GIS BASED FLOOD SUSCEPTIBILITY MAPPING USING FREQUENCY RATIO MODEL IN DAKSHINA KANNADA, KARNATAKA.

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Abstract

This present study of flood susceptibility mapping was carried out in GIS. I have taken into consideration Dakshina Kannada District of Karnataka. The study area is mainly Dakshina Kannada (South Canara) which is the southern coastal district of Karnataka State. The area receives rainfall mainly during south west monsoon season. The monsoon has mainly affected agricultural lands, buildup lands and other natural and man-made structures. I have mainly taken into analyze the flood affected details in this district over the period of ten years (2009-2019). Yearly once this type of natural disaster or heavy rainfall (flood) has affected this area. As Floods continue to pose greater threat to floura, fauna and properties a clear understanding and assessment is required to evaluate the flood prone areas. The Remote sensing and GIS were used to estimate the risk of flood susceptibility in this district. Frequency ratio model was used to derive the flood susceptibility map. ASTER DEM was used to generate the slope length. The Ten conditioning factors such as slope, aspect, elevation, Normalized difference vegetation Index (NDVI), Landuse/Landcover (LULC), distance from road, distance from river rainfall, soil types and Stream Power Index and Topographic Wetness Index and also flood inventory map were used.

Key words: flood, heavy rainfall, South West monsoon, damages, frequency ratio model, flood zone mapping, Dakshina Kannada, GIS.

Introduction:

Floods in the India have detrimental effect on the population, economy and governance. It is therefore essential to study these effects to understand the dynamics associated with them for proper planning recommendation. Rainfall extremes cause flood situations. Increased surface runoff and precipitation higher than the capacity of outgoing discharge causes the water level to rise leading to the submerge of areas which is not conducive to sustainable development. Prediction of floods is essential tool for all the decision makers with respect to the lives of people as well as resources. Flood models helps in understanding the floods and predict them beforehand so that proper checks and prevention measures are taken in advance to limit the loss of property as well as people. Reaction to natural disasters play a major role in managing them particularly in the case of floods. A good flood model should have a proper early warning system to facilitate prevention.

Flood hazard assessment and mapping is used to identify areas at risk of flooding, and consequently to improve flood risk management and disaster preparedness. Flood hazard assessments and maps typically look at the expected extent and depth of flooding in a given location, based on various scenarios (e.g. 100-year events, 50- year events, etc.). Measures to improve preparedness can include changes in land-use planning, implementation of specific flood-proofing measures, creation of emergency response plans, etc. Flood hazard assessments can be further expanded to assess specific risks, which take into consideration the socioeconomic characteristics (e.g. industrial activities, population density, land use) of the exposed areas.

Flood Hazard Mapping is a vital component for appropriate land use planning in flood-prone areas. It creates easily-read, rapidly-accessible charts and maps which facilitate the identification of areas at risk of flooding and also helps prioritise mitigation and response efforts (Bapulu & Sinha, 2005). Flood hazard maps are designed to increase awareness of the likelihood of flooding among the public, local authorities and other organisations. They also encourage people living and working in flood-prone areas to find out more about the local flood risk and to take appropriate action (Environment Agency, 2010). Flood hazard maps can be used by developers to determine if an area is at risk of flooding, and by insurers to determine flood insurance premiums in areas where flood insurance exists. Geographic Information Systems (GIS) are frequently used to produce flood hazard maps. They provide an effective way of assembling information from different maps and digital elevation models (Sanyal & Lu, 2003). Using GIS, the extent of flooding can be calculated by comparing local elevations with extreme water levels. Key components of flood hazard assessment and mapping include data for Digital Elevation Models (thus the topography characteristics of the area) and hydrological models to simulate various flood events and their impacts. The data can be further supplemented by land cover data, soil data, and other datasets. For creation of maps and visualization tools, additional software (e.g. ArcGIS) may be required. Topography data can be collected (e.g. using LIDAR technology), or already existing topography datasets can be utilized, where available. The depth and extent of flooding is mapped using GIS software by measuring local land elevations in relation to extreme water levels. Flood modelling and scenario design further requires hydrological data and historical data on flooding events and rainfall patterns, as well as climate data. These variables are used to assess the flood depth and extent under different scenarios.

High-risk flood areas can thus be identified, allowing planners to improve preparedness and design interventions. Flood hazard assessments and related maps can also be adopted by land use and development planners as part of an integrative approach to improve flood preparedness that can improve future land developments and raise community awareness.

Remote sensing and Geographic Information System techniques has made tremendous contribution in flood monitoring and damage/risk assessment that helps the disaster management authorities to mitigate and plan accordingly. They have been universally used in various environmental assessment studies as they are cost effective and reduction of errors. Advancement in RS and GIS techniques has led to improvement in disaster management studies such as flood susceptibility mapping. This mapping can be easily processed with the help of GIS and RS. Arc MAP is a comprehensive software package for the processing, display, analysis and modelling of flood susceptibility mapping.

Need for the study:

Flood maps are used for various purposes by governments, like emergency planning (e.g. evacuation) and spatial planning. In the case of spatial planning a distinction can be made between places where flood maps serve an advisory purpose, and places where there is a binding legislation to use flood hazard or risk information. Flood zones (either extent or danger zones) is an informative tool for decision makers. The flood zone maps can be used for land use planning, flood control and drainage planning and flood control and warning purposes. They are mainly used here because year by year this type of disaster (heavy rainfall) affected in this area, so flood zone mapping is very important of this district. This district is mainly for coastal nearer district so flood affection is yearly high. Some emergency planning purposes is very important and essential in this district.

Objectives of the study:

The scope of the study is to estimate the flood risk and flood susceptibility mapping for the Dakshina Kannada district, Karnataka. The objectives are as follows:

- To create flood inventory map for the study area.
- To create a flood susceptibility map using frequency ratio model.

Study Area:

Dakshina Kannada is a district in the state of Karnataka in India with Mangalore as its headquarters. It is sheltered by the Western Ghats on the east and surrounded by the Arabian Sea on the west, Dakshina Kannada receives abundant rainfall during the monsoon. According to the 2011 census of India, Dakshina Kannada district had a population of 2,083,625. Dakshina Kannada features a Tropical Monsoon climate . The average annual rainfall in Dakshina Kannada is 4,030 millimetres (159 in). The rainfall varies from 3,774.1 millimetres (149 in) at the Mangalore coast, 4,530 millimetres (178 in) at Moodabidri and 4,329 millimetres (170 in) at Puttur near the Western Ghats. The average humidity is 75% and peaks in July at 89%.

Dakshina Kannada (South Canara) is the southern coastal district of Karnataka State with an area of 4866 Sq.K.M. The district is bound by sea in the west and Western Ghats in the East, Udupi district in the North and Kerala State in the South. Mangaluru is the district head quarters of Dakshina Kannada and it has become an education hub with a number of reputed institutions offering variety of courses attracting students from all over the country and abroad. It is also famous for its beaches, temples and religious places of worship.

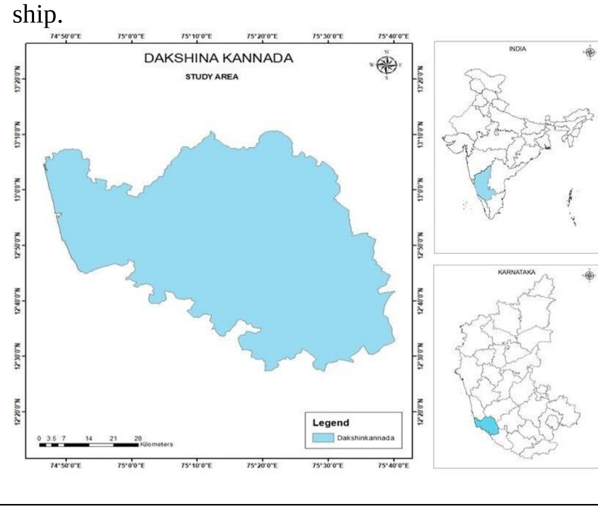

Fig 1. Study Area

Materials and Methods:

Table 1. Data for flood susceptibility mapping

Sl. No	Data	Source	Resolution/ Scale
1	Alti-tude	ASTER DEM from NASA Earthdata	30 m
2	Slop e	ASTER DEM from NASA Earthdata	30 m
3	As-pect	ASTER DEM from NASA Earthdata	30 m
4	LUL C	Sentinel – 1 from Alaska Satellite Facility	10 m
5	NDV I	Sentinel – 1 from Alaska Satellite Facility	10 m
6	Rain fall	Karnataka Statistical data from Government Website	From 2009 till 2019
7	Road Riv-er Fault Soil Type Li-tholo gy	Bhukosh	1:50,000

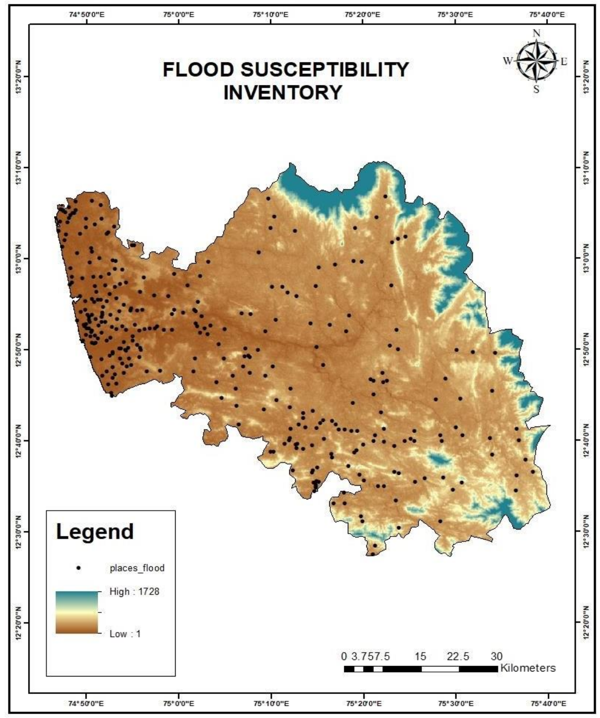

Fig 2. Flood Susceptibility Inventory Map

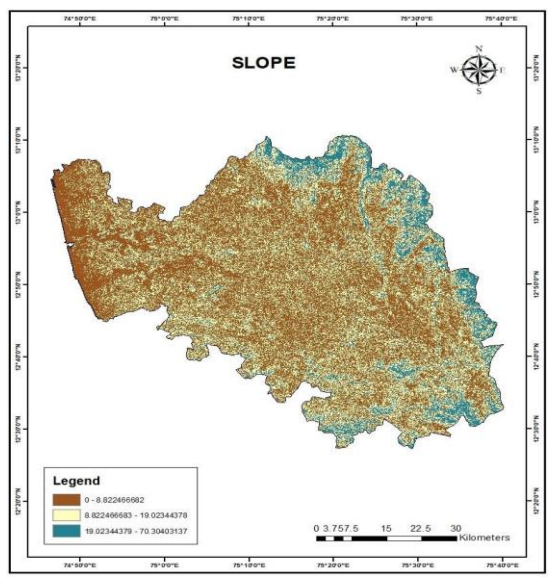

Fig 3. Slope

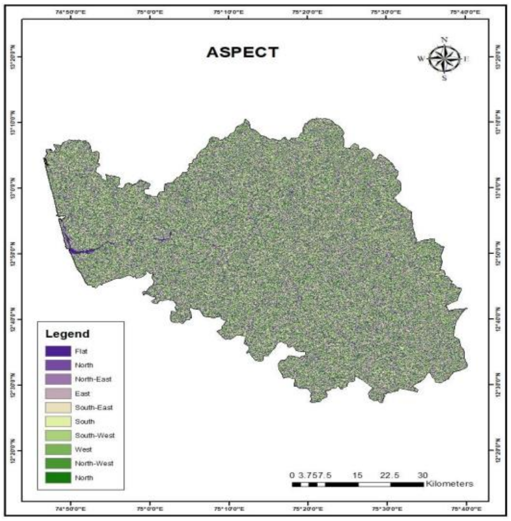

Fig 4. Aspect

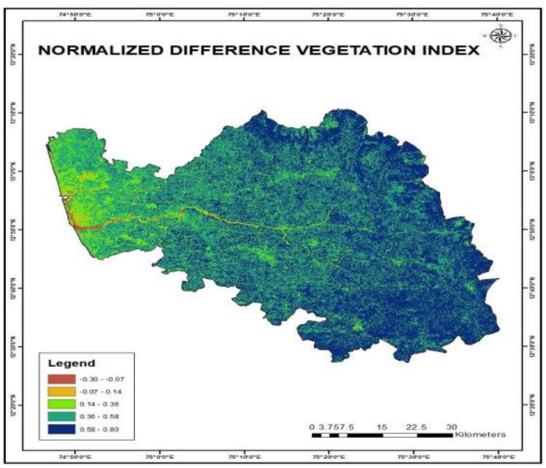

Fig 5. Normalized difference vegetation index

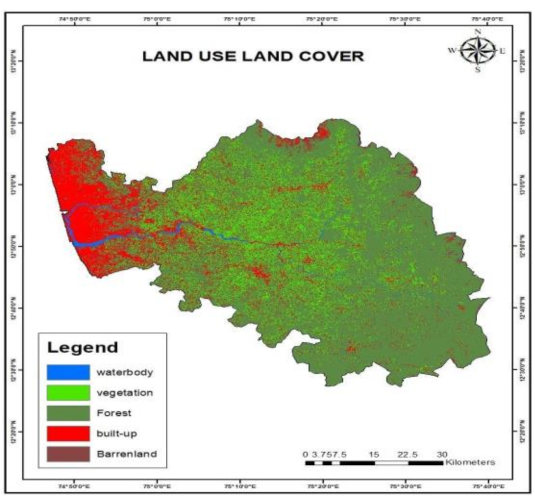

Fig 6. Land Use and Land Cover

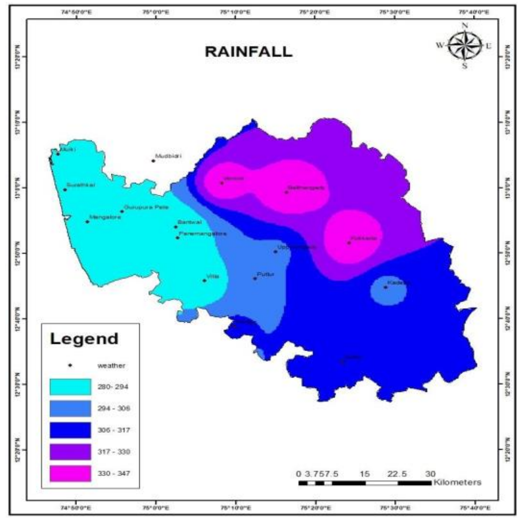

Fig 7. Rainfall

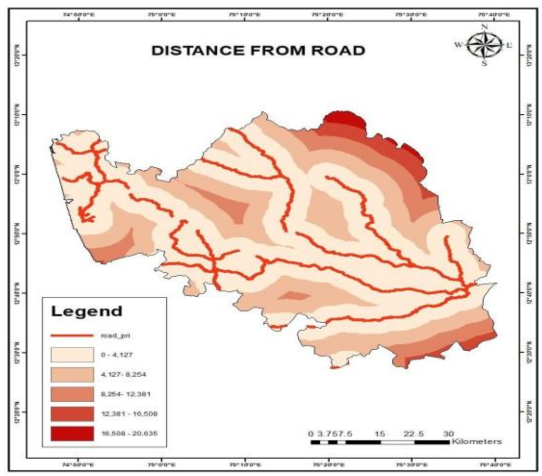

Fig 8. Distance from Road

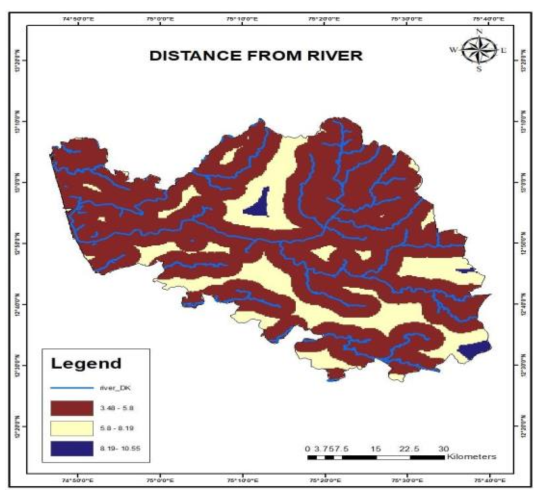

Fig 9. Distance from river

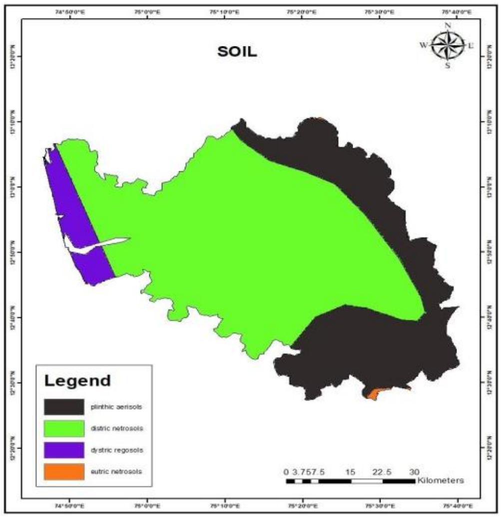

Fig 10. Soil

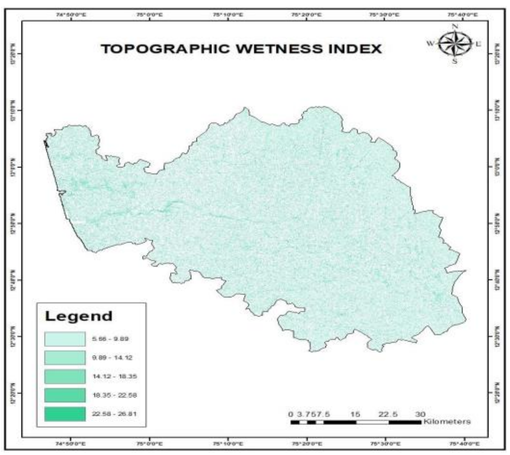

Fig 11. Topographic wetness index

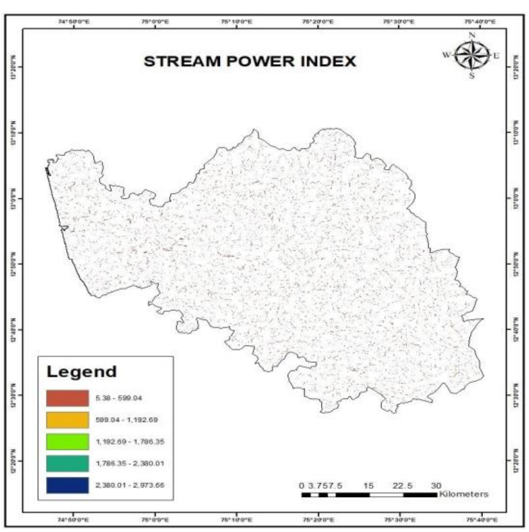

Fig 12. Stream Power Index

The flood conditioning factors used for the study are altitude, slope (Fig 3), aspect (Fig 4), geology, distance from river (Fig 9), distance from road (Fig 8), soil type (Fig 10), land use/cover (Fig 6), rainfall (Fig 7), Normalized Difference Vegetation Index (Fig 5), Stream Power Index (Fig 12), Topographic Wetness Index (Fig 11), Sediment Transport Index and curvature.

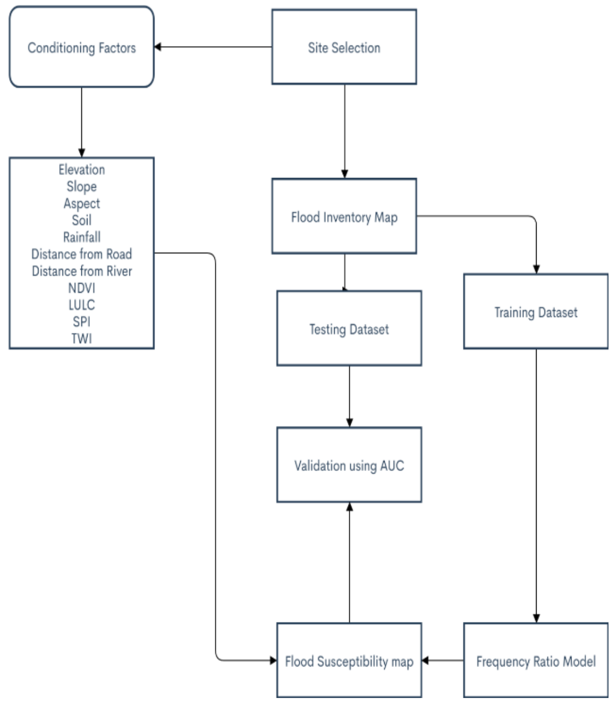

Fig 13. Methodology for Flood Susceptibility Map

Results and Discussions:

I. Estimation of Flood Susceptibility conditional factors

The flood inventory map was prepared by interpreting and compiled from news reports, literatures, Bhukosh website. Some random points were also used in this study. Because using the polygon format of the inventory was problematic for the algorithm and the results. In most of the similar susceptibility modelling, the inventory data was used as a point format. A total of 327 flood events were identified in the Dakshina Kannada district. In this study, models such as frequency ratio is used for flood susceptibility mapping.

The flood conditioning factors used for the study are altitude, slope, aspect, distance from river, distance from road, soil type, land use/cover, rainfall, Normalized Difference

Vegetation Index, Stream Power Index, Topographic Wetness Index.

The flood conditioning factors of altitude, aspect and slope were obtained from digital elevation model (DEM). DEM for the study area was generated from the ASTER.

The SPI and TWI conditioning factors were obtained by (fig 14)

$$SPI = A_s \tan\beta$$

$$TWI = \ln\left(\frac{A_s}{\tan\beta}\right)$$

Fig 14. SPI and TWI formulae

where As is the specific catchment area, and β (radian) is the slope gradient (in ◦).

STI (fig 15) and NDVI were obtained by

$$STI = \left(\frac{A_s}{22.13}\right)^{0.6} (\sin\beta/0.0896)^{1.3}$$

Fig 15. STI fomulae

where β is the slope at each pixel, and As is the upstream area NDVI = NIR - RED /NIR + RED.

where NIR is the near-infrared band and RED is the red band.

The factors such as soil types was constructed with 4 groups namely Dystric Netrosols, Dystric Regosols, Eutric netrosols and Plinthic Aeriosols. The rainfall factor has 16 stations.The NDVI was reclassified into 5 factors. The Landuse/Landcover was reclassified into(Waterbody, Forest, Barren land, Vegetation and Built-up). Distance from also classified into 5 factors. Aspect (Direction) was constructed using 10 factors namely flat, north, northeast, east, southeast, south, southwest ,west , northwest and north.

II. Frequency Ratio Model

FR is a cost effective and essential BSA method for evaluating the impact of each classes of the conditioning factors on the flood occurrences. FR is the expression of the ratio of the probability of an occurrence of any environmental attribute to that of a non-occurrence for said attribute (Lee and Sambath 2006; Lee and Pradhan 2007). It is regarded as a simple, easily understandable method (Yilmaz 2007). The greater the FR, the more substantial is the relationship between occurrence and specific variable (Pradhan 2010b; Sujatha et al. 2013). All the scaled flood conditioning factors were classified, in order to perform FR analysis in GIS. While many classification techniques exist, the quantile method was chosen for this purpose, based on its popularity (Tehrany et al. 2013). Altitude, slope, SPI, TWI, NDVI, rainfall, distance from river and distance from road were categorized into 10 equal area classes. FR was applied and the weights were assigned to each class of each conditioning factor. A greater ratio indicates a stronger relationship between a conditioning factor and flooding, and vice versa. If the FR value is higher than 1, the relationship is strong, and conversely weak if less than 1(Lee and Talib 2005; Sujatha et al. 2013). For calculating a Flood Probability Index (FPI), the FR value for each factor was added to the training area. The flood hazard value represents the relative hazard to landslide occurrence.

$FPI = Fr1 + Fr2 + Fr3 + K + Frn$

where $Fr1$ is the rating of each factor's type or range, such that the greater the value, the higher the susceptibility to flood occurrence and the lower the value, the lower the susceptibility to landslide occurrence.The frequency ratio was the ratio of the probability of an occurrence to the probability of a non-occurrence for given attributes. The frequency ratio will be calculated according to equation 1:

FR= % of pixels of flood /% of pixels in domain (1)

Tab 2. Frequency Ration Model Calculation

S.No	FACTORS	CLASSES	Number of Pixels in flood	Pixels in flood (%)	Pixels in Domain	Pixels in Domain (%)	FR
1	SLOPE	1	191	58.40979	2039619	40.55869	1.440130
		2	119	36.39144	1900220	37.78668	0.963075
		3	16	4.892966	721614	14.3496	0.340982
		4	1	0.30581	272624	5.421244	0.056409
		5	0	0	94732	1.883786	0
		Total	327	100	5028809	100	
2	ELEVATION	1	323	98.77676	3908312	78.11231	1.264548
		2	4	1.223242	724197	14.47392	0.084514
		3	0	0	206803	4.13320	0
		4	0	0	110453	2.20753	0
		5	0	0	53693	1.07311	0
		TOTAL	327	100	5003458	100	
3	ASPECT	1	31	9.48012	527817	10.42267	0.909566
		2	34	10.39755	497909	9.832093	1.057511
		3	33	10.09174	497972	9.833337	1.026278
		4	24	7.339449	480896	9.496141	0.772887
		5	36	11.00917	522258	10.31290	1.067514
		6	33	10.09174	534876	10.56207	0.955470
		7	25	7.645259	502667	9.926048	0.770221
		8	36	11.00917	499453	9.862582	1.116256
		9	39	11.92660	478934	9.457398	1.261087
		10	36	11.00917	521338	10.29474	1.069397
		TOTAL	327	100	5064120	100	
4	SOIL TYPES	1	7	2.140673	113672	2.27000	0.943027
		2	23	7.033639	1732942	34.60649	0.203246
		3	10	3.058104	274483	5.481368	0.557908
		4	287	87.76758	2885600	57.62483	1.523086
		5	0	0	867	0.017314	0
		Total	327	100	5007564	100	
5	DISTANCE FROM ROAD	1	272	83.18042	1235812	24.57037	3.38539
		2	43	13.14984	94596	1.88075	6.99179
		3	7	2.140672	314387	6.25063	0.342472
		4	5	1.529051	3061402	60.8666	0.02512
		5	0	0	323486	6.43153	0
		Total	327	100	5029683	100	

6	DISTANCE FROM RIVER	1	278	85.01529	1235817	24.61938	3.453185
		2	32	9.78593	184597	3.677457	2.661059
		3	17	5.19877	414382	8.255129	0.629767
		4	0	0	2561409	51.02722	0
		5	0	0	623486	12.42080	0
		Total	327	100	5019691	100	
7	RAINFALL	1	34	10.39755	1335818	26.50595	0.392272
		2	36	11.00917	134598	2.670758	4.122114
		3	43	13.14984	314387	6.238219	2.107948
		4	49	14.98470	2961402	58.76157	0.255008
		5	165	50.45871	293486	5.823491	8.664683
		Total	327	100	5039691	100	
8	NDVI	1	17	5.198776	1756819	34.990992	0.148574
		2	52	15.90214	129590	2.5810756	6.161051
		3	93	28.44036	104483	2.0810133	13.66659
		4	102	31.19266	2785400	55.477491	0.5622573
		5	63	19.26605	244483	4.8694275	3.9565338
		Total	327	100	5020775	100	
9	LANDUSE/ LANDCOVER	1	8	2.44648	1536819	30.60919	0.079926
		2	34	10.39755	154590	3.07900	3.376918
		3	123	37.61467	204483	4.07273	9.23572
		4	95	29.05198	2881400	57.38954	0.506224
		5	67	20.48929	243483	4.84951	4.225023
		Total	327	100	5020775	100	
10	STREAM POWER INDEX	1	7	2.140673	113672	2.27000	0.943027
		2	23	7.033639	1732942	34.60649	0.203246
		3	10	3.058104	274483	5.481368	0.557908
		4	287	87.76758	2885600	57.62483	1.523086
		5	0	0	867	0.017314	0
		Total	327	100	5007564	100	
11	TOPOGRAPHIC WETNESS INDEX	1	34	10.39755	1335818	26.50595	0.392272
		2	36	11.00917	134598	2.670758	4.122114
		3	43	13.14984	314387	6.238219	2.107948
		4	49	14.98470	2961402	58.76157	0.255008
		5	165	50.45871	293486	5.823491	8.664683
		Total	327	100	5039691	100	

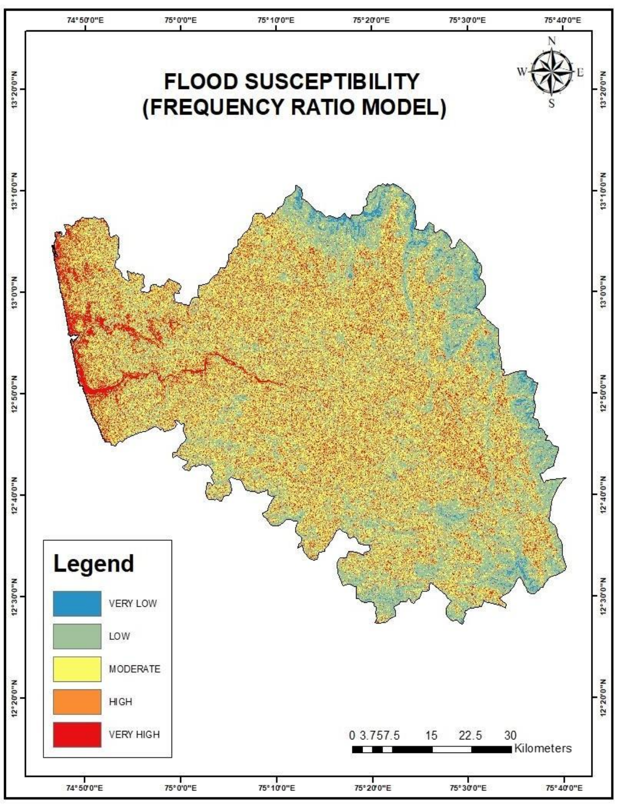

Fig 16. Flood Susceptibility Map

Conclusion:

Frequency ratio can therefore be efficiently used in flood susceptibility mapping. In particular, the particular method can be quickly and effectively applied to areas with less map data, and at minimal to low cost. Flood susceptibility maps are of increased help to urban planners and engineers. They can easily choose and mark high susceptible area with respect to floods for further detail survey and identification of suitable locations to implement development. The results discussed here may be used as basic data to assist in slope management and urban land use planning.

GIS techniques and analysis are valuable tools pertaining to various fields. They have been used for mapping, modelling and analysis of various applications in disaster management at different scales. Floods are hazardous natural disaster phenomena which cannot be prevented. The present study shows a simple and cost-effective way of using geographical information system for creating flood susceptibility map from the available data base. This study attempts to prepare flood susceptibility map using ArcGIS software tools. Using the flood susceptibility map, flood prone areas can be identified, which will assist in appropriate planning of development works.

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