Flood Hazard Mapping and Assessment Using Geospatial Techniques and AHP Model based hazard Zonation – A case study of Coastal Taluks of Cuddalore District, Tamil Nadu, India

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Abstract

Floods are one of the most widespread natural hazards that take place approximately everywhere around the world except Polar Regions. Natural disaster like flood is causing huge indemnity to natural and human resources, especially in coastal areas. In respect to socio-economic and environmental perspective, flood is one of the most devastating disasters in coastal regions of Cuddalore for the recent days. The main aim of this study is to identify the various flood hazard zones along the coastline of district Cuddalore with the integration of Remote Sensing (RS) and Geographic Information System (GIS), and the Multi-criteria Decision-Making-Analysis (MCDM) based Analytical Hierarchy Process (AHP) model in the geospatial environment. The weights derived from (10*10) decision matrix of AHP model for the flood inducing factors are reflecting their varied priorities from high to low priority as distance from river (13.70%), Topographic Wetness Index (TWI)(13.60%), rainfall (12.40%), slope (10.00%), soil type and Drainage density (9.60%), Landuse Landover (LULC)(6.80%) , Normalized vegetative index (NDVI) (6.40%), and distance from road (5.80%), respectively. High to very high vulnerable coastal taluks includes Chidambaram, followed by Kurinjipadi, and Cuddalore. As a result, a flood vulnerable map has been produced, which shows that about 15% of the total study area is having very high , 28% high, 28% moderate, 19% low, and 10% very low respectively. It was also identified that nearly 43% of the total area of 1281 km^2 were having a high chance during flood times; these regions are requiring some serious attention of governmental and local bodies to reduce the flood risk. This current study will be a very useful tool for the policy planners and coastal management planners to make effective decisions towards mitigation measures in flood prone areas along the coastline.

Keywords: Flood Hazard, AHP, DEM, TWI, LULC, NDVI and Vulnerable zones.

Introduction

Flood is a natural phenomenon that results in the short-term submerging of land areas due to extreme rainfall events within a short period of time. Flood is a condition of partial or complete inundation of normally dry areas due to the rapid accumulation of runoff (Jeb & Agarwal 2008).Flood is the most frequent natural hazard in the world which is widely distributed leading to significant demerges to human lives (DMSG 2001), infrastructures, and livelihood and also accelerates soil erosion. Occurrence of the flood is a very complex phenomenon that always attracted researchers from the different part of this world to understand and explore the mechanism for better management and prevention. Several natural as well as human factors are responsible, which can trigger a catastrophic flood event. Recent days, climate change is a considerable factor in extreme flood events (Rojas et al.

2012; Charlton et al. 2006; Sampson et al.2015) argued that the flood risk of an area can significantly be influenced by climate-induced alterations, and it can change the land use pattern and create an impermeable surface, which may increase the velocity of the flow in addition to the climate, several factors in which occurrence of flood depends are altitudinal characteristics of a region, slope ,proximity from the main channel, drainage density, topographic wetness index , Landuse/ Landover ,rainfall, and NDVI and many more factors (Khosravi et al.2016;Lim and Lee 2017). According to the National Oceanic and Atmospheric Administration (NOAA 1998), a flood is a flow of water above the carrying capacity of a channel. Worldwide, there is an estimation of about 1.5 billion people who were affected by floods in the past decades in 21 centuries (Khole and De 2001; De and Dandekar 2001; De et al. 2013). Climate change is playing a vital role in inducing the extreme rainfall which is visible in the recent decades. Climate model simulations and empirical evidence confirm that warming climates owing to increased water vapor lead to more instance precipitation events and therefore increase risks of floods (Hennessey et al.1997; IPCC 2007).As per the Intergovernmental Panel investigation on Climate Changes (IPCC 2007), the wet extremes' are projected to become more severe in the future and mean precipitation is also expected to be on the rise. The findings of extreme rainfall events could be useful in terms of flood management, as in the resent years, many places over India experienced heavy rainfall events. Resent examples would be events which happened due to multi-day cloud burst which was centered in the states of Jammu and Kashmir, and Uttarakhand during 2014 and 2015, respectively. Further, the consecutive flash floods in the three major metro cities in India experienced excessive in the year 2005 i.e. Mumbai in July 2005, Chennai in October and December 2005, which caused heavy damages to the loss of human lives, properties, livelihood, systems, infrastructures, and public utilities. Some of the studies on extreme rainfall events show that the frequencies of extreme rainfall events show that the frequencies of extreme rainfall events may increase in the future over the central parts of India (Goswami et al. 2006) . in this aspect, the geographical location of the state of Tamil Nadu makes it as one of the most vulnerable maritime state in India, particularly to tropical cyclones and their associated storms surges. It is also frequently subjected to extreme weather conditions of flooding in coastal districts (Bal et al.2015).

In this context, the Cuddalore district of Tamil Nadu state is experiencing these severe floods frequently due to its geographical location as it is situated near the coast of the Bay of Bengal. Several districts of the Tamil Nadu have battled floods during November and December 2015, when an area of the deep depression formed over the Bay of Bengal and dumped heavy rainfall across parts of the state. The El Nino effect, in particular, has played a vital role in this deep depression (Szynkowska 2015).

Flood hazard mapping is a significant component for policy planners to identify the areas which are vulnerable to floods. Furthermore, flood hazard zone mapping will be significantly important for urban planning and risk management.

Study area

The study area is confined to three coastal taluks of district Cuddalore Tamil Nadu, i.e., Cuddalore, Kurinjipadi and Chidambaram, comprising a total geo-graphical area of 1281 km^2. Its longitude and latitude extend from 79^{o}30''00E to 79^o 40"00E and 11^{o}20" 00N to 11^o 50" 00 N. the study area is bounded by the Puducherry and Panruti on north,Virudhachalam

,kattumannarkail, in west as shown in Fig .1 , Nagapattinum in south and on east there is Bay of Bengal. It is a low-lying coastal district having four major rivers namely Cauvery, Vellar, Paravanar, and Pennaiyar. It is very frequently subjected to extreme weather conditions of flooding mainly in coastal planes. The average rainfall of coastal region ratings from (1050 to 1400 mm), the intensity of rainfall is more along the coastal stretch during the low pressure created in Bay of Bengal. Almost these three coastal taluks are badly affected during the north-eastern monsoon .It also undergoes pleasant tropical climate all-around the year with summer temperature rising from 22-36 ^{0}C and winter temperature from 21 to 33 ^{0}C, respectively.

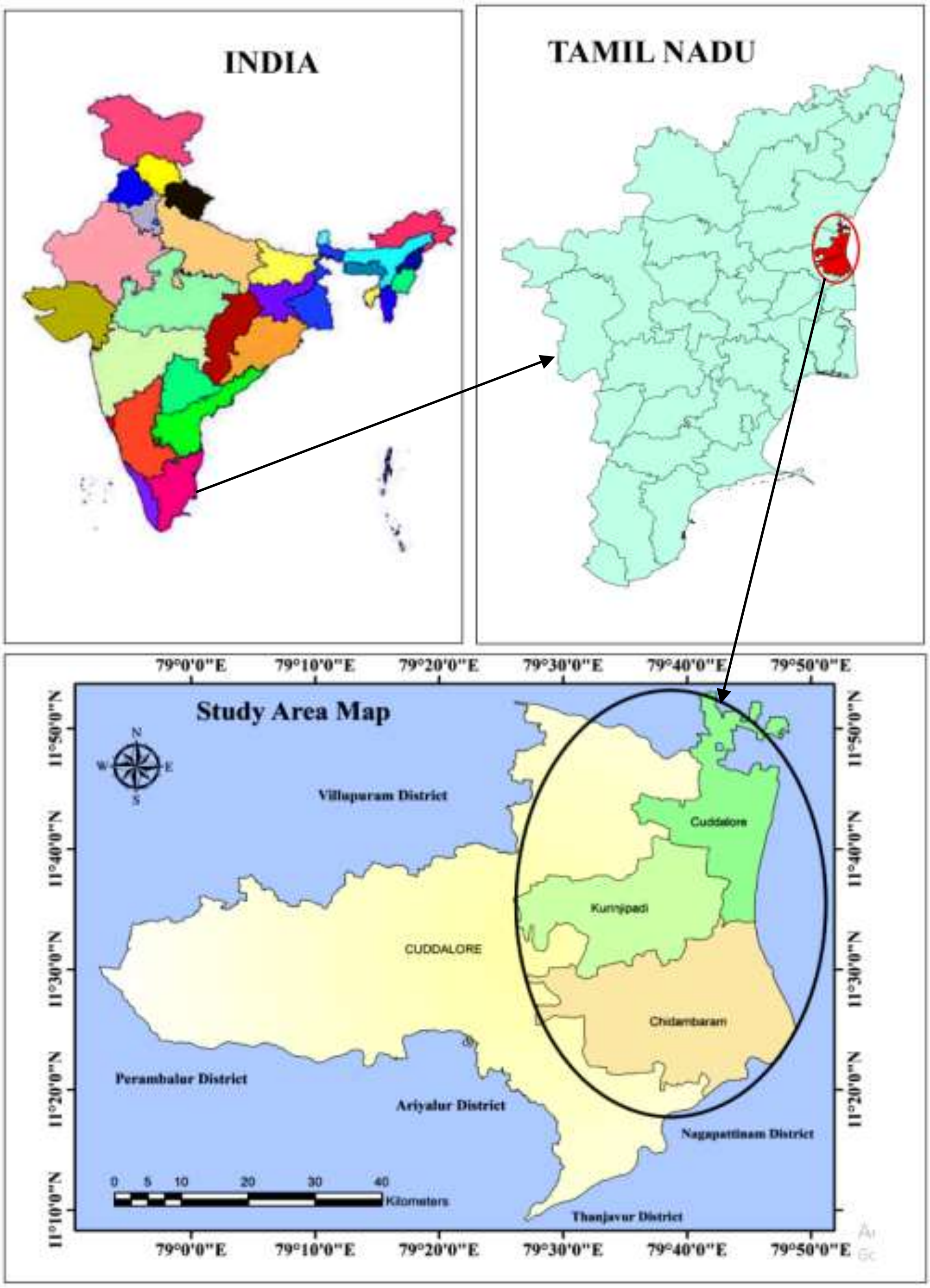

Fig.1. Study area map of coastal Taluks of Cuddalore district.

Materials and Methods

The study was conducted on flood hazard assessment in coastal taluks of Cuddalore district; various datasets comprising sequential steps of methods have been followed. The present research has been carried out to framework the Analytical hierarchy process (AHP) model coupled with Remote sensing and GIS in the geospatial environment using ArcGIS 10.8.1.The formulation of the model requires the ten- flood influencing physical variables viz. DEM, slope, TWI, rainfall, drainage density, LULC, NDVI, soil type, distance from river, and distance from road (Ali et al. 2019).The datasets used in this research are described accordingly in Table (1a). Based on this analysis, a flood hazard zone map was developed to identify very high, high, moderate, low and very low flood vulnerable zones. The developed flood hazard map was validated with sentinel 1A satellite imagery flood inundation map.

Table (1a) Datasets used in the study

S. no	Datasets	Description	Resolution/scale	Source
1	Digital Elevation Model (DEM)	SRTM (DEM)	30 m	USGS earth explorer https ://earthexplrer.usgs .gov/
2	LANDSAT-8	Downloaded	30 m	USGS earth explorer https ://earthexplrer.usgs .gov/
3	Soil	Digitized from soil texture map of Cuddalore District.	-	National Bureau of Soil Survey and Land Use Planning (NBSSLUP)
4	Rainfall	Using (IDW) Interpolation method	mm	Indian Meteorological Department (IMD) https ://www.imdpune.gov.in/
5	Slope	Derived from DEM	30 m	USGS earth explorer https ://earthexplrer.usgs .gov/
6	NDVI	LANDSAT-8	30 m	USGS earth explorer https ://earthexplrer.usgs .gov/
7	Topographic Wetness Index (TWI)	SRTM (DEM)	30 m	USGS earth explorer https ://earthexplrer.usgs .gov/
8	Distance From River	Derived From DEM	30m	USGS earth explorer https ://earthexplrer.usgs .gov/
9	Drainage Density	Derived from DEM	30 m	USGS earth explorer https ://earthexplrer.usgs .gov/
10	Distance From Road	Derived From Open street map (OSM)	-	(OSM) Data https ://openstreetmap.org

Methods

Flood vulnerable zone preparation in this study was carried out in number of steps: identifying and defining the complex problem, generate the AHP model-based hierarchical structure for the selected criteria, perform the pair-wise comparison matrix analysis for the chosen influencing variables (binary comparison), assessment of priorities values and the determination of relative weights for each variable, measurement of consistency value for the evaluations and discussions, synthesize the conclusions on priority variables to identify the FVZ (Dandapat and Panda 2017; Danumah et al.2016; Roy and Blaschke 2015; Sulaiman et al.2015). The considered with the application of MCDM to compute the relative weights (or priorities) among the factors to attain a significant outcome are discussed below in detail. MCDM-based AHP model was used to quantify the weightage of ten selected flood initiation factors, responsible for the determination of the potential of individual elements in including the flood hazard (Chakraborty and Mukhopadhyay 2019; Lawal et al.2012). The above influencing factors were further reclassified into the sub-classes according to their relative ranks for the computation of their relative weights (Danumah et al.2016; De Brito and Evers 2016).

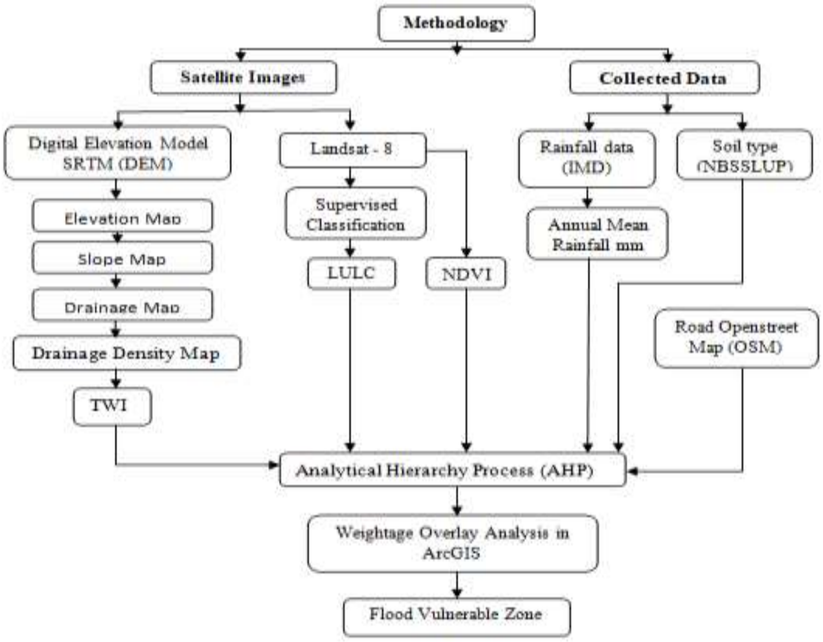

Fig.2 Methodology flow chart

Analytical Hierarchy process (AHP) model

AHP is a multi-criteria decision making approach and was introduced by (Saaty 1980; Dou et al. 2017). The AHP is a decision support tool. It is used to solve complex decision problems, uses a multi-level hierarchical structure of objectives, criteria, sub criteria and alternatives. It determines the weights and ranks of different parameters for the flood vulnerable zones (FVZ). For preparing the all thematic layers, the AHP model has been Grouping the prepared thematic maps into five vulnerable categories, an AHP- based pair-wise comparison matrix of different variables described above is constructed (Table 6). The model is applied to assign varied weights for comparing the ten individual factors, and according to their relative importance, these ten parameters are rated from 1 to 9 (Table. 1) on an absolute number scale (Saaty 1980).

Table 1 Pair-wise comparison scale weights on the bases of AHP scale (Saaty 1980)

Numerical rating	Verbal judgments of preferences
1	Equally preferred
2	Equally to moderately
3	Moderately preferred
4	Moderately to strongly
5	Strongly preferred
6	Strongly to vary strongly
7	Very strongly preferred
8	Very strongly to extremely
9	Extremely preferred

The values of the size range from less to more size by dividing each element of matrix by its column total. However, the priority vector is derived by calculating the row averages.

Table 2 Pair-wise comparison of 10*10 decision matrix

Parameters	TWI	DEM	Slope	Rainfall	LULC	NDVI	D.F. River	D.F. Road	D.D	Soil type
TWI	1	1	1	1	3	5	1	3	1	1
DEM	1	1	1	1	2	3	1	3	1	1
Slope	1	1	1	1	3	1	1	1	1	1
Rainfall	1	1	1	1	3	2	1	3	1	1
LULC	1/3	1/5	1/3	1/3	1	1	1	3	1	1
NDVI	1/5	1/3	1	1/5	1	1	2	1	1	1
D.F. River	1/3	1	2	1	3	5	1	3	1	1
D.F. Road	1/3	1/3	1	1/3	1/3	1	1/3	1	1	1
D.D	1	1	1	1/3	1	1	1	1	1	1
Soil Type	1	1	1	1	1	1	1	1	1	1
Sum	7.50	8.17	10.33	8.17	18.33	21	10.37	20	10	10

Consistency ratio

To rectify the constructed pair- wise matrix and its given weightage method is done by the following equation (Saaty 1980): evaluation through the consistency ratio (CR) was formulated where the acceptable CR must be blow 0.1. In the present study, the consistency of the derived Eigen vector- matrix following the index below found is 0.093 concludes that the set of decision considered is acceptable.

$$CR = \frac{CI}{RI} \quad \text{Eq.1}$$

CI is computed using Eq.2

$$CI = \frac{\lambda max - n}{n-1} \quad \text{Eq.2}$$

Where CR represents the consistency ratio, CI stands for the consistency index, RI indicates the random index. , λ max represents the principle Eigen value of the comparison-matrix, and n is the number of components or factors in matrix. RI refers to the consistency of the randomly evolved pair-wise matrix depicted in (Table 3). The values provided in the table are subjected to various parameters involved in AHP. Therefore, based on the ten variables, the derived RI obtained in the study is 1.49.

Table 3 Random Index (RI) value

Size of Matrix (n)	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

$$FVI = \sum_{i=1}^{n} Wi * Ri \quad \text{Eq.3}$$

Where WI is the individual weights for individual flood conditioning of each parameter, and RI is the rating class.

Finally, the obtained FVZ was classified into five classes are very low, low, moderate, high, and very high using natural breaks (Rocha et al. 2020).

Results and discussion

Slope

In the hydrological study, slope plays a vital role to regulate the flow of surface water, and slit is one of the most important topographic factors for such studies (Tehrany et al. 2013; Mojaddadi et al. 2017; Das et al.2018). Land surface slope is one of the effective factors in floods lower the slope higher is the intensity of flood and the higher the slope lower is the intensity of flood occurrence. The slope of a channel in a region is having a direct relationship with the flow velocity (Das and Pardeshi 2018). When the river slope increases then the flow velocity in the river also will increase (Masoudian, 2009). The slope has a direct relation to infiltration. An increase of the surface slope reduces the infiltration process but increases the surface runoff; as a result, in the regions having a lower surface slope, an enormous volume of water becomes stagnant and causes a flood situation. The slope map has been created from the Shuttle Radar Topographic Mission (SRTM) Digital elevation model (DEM) 30 m satellite image of the study area where the area ranges from (0^o to 57^o) (Fig.1).

Elevation (DEM)

In the study of flood hazard mapping, according to the expert's opinion, the elevation of an area is the most important factor for controlling the flood vulnerability (Botzen et al. 2012; Pradhan 2009; Mojaddadi et al. 2017). Reasons located in higher elevation generally have the lower potentiality to be flooded, whereas lower elevated regions are having higher vulnerability potential. Water is having the tendency to flow towards the lower region from a higher region; and therefore, low elevated regions with a flat surface area have a higher potential of flood occurrences (Das et al.2018). The elevation of the study area ranges from 0 to 123 m. Fig(A)

Table 4 Normalized and the weight values in the standardized pair-wise comparison matrix.

Class	TWI	DEM	Slope	Rainfall	LULC	NDVI	D.F. River	D.F. Road	D.D	Soil type	Weight
TWI	0.13	0.12	0.1	0.12	0.16	0.24	0.14	0.15	0.1	0.1	13.60%
DEM	0.13	0.12	0.1	0.12	0.11	0.14	0.14	0.15	0.1	0.1	12.10%
Slope	0.13	0.12	0.1	0.12	0.16	0.05	0.07	0.05	0.1	0.1	10.00%
Rainfall	0.13	0.12	0.1	0.12	0.16	0.1	0.14	0.15	0.1	0.1	13.40%
LULC	0.04	0.06	0.03	0.04	0.05	0.05	0.05	0.15	0.1	0.1	6.80%
NDVI	0.07	0.04	0.1	0.06	0.05	0.05	0.03	0.05	0.1	0.1	6.40%
D.F. River	0.04	0.12	0.19	0.12	0.16	0.24	0.14	0.15	0.1	0.1	13.70%
D.F. Road	0.04	0.04	0.1	0.04	0.02	0.05	0.05	0.05	0.1	0.1	5.80%
D. Density	0.13	0.12	0.1	0.12	0.05	0.05	0.14	0.05	0.1	0.1	9.60%
Soil Type	0.13	0.12	0.1	0.12	0.05	0.05	0.14	0.05	0.1	0.1	9.60%

*(TWI) Topographic wetness index, (SRTM DEM) Digital elevation model, Slope, Rainfall(IMD), (LULC) Landuse/Landcover, (NDVI) Normalized vegetation index, Distance from river, Distance from road, (D.D) Drainage Density, Soil Type.

Normalized Difference vegetation index (NDVI)

The NDVI is another factor that is a valuable index in assessing vegetation coverage and its outcome on flooding in a study area. Normally NDVI value ranges from -1 to +1. NDVI map was prepared from satellite image of LANDSAT 8 OLI the NDVI values are calculated from below equation:

$$NDVI = (NIR - VIS) / (NIR + VIS) \quad \text{Eq. 4}$$

The NDVI values ranged from -0.30 to 0.63 in the study area. Stated that the negative values show water and the positive values show vegetation. So, NDVI has negative relationship with flooding: higher NDVI values indicate lower probability of flood and lower NDVI values indicates higher flood probability. In this study, the NDVI value ranges from -0.30 to 0.63 and were classified into five classes using natural brakes method. Fig.(D)

Soil Type

The water holding capacity and surface infiltration characteristics of an area are determined by two main factors, such as soil type and texture (Nyarko 2002). In this study, the study area was divided into 8 soil classes. The soil type map was obtained from the Disaster Management cell, Government of Tamil Nadu. The produced map was classified on the bases of the infiltration capacity; the weightage has been assigned to each soil type. Sand and clay types of soils are found along the Pennaiyar River. The coastal area of the study area is covered by sand, sandy loam, sandy clay loam, and clay. Silt clay loam and sandy loam are found in the Coleroon River, and the rest of the study area is of other types in fig. F. The distribution of soil covered in the study area is given in Table 5.

Table 5 Different Soil types in study area.

S.No.	Soil type	Area_km^2	Area of the soil %
1.	Clay	172	13.4
2.	Clay Loam	140	10.9
3.	Sand	91	7.1
4.	Sandy Clay	183	14.3
5.	Sandyclayloam	175	13.7
6.	Sandy Loam	451	35.2
7.	Silty Clay	7	0.5
8.	Mines	62	4.8
Total		1281	100 %

LULC

Land use land cover is the primary driver in changing the landscape of a specific area. LULC map has been extracted from Landsat-8 using supervised classification and are classified in to eleven classes, then further reclassified into five classes on the bases of weights such as class one forest land / plantation having area of 203 km^2, second class sand / scrubland having area of 229 km^2, third class urban area/built-up / bare soil area of 296 km^2, fourth class agriculture land / grassland having area of 495km^2, and fifth class water bodies / wetland /mudflat having area of 59 sq km^2. The study highlighted that the class third, fourth and fifth are regarded as highly susceptible, while class first and second are least vulnerable to flood. Fig. (C)

Distance from River

Distance from the river is one of the most important factors in flood hazard mapping. As the distance increases, the elevation and slope becomes higher. Also, Stream is generally the lowest point of that particular region. As a result of this, areas far from the river are having lower vulnerability of flood occurrence. During floods, river banks get overflowed and submerge the dry land nearby the river. In this study we have classified distance from river in to five classes from very high (0 - 500 m), high (501 – 1,000 m), moderate (1,010 – 1,500 m), low (1,510 – 2,000 m), and very low (2,010 – 4,030) fig. (G). Lesser the distance from the river more is the flood vulnerability occurrence and more is the distance from the river lesser is the vulnerability.

Distance from Road

Distance from the road is also an important factor in quantifying flood vulnerability. During floods when water flows over banks of rivers incites as well as low lying areas flood water enters the roads and streams and damages the public properties and also damages the roads and houses as well. In this study distance from road is classified in to five classes from very high (0 - 500 m), high (501 – 1,000 m), moderate (1,010 – 1,500 m), low (1,510 – 2,000 m), and very low (2,010 – 4,030) fig. (H). Lesser the distance from the river to the road more is the flood vulnerability and more is the distance from the river to road lesser is the vulnerability.

Rainfall

It forms the most striking factor since the coastal area districts receive enough rainfall from both northeast and southwest monsoon, but northeast monsoon season (October to December is considered more rainy season than southwest monsoon. For the precipitation of the rainfall distribution map, the rainfall data of all the rain gauge stations have been calculated through the Inverse Distance Weighted (IDW) interpolation tool in ArcGIS 10.8.1. It is Annual rainfall data for the period of 20 years 2000 - 2020. Rainfall data was collected from Indian Meteorological Department (IMD). And are classified into five classes, shown in, (Fig. E).

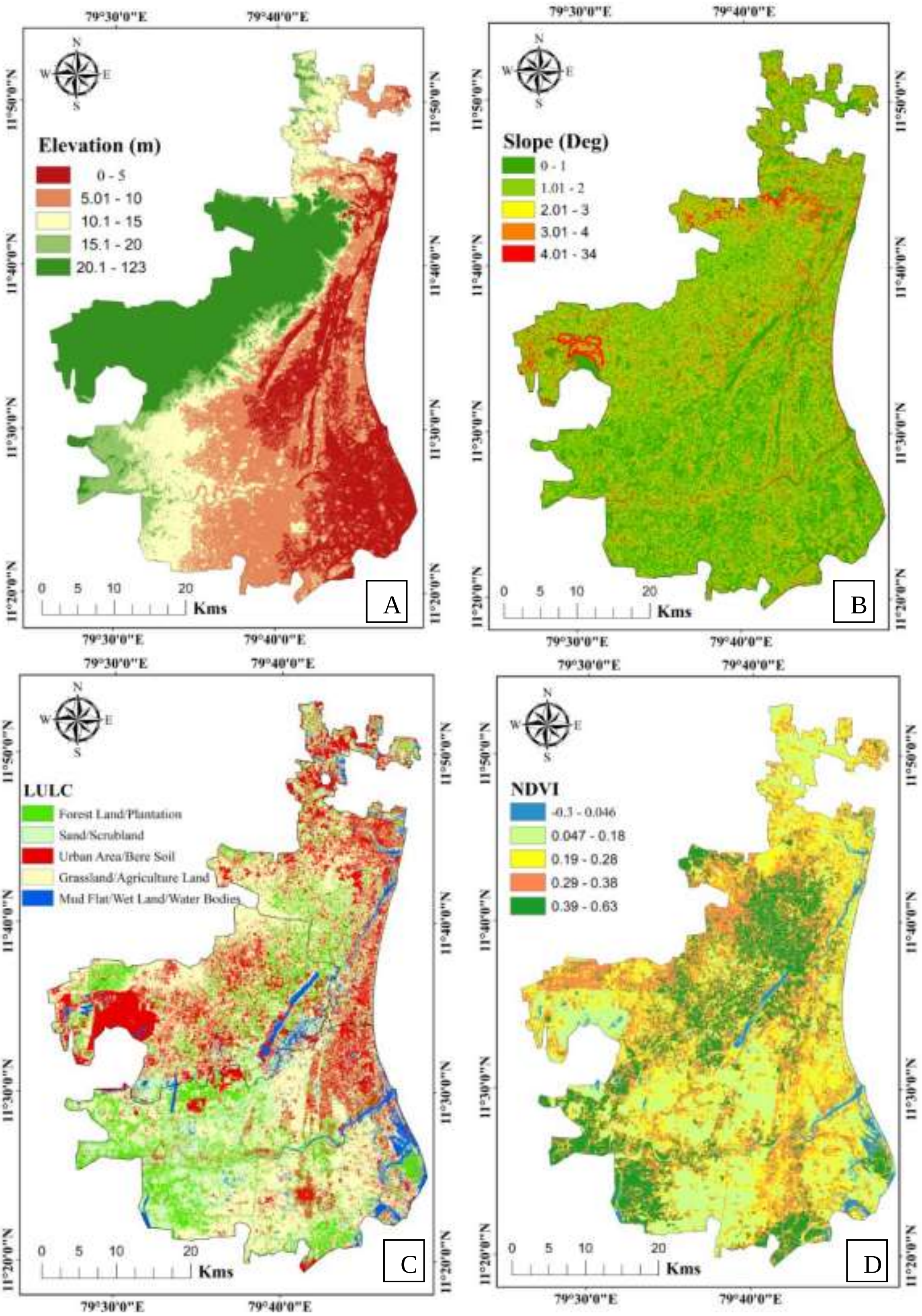

Fig. 3 (A) Elevation map (B) Slope map (C) LULC map, and (D) NDVI map.

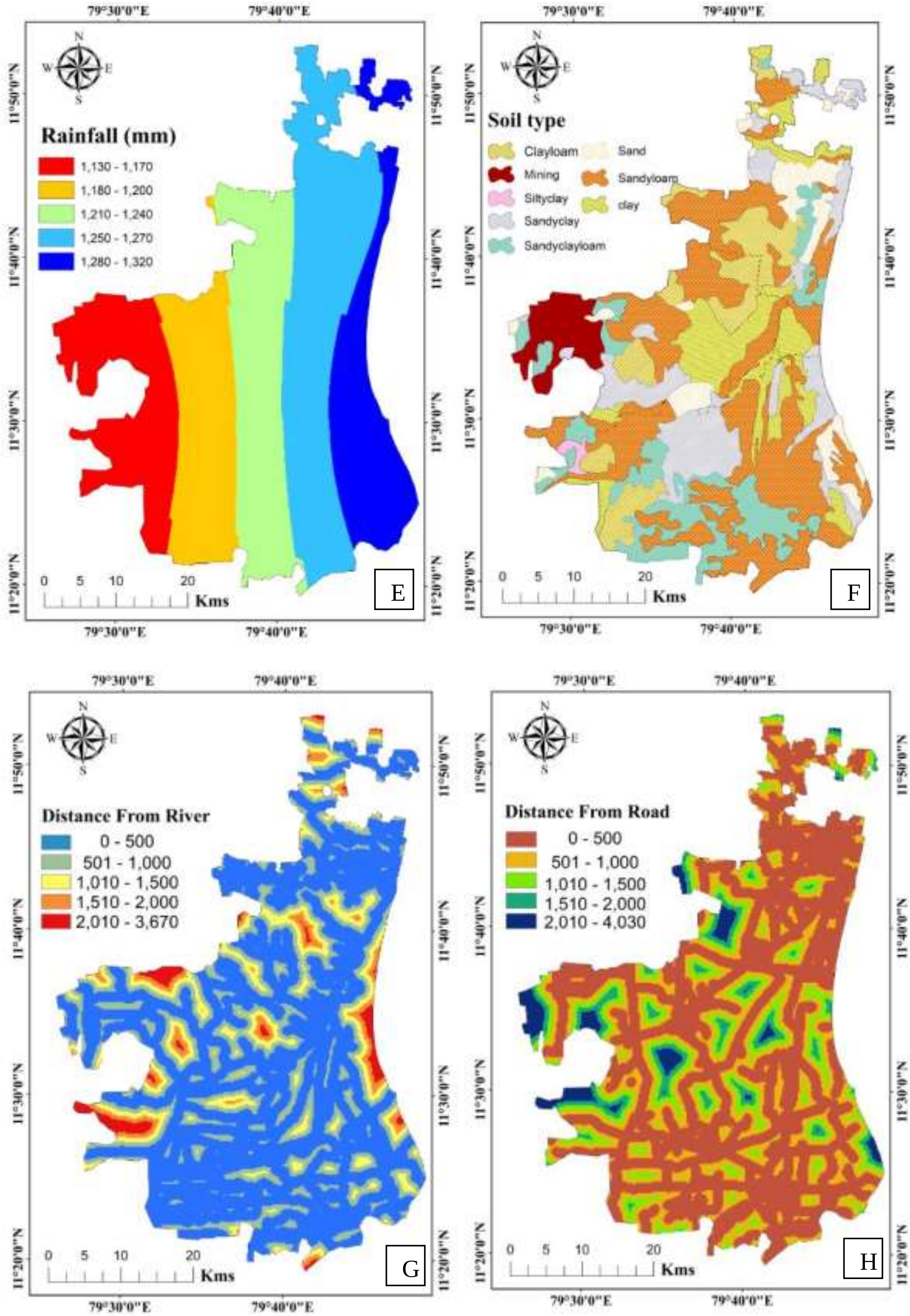

Fig. (E) Rainfall map (F) Soil type map (G) Distance from river, and (H) Distance from road.

Flood Causative Criterion	Units	Class	Susceptibility Class Ranges and Ratings	Susceptibility Class Ratings
TWI	Level	3.88- 5	Very Low	1
		5.1 – 8	Low	2
		8.1 – 10	Moderate	3
		10.1 – 12	High	4
		12.1- 23.7	Very High	5
Elevation	m	0 - 5	Very High	5
		5.01 – 10	High	4
		10.1 – 15	Moderate	3
		15.1 – 20	Low	2
		20.1- 123	Very low	1
Slope	(Degree)^o	0 - 1	Very High	5
		1.01 – 2	High	4
		2.01 – 3	Moderate	3
		3.01 – 4	Low	2
		4.01- 34	Very low	1
Precipitation	mm/year	1560 – 1600	Very Low	1
		1610 – 1650	Low	2
		1660 – 1700	Moderate	3
		1710 – 1750	High	4
		1750 – 1770	Very High	5
LULC	Level	Water Bodies	Very High	5
		Agriculture	High	4
		Urban	Moderate	3
		Bare Land	Low	2
		Forest	Very Low	1
NDVI	Level	-0.3 – 0.046	Very High	5
		0.046 – 0.18	High	4
		0.19 – 0.28	Moderate	3
		0.29 - 0.38	Low	2
		0.39 – 0.63	Very Low	1
Distance From River	m	0 – 500	Very High	5
		501 – 1000	High	4
		1010 – 1500	Moderate	3
		1510 -2000	Low	2
		2010 - 3670	Very Low	1
Distance From Road	m	0 – 500	Very High	5
		501 – 1000	High	4
		1010 – 1500	Moderate	3
		1510 - 2000	Low	2
		2010 - 4030	Very Low	1
Drainage Density	km/km^2	< 1	Very Low	1
		1.01 – 2	Low	2
		2.01 – 3	Moderate	3
		3.01 – 4	High	4
		>4	Very High	5
Soil Type	Level	Clay/Sandy Clay	Very High	5
		Sandy Clay Loam	High	4
		Sandy Loam	Moderate	3
		Loamy Sand	Low	2
		Sand / Rock land	Very Low	1

Table 6 weights of sub-classes using (AHP) comparison matrix.

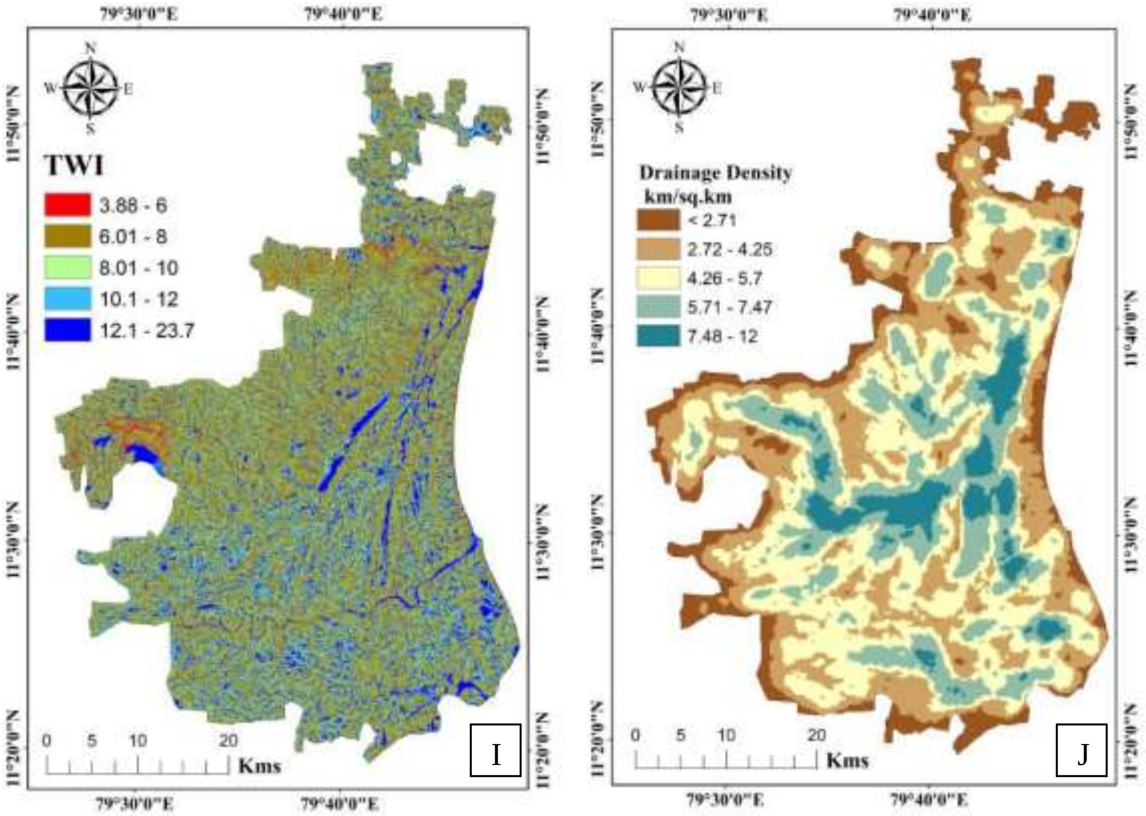

Fig. (I)Topographic Wetness Index (TWI) and (J) Drainage density map.

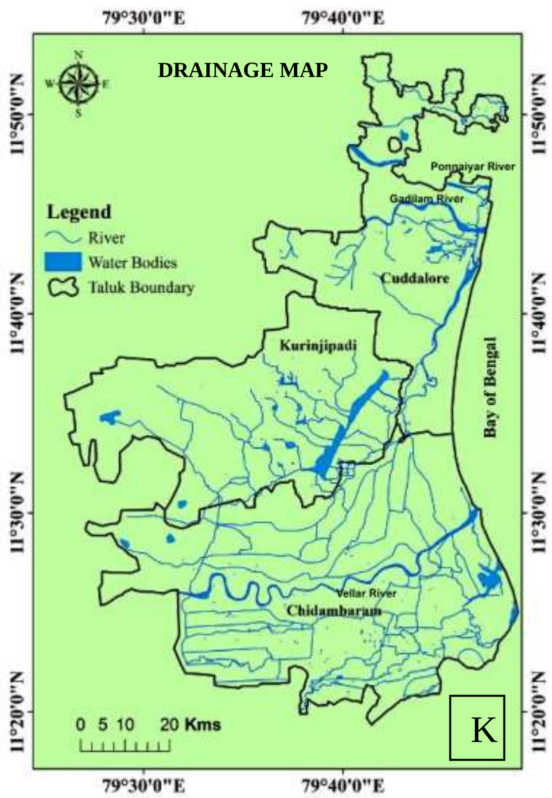

Fig. (K) Drainage Map.

Topographic Wetness Index (TWI)

Topographic wetness index (TWI) indicates the effect of Topography on Runoff Generation and the amount of flow accumulation at any location in river catchments (Gokceoglu et al.2005) the formula for calculating the TWI can be expressed as below:

$$TWI= \ In \left(\frac{As}{\tan\beta}\right) \qquad Eq. 5$$

Where, As represents the area in (m^2 m^{-1}), and $\boldsymbol{\beta}$ indicates the local slope gradient in degree. Higher TWI regions have a higher potential of Vulnerability to flooding. Inversely, the lower TWI regions have a lower potential for Vulnerability. The TWI for the study area ranges from -3.88 to 23.7 m^2, calculation of the TWI has been generated from SRTM DEM Using ArcGIS 10.8.1.fig. (I)

Drainage Density (DD)

Drainage density has a direct influence on flood vulnerability. The drainage density map is directly derived from SRTM DEM (30) using a hydrological tool and line density tool in ArcGIS. The entire region is classified in to five classes (0 - 1.5 km/km^2) very low, (1.5 -3 km/km^2) low, (3.01 - 4.5 km/km^2) moderate, (4.51-6 km/km^2) high, (6.01 - 12 km/km^2) and very high. Drainage density can be integrated with other parameters in GIS environment to identify the areas which are more likely to get flooded. The drainage network information can be taken from Toposheets, but the development of DEM based elevation information for drainage networks having more accuracy (Forte and Strobl 2006).

Assessment of flood vulnerable zone

The resultant flood susceptibility map exhibits values, ranging from 163 to 494, are categorized into five distinctive classes, using the natural breaking method in ArcGIS 10.8.1 (Fig.4). The classes are very low. Low, moderate, high and very high probability of flood ,comprising 10%, 19%, 28%, 28%, and 15%. And are having the area of 127 km^2, 242 km^2, 357 km^2, 356 km^2, and 199 km^2 of the study area respectively (Fig.2, 3) and (Table 6). The high vulnerable locations are situated in Chidambaram fallowed by Cuddalore and Kurinjipadi, it is because of their low elevation and slope the possibility of flood is more along the river basins. The elevation range in the costal planes varies from (0 to 5 m), his indicate that this area is very prone to natural hazards especially floods during northeast monsoon (October to December) is dominant period for flood occurrences in this area. By contrast, regions having a higher degree of slope are less susceptible to flood. Hence, the elevation and slope plays a crucial role to control the flood potentiality of an area. (Zaharia et al. 2017) postulated that regions with slopes exceeding 15^o do not favor the accumulation of water and the process of stagnation, whereas regions having a large cover of dense vegetation and flat surface topography favor the retention of the excess surface water during a flood.

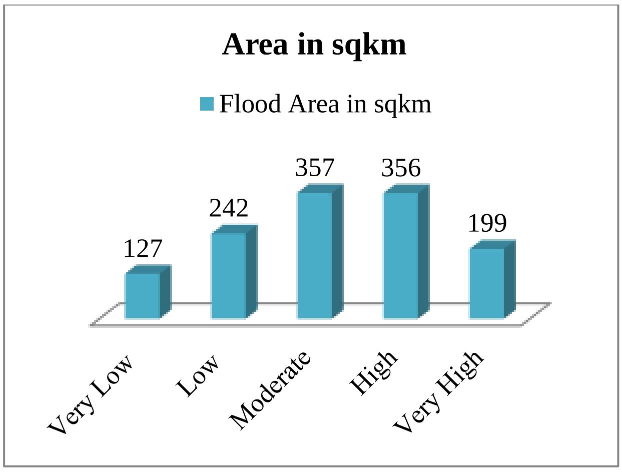

Fig. 3 Area in km^2

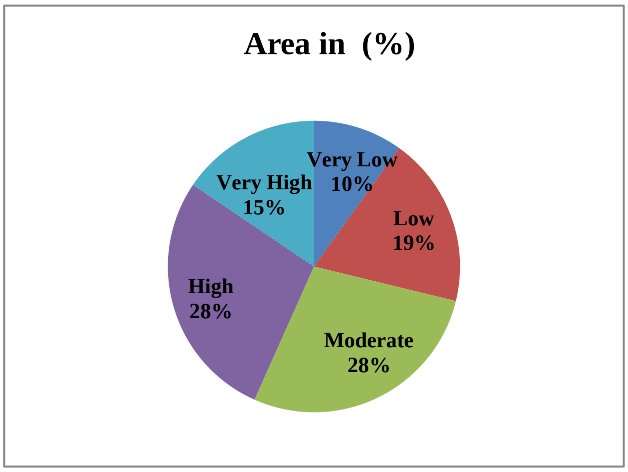

Fig. 4 Area in percentage (%)

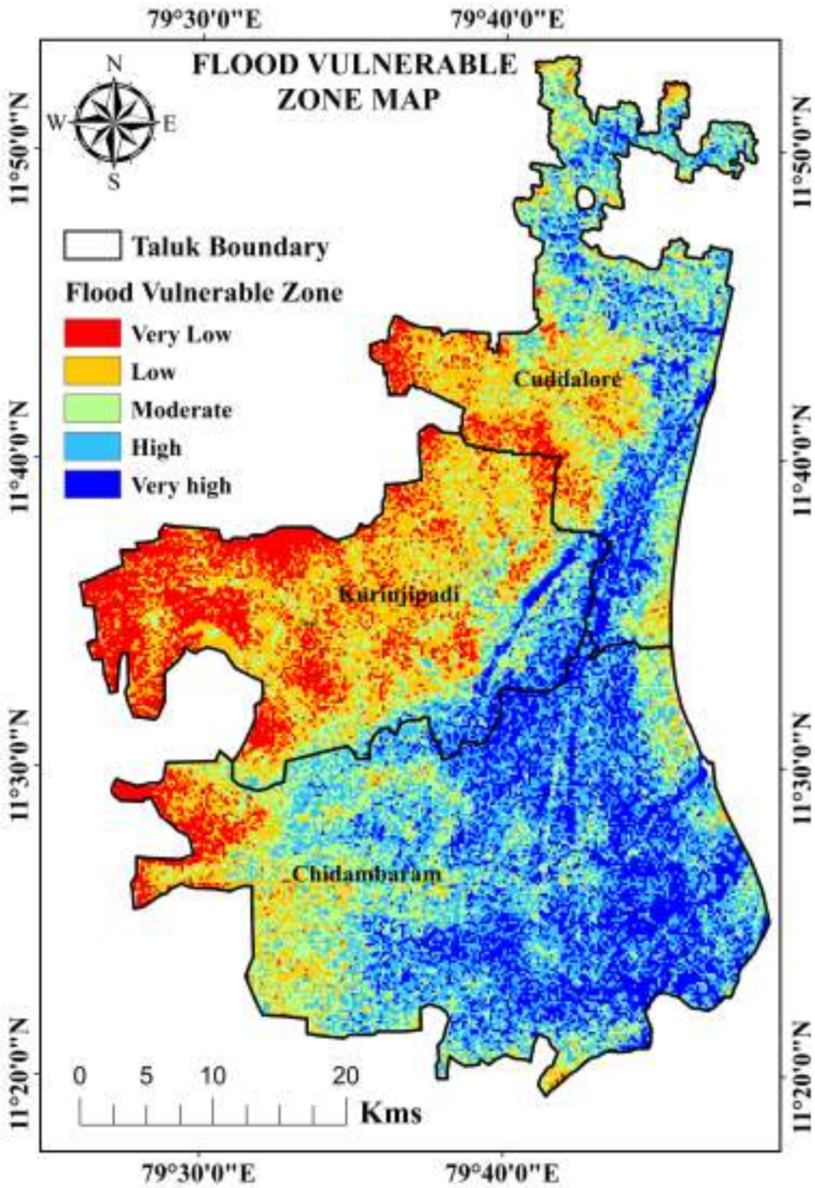

Fig. 5 Flood Vulnerability zone map

Flood vulnerable zone	Area in km^2	Area in (%)
Very Low	127	10%
Low	242	19%
Moderate	357	28%
High	356	28%
Very High	199	15%
Total Sum	**1281**	**100%**

Table 7 Flood vulnerable zones area km^2 and in percentage.

About 28% area in the study area shows moderate susceptibility of flood. These locations are mostly agricultural along the coastal rivers and water bodies are very high, high, and moderately affected, northeastern part of the study area along the coast having lower elevation and slope, and are more susceptible for water accumulation, because of its topography, are more vulnerable to floods.

The north-western part of the study area is less vulnerable than north eastern part because of its steep slope (10^o to 34^o) and slight high elevation (20 to 123 m) than the northeastern part of the study area. In this area the streams to have high velocity, which cannot allow the water to accumulate in this regions, consequently, these regions shows very low flood vulnerability.

Moreover, the flood susceptibility through geospatial mapping can be improved by the selection of high-resolution spatial datasets (Senanayake et al. 2016), accurate convention data, and an advance the accuracy by comparing the results, and it will helps the decision makers and administrative bodies in achieving proper planning and management. Although floods are not very catastrophic in this region, but on the other hand cause measurable demerges to the agricultural activities. The regions identified as high flood zone (HFZ) require some serious attention of the administrative bodies to prevent flood conditions in future.

Previously, several studies are carried out in the different places around the world to build an accurate flood susceptibility map using several decision- making and machine learning approaches. (Dou et al. 2017) made an attempt to identify probable high flood susceptible regions by analytical hierarchy process using geospatial techniques. Kaur et al. (2017) employed Yule's (1912) coefficient model through weighted overlay analysis in GIS to predict possible flood susceptible regions in West Bengal, India. Prediction of flood using all these methods offered quite an accurate result. Similar methods are adapted by many researchers to assess hazard zonation using geospatial modeling (Bonham-carter 1994; Ghosh et al. 2011). Risi et al.(2017) carried out flood predication analysis by assessment of TWI and maximum likelihood modeling. AHP is a simple decision- making approach based on relative importance of different factors. In the present study, it is seen that elevation, slope, and rainfall are the most important parameters for the assessment of flood hazard.

In current times, planners from different places of the world emphasized the significance of decision-making approaches through GIS techniques in flood susceptible zonation, which is very cost- time- effective. The accuracy of the AHP technique depends on assigned weights. However, the significant point is that in different studies it is observed a inequality in weightage and ranking given for a certain parameter by different researchers. The attempt to prepare precise flood susceptible map depends on the data accessibility of different parameters, accuracy, and regional conditions.

Conclusion

The present study identifying the flood vulnerability zones, as a prerequisite approach in demarcating the degree of susceptibility of various regions towards the natural calamity. Being the most efficient and widely acceptable techniques, MCDM-based AHP model approach was carrying out the flood vulnerability analysis of the coastal tehsils of Cuddalore district. The research has been conducted by utilizing analytical hierarchy process (AHP) and geospatial techniques that provided a cost-effective and less time-consuming methodology. Numerous factors such as elevation, slope, rainfall, Landuse/Landover, NDVI, TWI, distance from river, distance from road, drainage density, and soil type map are integrated in the ArcGIS platform. As a result, a flood vulnerable map has been produced, which shows that about 15% of the total study area is having very high , 28% high, 28% moderate, 19% low, and 10% very low respectively. These regions are mostly located near southern part of the study area along the coastline. . It was also identified that nearly 43% of the total area of 1281 km^2 were having a high chance during flood times; these regions are requiring some serious attention of governmental and local bodies to reduce the flood risk. This current study will be a very useful tool for the policy planners and coastal management planners to make effective decisions towards mitigation measures in flood prone areas along the coastline.

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