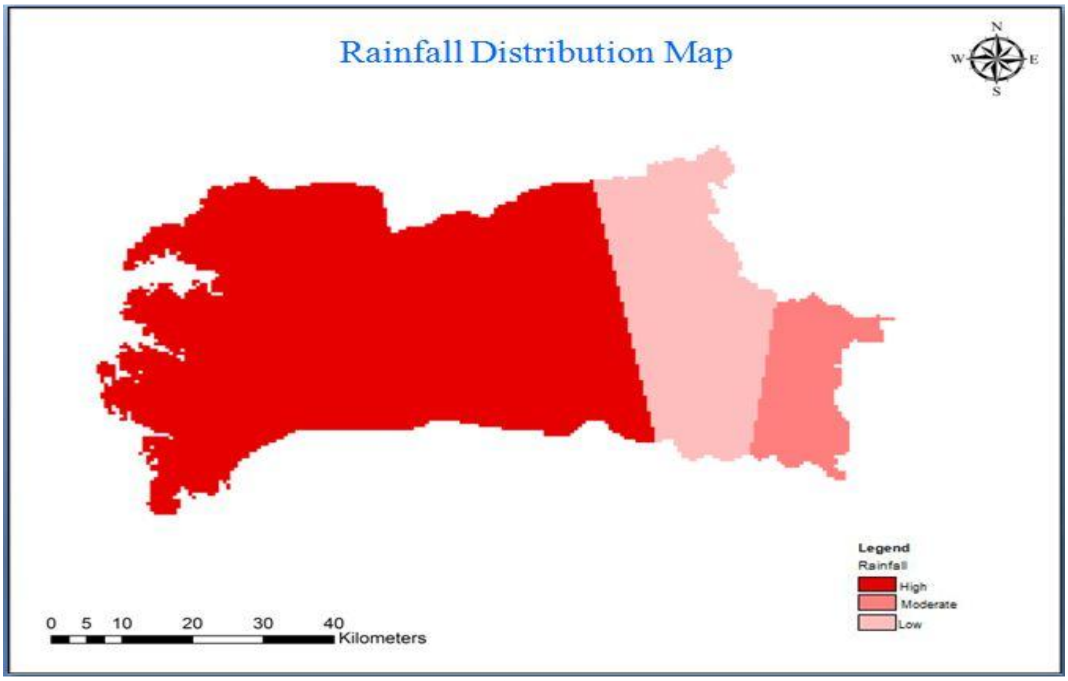

Figure 3. Rainfall Distribution Map

B. Drainage density

High drainage density values are favourable for runoff, and hence indicate low flood chance. In basin with smaller drainage density values are less favourable for runoff, and hence indicate high flood chance. The drainage density of the watershed is calculated as: Dd = L/A; Where, Dd = drainage density of micro watershed, L = Total length of drainage channel in micro watershed (km), A = area of micro watershed (km^2) (Ajin.R.S. et al,2013). Using the micro watershed map obtained from BISAG, Gandhinagar, the length of the river/ Tributaries have been measured by "Measure Tool" of the ARC GIS software and subsequently the drainage density of each micro watershed is calculated in MS Excel **(Fig 3).** These parameter classified into five categories **(Table3).**

Table 3. Criteria and Weights of Drainage density map

Criteria	Weight Variables	Sub class of criteria	Rating level
Drainage Density	5	<0.5	1
		0.5-2.0	2
		2.0-3.0	3
		3.0-5.0	4
		>5.0	5

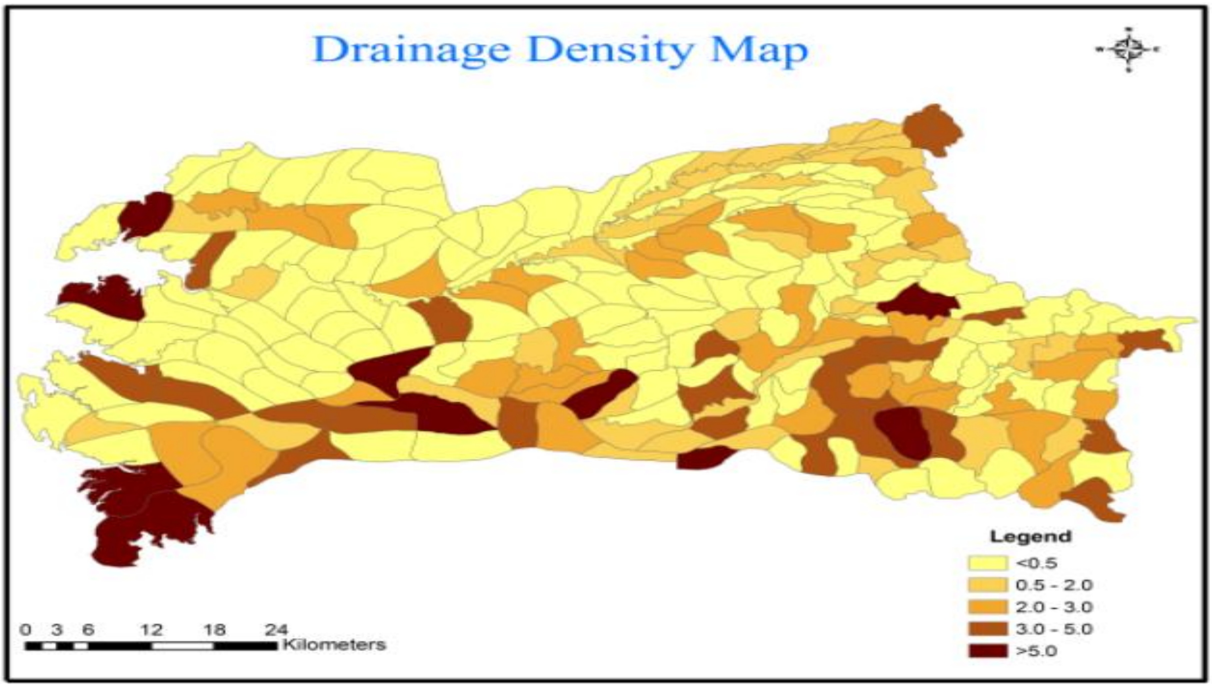

Figure 4. Drainage Density Map

C. Slope

The slope map is available as a data from BISAG, Gandhinagar and have been classified in seven classes from 0 to 50%.**(Table4) (Fig 4)**

Table 4. Criteria and Weights of Slope Map

Criteria	Weight Variables	Sub class of criteria	Rating level
Slope	7	0 - 1%	1
		1 - 3%	2
		3 - 5%	3
		5 - 10%	4
		10 - 15%	5
		15 - 35%	6
		35 - 50%	7

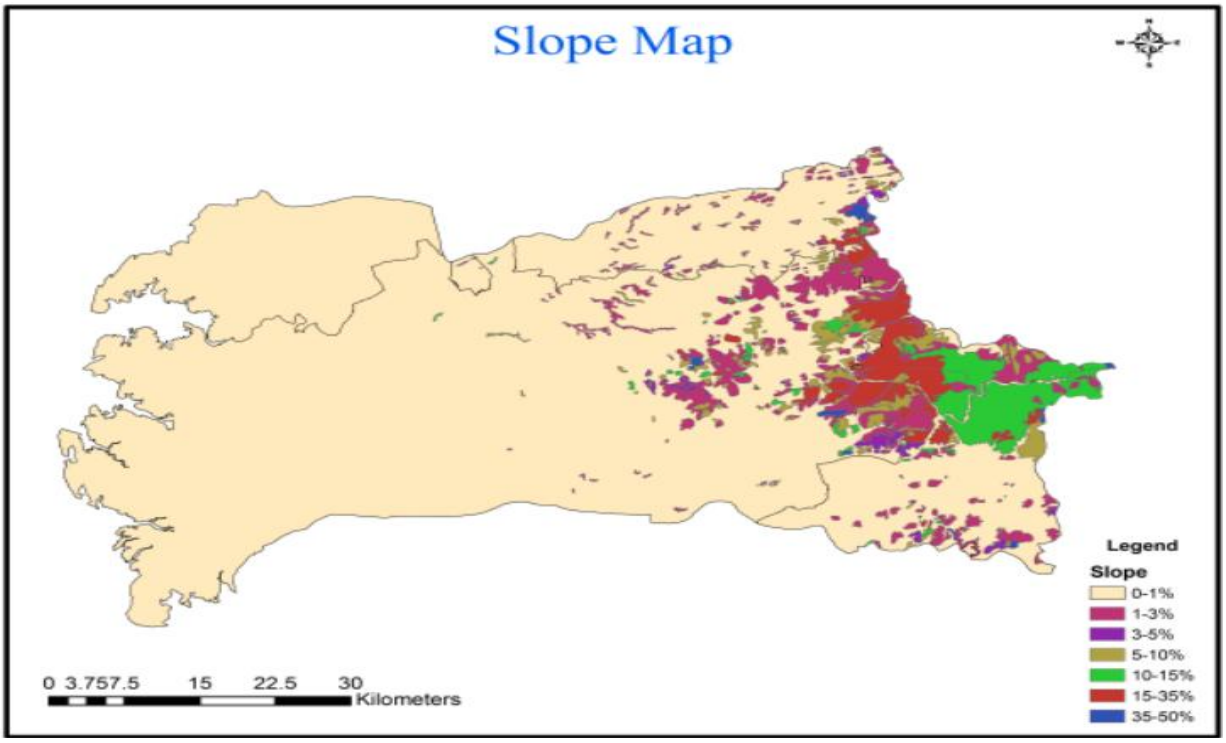

Figure 5. Slope Map

D. Type of Soil

Soil map was classified on the basis of infiltration capacity. On the basis of infiltration capacity, the soil types found in the basin include: Clayey, Fine sand sand and Very fine sand. Type of soil map is available from BiSAG, Gandhinagar**(Fig 5).** These parameter classified into three categories **(Table5).**

Table 5. Criteria and Weights of Type of Soil

Criteria	Weight Variables	Sub class of criteria	Rating level
Type of soil	3	Clayey	1
		Fine Sand	2
		Very fine Sand	3

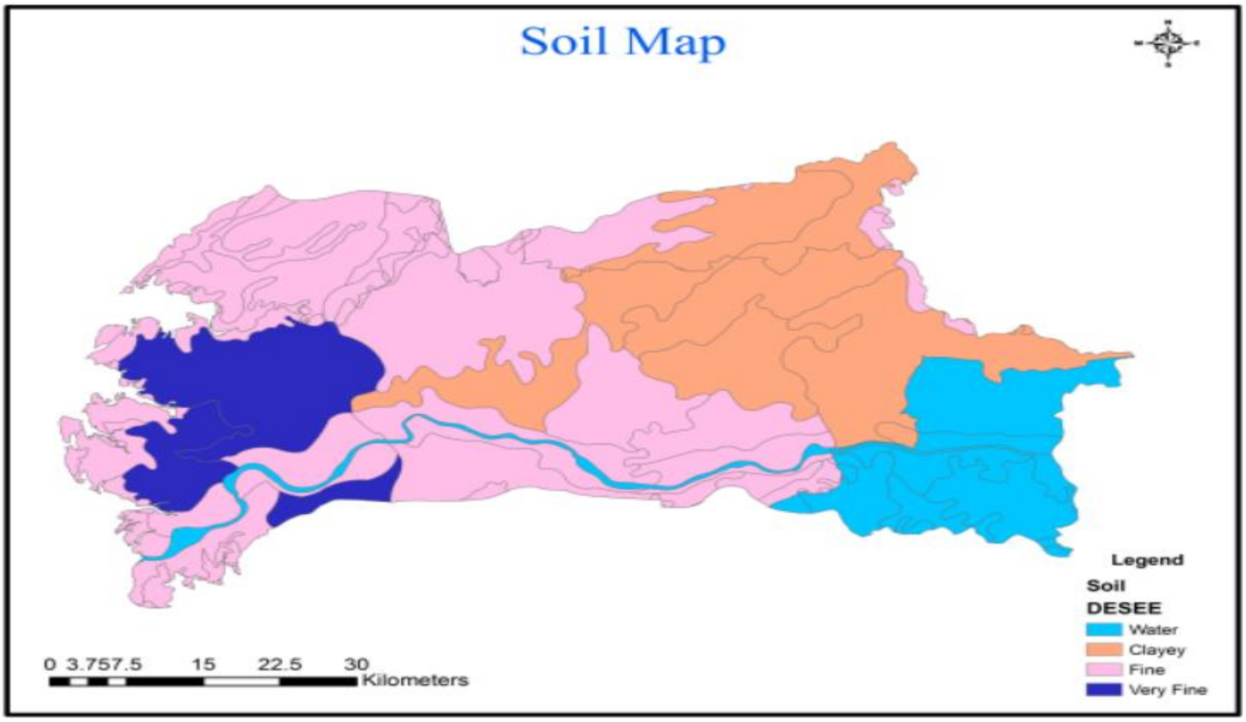

Figure 6. Soil Map

E. LAND USE

Digitizing is the process of making features on the image editable and making them features to which additional spatial and non-spatial attributes can be assigned. When digitizing we can digitize points, lines, or polygons. The digitizing process is started by creating new layers in ArcCatalog, and then adding features to them in ArcMap. The land use data derived from the satellite imageries. These maps have been developed using Arc GIS software. Vegetation and forests increase the infiltration and storage capacities of the soils. **(Fig 7).** These parameter classified into eight categories **(Table 6).**

Table 6. Criteria and Weights of Landuse Map

Criteria	Weight Variables	Sub class of criteria	Rating level
Landuse	8	Water bodies	1
		Wetlands	2
		Buit-up	3
		Wastelands	4
		Agriculuture	5
		Grass Land	6
		Forest	7
		Other	8

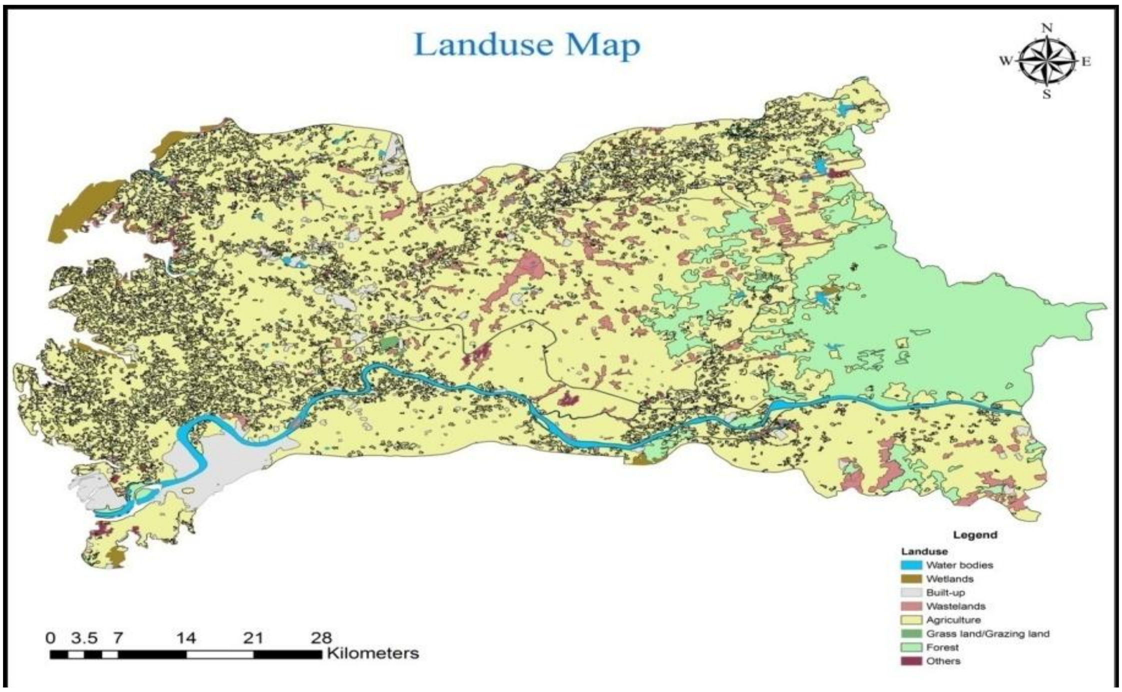

Figure 7. Landuse Map

F. Size of Microwatershed

Micro watersheds with larger drainage areas require runoff of longer duration for a significant increase in water level to become a flood. Therefore the micro watersheds with smaller area (size) are greatly affected by floods. (Ajin.R.S. et al.,2013). These were digitized and size of each watershed was computed, and the maps were prepared by classifying Micro watershed on the basis of size using ArcGIS**(Fig 8).** These parameter classified into five categories **(Table7).**

Table 7. Criteria and Weights of Size Micro Watershed

Criteria	Weight Variables	Sub class of criteria	Rating level
Size of micro-watershed	5	3-10 sq.km	1
		10-15 sq.km	2
		15-20 sq.km	3
		20-25 sq.km	4
		25-35 sq.km	5

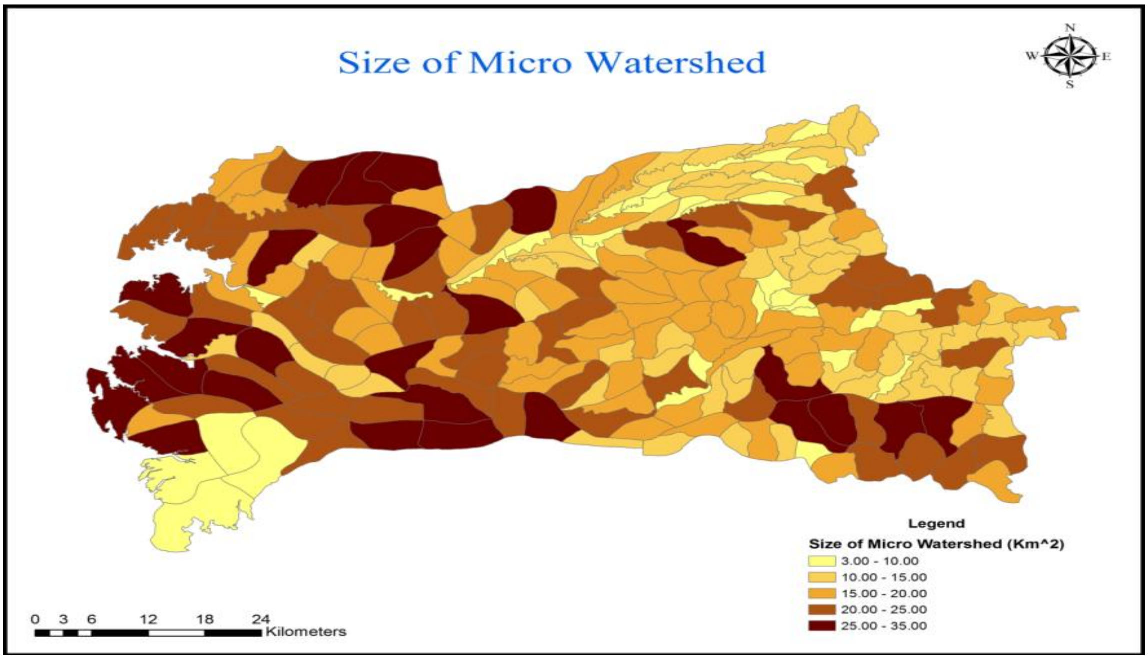

Figure 8. Size of Microwatershed

VI. RANKING SUM METHOD OF MULTICTITERIA EVALUTION

Multi-criteria evaluation (MCE) methods have been applied in several studies. Since 80 per cent of data used by decision makers is related geographically (Malczewski, 1999), Geographical Information System (GIS) may provide more and better information about decision making situations. GIS allows the decision maker to identify a list meeting a predefined set of criteria with the overlay process (Heywood et al., 1993). In order to create flood Vulnerable maps ranking method is used and each factor is weighted according to the estimated significance for causing flooding.

VII. CONVERSION OF THEMATIC MAPS

All thematic maps have been converted into raster map by using Spatial Analyst Tools in ArcGIS.

VIII. RESULTS AND DISCUSSIONS

A. Flood vulnerable areas

To evaluate the effect of the above mentioned factors, the multi-criteria Evaluation method has been used in this study. The ranking sum method (Lenka ganova et al.,2010) is found suitable to evaluate the food vulnerability of the areas in the study area i.e. Lower Tapi River basin.

Table 8. Order preference of criteria

Order of preference	Criteria
1	Rainfall distribution
2	Drainage density
3	Slope
4	Soil Type
5	Land Use
6	Size of microwatershed

The criterion weights and normalized weights are decided for ranking sum method, using the equation (1) and (2) respectively, as given below: (Lenka Ganova et al.,2014)

$w = n - r_j + 1$ (1)

Where: n – Total number of criteria under consideration
r_j - is the rank position of the criterion j

The normalized weight of each criteria is denoted as Wj. And it is evaluated as:

$Wj = n - r_j + 1 / \sum(n - r_j + 1)$ (2)

Table 9. Normalized weight assessment by Ranking-sum Method

Sr.no	Criteria	Rank(order of preference)	Weight (w)	Normalized weight(Wj)	Weight in %
1	Rainfall	1	6	0.2857	28.57

2	Drainage density	2	5	0.2380	23.80
3	Slope map	3	4	0.190	19.00
4	Soil map	4	3	0.1428	14.28
5	Landuse map	5	2	0.0952	9.52
6	Size of Micro water shed	6	1	0.0476	4.76
SUM			21	1.00	100

The normalized weight of each criteria have been also incorporated in raster calculator. The flood vulnerability in classified 5 classes, namely 1) very low 2) Low 3) Moderate 4) High and 5) Very high

The food vulnerable areas of Lower Tapi basin obtained using Raster calculator. **(Fig 9).**

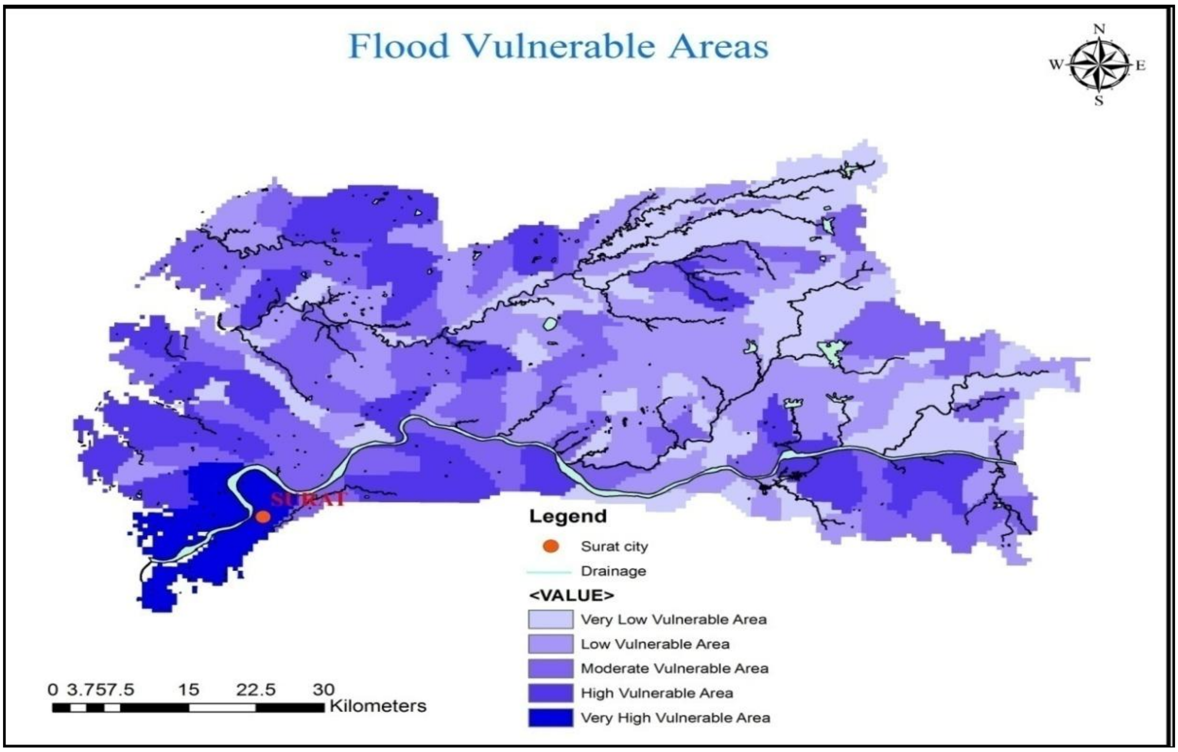

Figure 9. Flood Vulnerable areas

B. Shaded relief map

Shaded relief map showing contours and slopes of area around surat city in lower tapi basin. Longitude, latitude and elevation of area around surat city are collected from google earth. This longitude and latitude are converted into decimal to generate contours with the help of surfur software to finding out lowlying areas which are vulnerable to flooding. This is corroborated with the multi criteria flood vulnerability analysis.

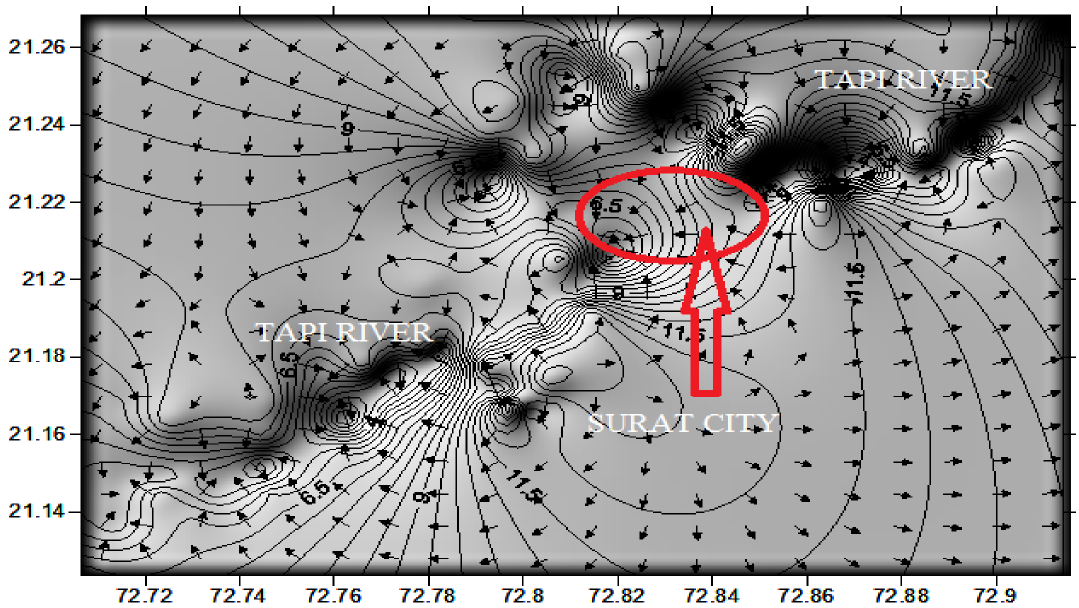

Figure 10. Shaded Relief Map showing contours and vector of slopes of area around Surat City In Lower Tapi Basin

IX. CONCLUSIONS

Areas of submergence and vulnerability of flooding can be easily visualized and analyzed with the help GIS study. In view of frequent floods occurring in Lower Tapi River basin, flood vulnerability maps have been prepared based on multi-criteria analysis. These maps will be helpful in identifying the areas which are vulnerable to flooding. With the help of these maps and GIS study flood vulnerable areas can be identified and visualized easily for planning, development and management of the Lower Tapi River Basin and for adopting adequate remedial measures to lessen impact of flooding in time.

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