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Assessment of Sustainable Tourism Places with the help of Geospatial technology in South-Eastern Coastal District of Nagapattinam

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Abstract

Flood is an event that generates loss of lives and properties. If such an event is not so much of life threatening one, it will still generate collective stress and serious disruption of community live even after a long time later. The present study presents an integrated approach using Geographical Information System (GIS) and Remote Sensing for creating flood hazard map from the available data base, for sustainable Tourism Places identification of Nagapattinam District. The criteria considered in this study were chosen due to their significance in causing flood in the study area. The factors considered are elevation, slope, soil, annual rainfall distribution; drainage density and land-use/land-cover information. To derive the flood vulnerability map, a weighted linear combination (LC) overlay of the decision factors is used. The result is a flood hazard map showing the most vulnerable areas to flooding within the district. The results show that almost a fifth of the total study area was prone to “high” and or “very high” flood hazards. The final output show significant Tourism places comes under high risk zone will represent the desired result for flood prediction map for the duration of study.

1. Introduction

The phenomenon of flooding is a natural occurrence, which may bring both adverse and beneficial environmental changes. Rowsell *et al.*, (2013), an effective approach to enumerate flood risk management especially for road disruptions which is presumed closed, if the crown of a road is covered by water and loss in time or space travelling. Pyatkova *et al.*, (2015) found a multiple transport modeling which approaches impact assessment on vehicle network. For studying the disturbances in pavement due to flood using flood and transport model. This methodology lacks in rationality since it is limited to brink of 200 mm which determine roads as trafficable or not and it is restricted to a binary representation of inundated roads.

Teo *et al.*, (2013) discussed hydraulic behavior and safety degree of vehicles during flood, were accessed by Numerical model using hydrodynamic models of parked cars. Kramer et al. (2016) the safety criteria of traffic during flood events, is determined by the flume experiments which is conducted on prototype die-cast models of vehicles. The inference from this study is those safety threshold depths of 0.3 m for passenger cars (VW Golf) and 0.6 m for emergency vehicles. Gomariz *et al.*, (2017) Effects of both friction and buoyancy were analyzed by experimenting with 12 different car models which developed a stability coefficient for vehicles exposed to flooding by three scales. It reveals to standardize the term stable area in the flow depth-velocity domain for parked vehicles in flood waters.The main cause of flash flood casualties is due to flooded roads got stuck inside the cars or by exit of people in the rising open water (Drobot *et al.*, 2007; Versini *et al.*, 2010).Urban flood risk vulnerability assessment thus requires detailed knowledge about the risk in respective parts of a town or municipality to be effective and of use for urban planning and hazard management. In this context, the following research questions are addressed: (i) which criteria of risk should be considered for an urban integrated flood risk assessment and (ii) how do differently weighted criteria sets alter both the value and spatial distribution of the multi-criteria flood risk in an urban area. The main objectives of the present study are to develop flood risk analysis and carry out an flood risk index (FRI) mapping for sustainable Tourism Places identification of Nagapattinam District.

2. Study area

The study area, Nagapattinam District has a long history. Nagapattinam district was carved out by bifurcating of the composite Thanjavur district on 18.10.1991. Though the nomenculture is new, it has been traditionally referred to as East-Thanjavur. The present study area is located eastern part of Tamil Nadu, India and is one of the coastal Districts of the State. It is a Peninsular Delta district surrounded by Bay of Bengal on the East, Palk Strait on the South and land on the West and the Northern side. The District is geographically located between 10° 10' and 11° 50' North latitude and between 79° 30' and 79° 50' East longitude. The total geographical area of the district is 2569 sq.km. It has a coastal line of about 188 km. The famous Point Calimere or Kodiakkarai is located in this District. Figure 1 has shown the study area details. It has visualizes the administrative units of the District such as the taluk boundary with their headquarters and also depicted important urban centres.

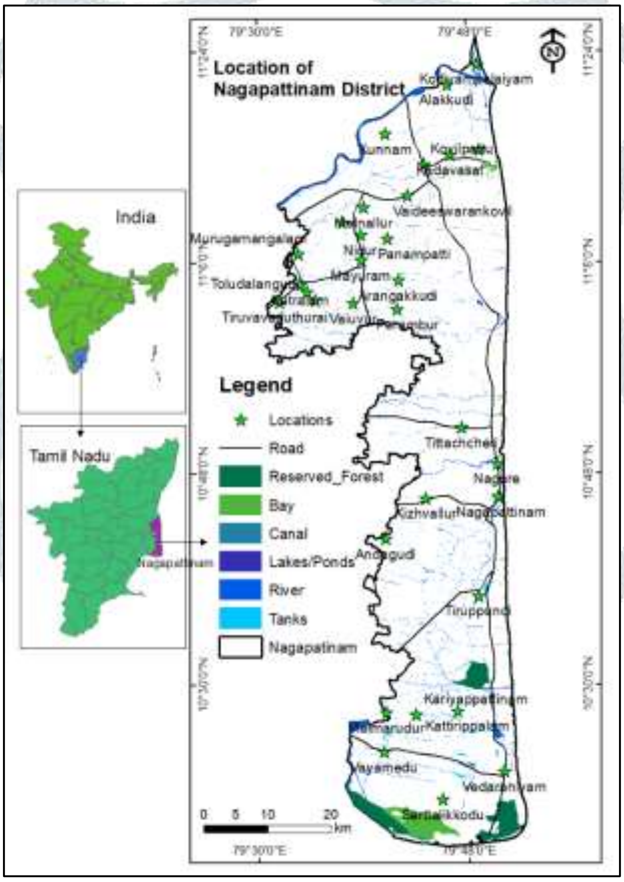

Figure 1 Location of Nagapattinam District

3. Methodology

The choice of criterions that has a spatial reference is an important and profound step in multi-criteria decision analysis. Hence, the criteria considered in this study were chosen due to their significance in causing flood in the study area. The factors considered are: elevation, slope; soil types; annual rainfall distribution; drainage density and land-use/land-cover information.

3.1 Elevation

Elevation plays an important role in governing the stability of a terrain. The slope influences the direction of and amount of surface runoff or subsurface drainage reaching a site. Areas with high slope gradients do not permit the water to accumulate and result into flooding. If the main concern is river caused flood, elevation difference of the various DEM cells from the river could be considered, whereas for pluvial flood local depressions, *i.e.*, DEM cells with lower elevation than the surrounding ones would be more important. This implies that the way in which elevation could be associated with risk is important. Elevation map generated from SRTM DEM and reclassified in to five category based on natural break (Fig.2).

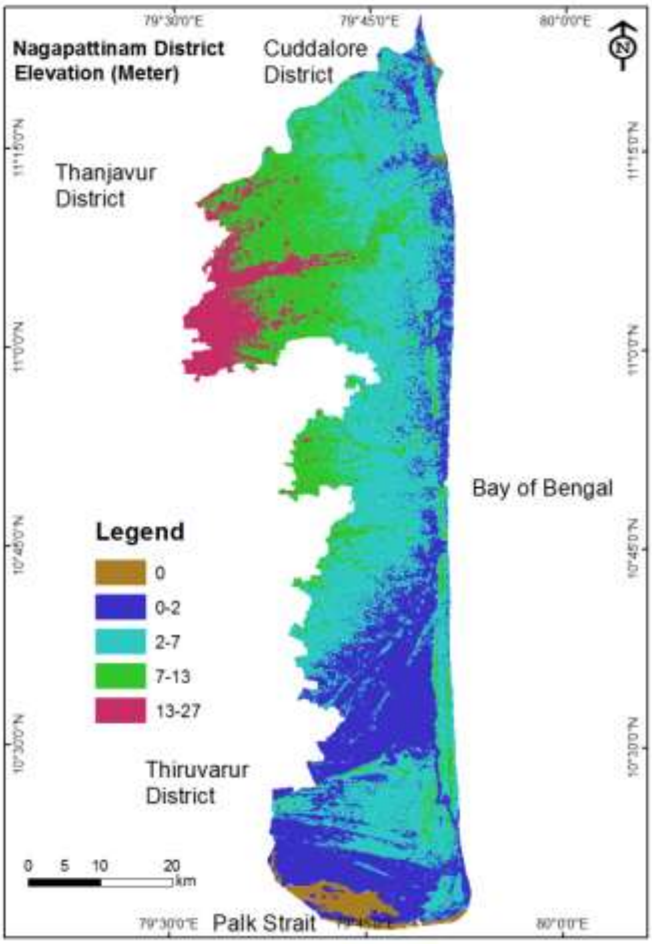

Figure 2 Elevation map generated from SRTM DEM

3.2 Slope

In this study, the slope map was prepared using the SRTM 90 m digital elevation model (DEM) and slope generation tools in ArcGIS software. The slope classes having less values was assigned higher rank due to almost flat terrain while the class having maximum value was categorized as lower rank due to relatively high run-off. For the case study, the results of the original and reclassified elevation and slope layers are presented in Figure 3. According to slope map the entire study area lies in a moderately steep slope. This implies that slope may not be the predominant factor in ranking hazard and risk classes.

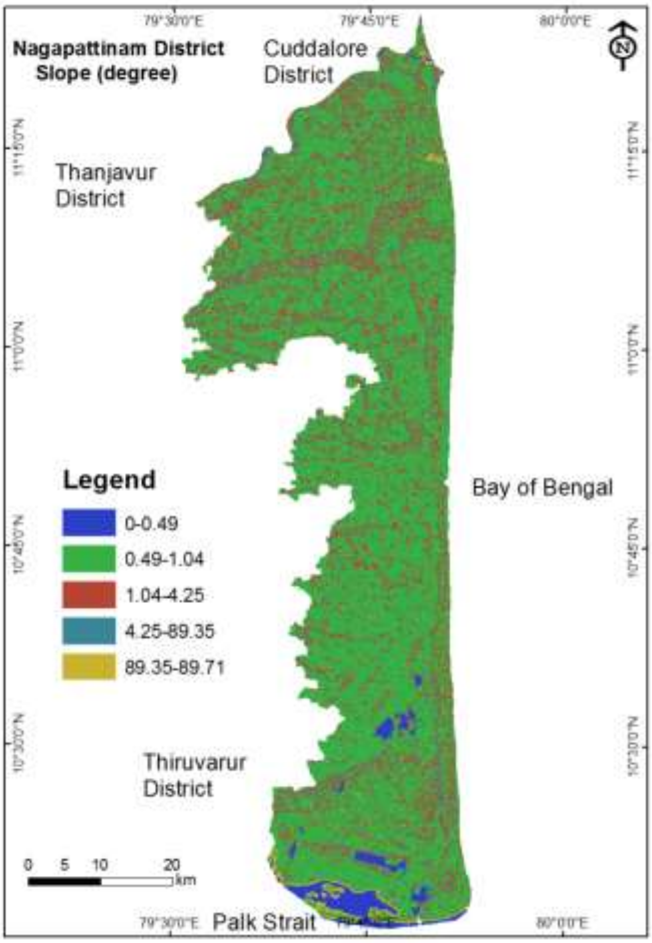

Figure 3 Slope (degree) map of the study area

3.3 Soil order

The chance of flood hazard increases with decrease in soil infiltration capacity, which causes increase in surface runoff. When water is supplied at a rate that exceeds the soil's infiltration capacity, it moves down slope as runoff on sloping land, and can lead to flooding (Lowery et al, 1996). In the present study, the soil order was classified on the basis of infiltration capacity. The soil types found within the municipality were considered into the three broad categories: highly infiltrated, moderately infiltrated, and less infiltrated. The infiltration classes were converted into five raster data groups. The weighted soil map was prepared by assigning weights to each soil classes such that the soil type that has very high capacity to generate very high flood rate is ranked 5 and the one with very low capacity in generating flood rate is ranked 1. The results of the soil factor in the study area are presented in Figure 4.

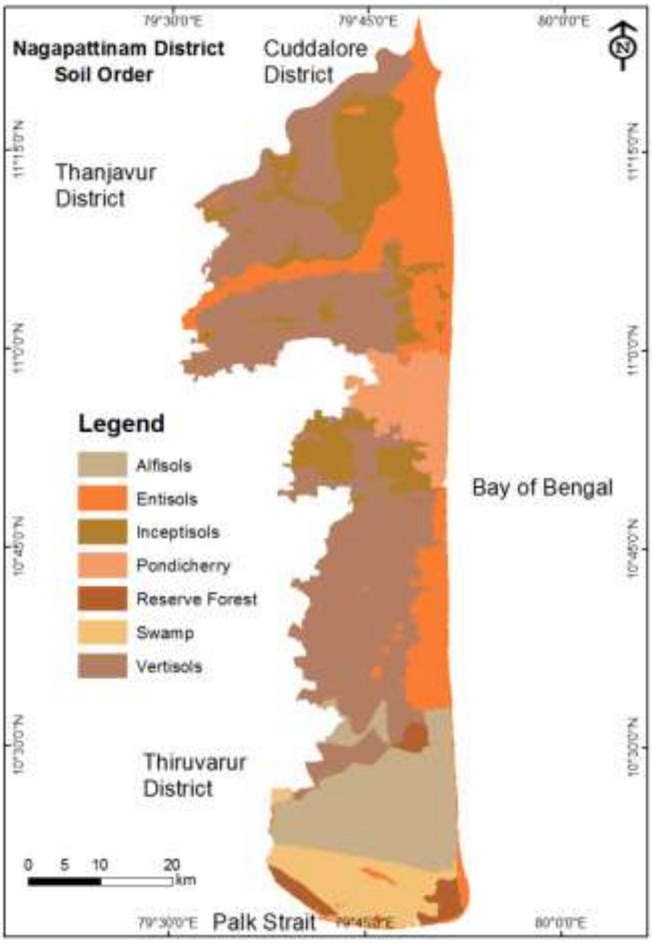

Figure 4 Soil order in the study area

3.4 Rainfall Distribution

Heavy rainfall is one of the major causes of floods. Flooding occurs most commonly from heavy rainfall when natural watercourses do not have the capacity to convey excess water. Floods are associated with extremes in rainfall, any water that cannot immediately seep into the ground flows down slope as runoff. In the study, it was observed that while the local rainfall is relevant for pluvial flooding, rainfall amounts on the upstream catchments contribute to flood hazard and risk caused by the rivers. Therefore both the local and upstream rainfalls were integrated in the analysis, due to the limited size of the study areas. A mean annual rainfall for eleven years (2001–2020) was considered and interpolated using Inverse Distance Weighting (IDW) to create a continuous raster rainfall data within and around study area boundary. The resulting raster layer was finally reclassified into the five classes using an equal interval. The reclassified rainfall was given a value 1 for least rainfall to 5 for highest rainfall. Figure 5 shows the results of the raster rainfall layer, IDW interpolated data layer and the reclassified rainfall data.

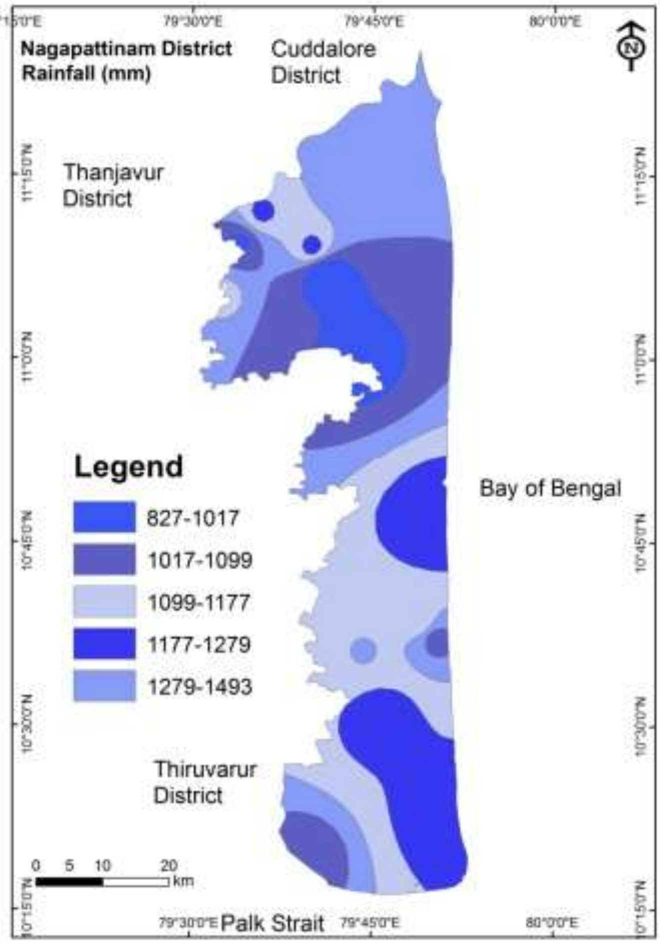

Figure 5 Rainfall distributions in the study area

3.5 Drainage Density

Drainage is an important ecosystem controlling the hazards as its densities denote the nature of the soil and its geotechnical properties. The first step in the quantitative hazard analysis is designation of stream order. The Stream ordering in the present study area was done using the method proposed by (Strahler, 1964). Drainage density map could be derived from the drainage map. *i.e.*, drainage map is overlaid on watershed map to find out the ratio of total length of streams in the watershed to total area of watershed and is categorized. For the study area, higher weights were assigned to poor drainage density areas and lower weights were assigned to areas with adequate drainage. The drainage density layer was further reclassified in five sub-groups using the standard classification Schemes (1–5) (Fig.6). Areas with very low drainage density are ranked as 5 and those with very high drainage density were ranked with value of 1 as depicted in the results.

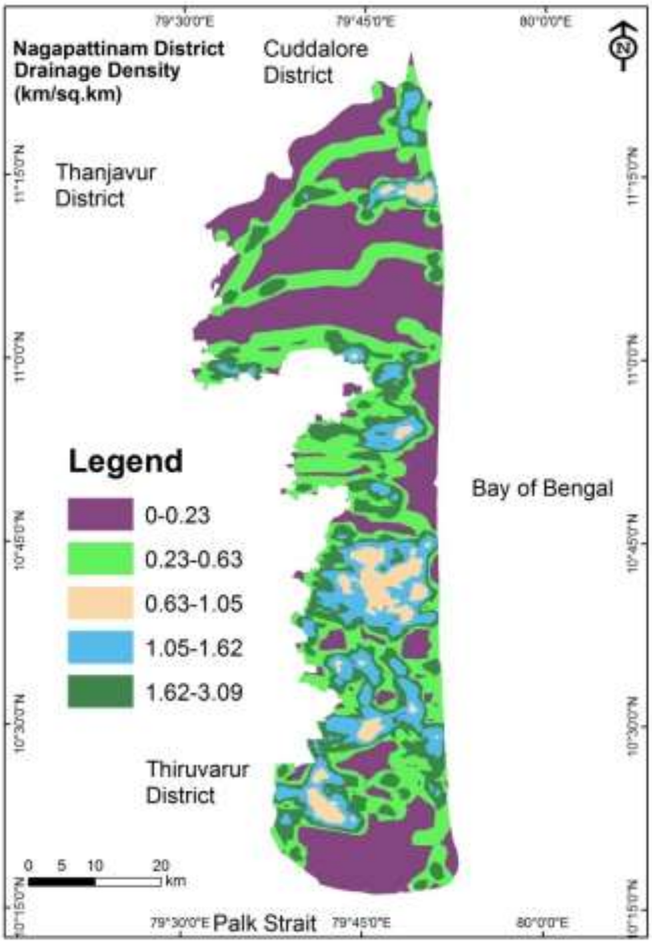

Figure 6 Drainage densities in the study area

3.6 Land use / land cover

The land-use and land-cover management of an area is also one of the primary concerns in flood hazard mapping because this is one factor which not only reflects the current use of the land, pattern and type of its use but also the importance of its use in relation to soil stability and infiltration. Land-cover like vegetation cover of soils, whether that is permanent grassland or the cover of other crops, has an important impact on the ability of the soil to act as a water store. This implies that land-use and land-cover are crucial factors in determining the probabilities of flood happenings. The existing land-use classes of the area were reclassified into five groups in order of their capacity to increase or decrease the rate of flooding. The results of the land-use/land-cover data analysis are shown in Figure 7.

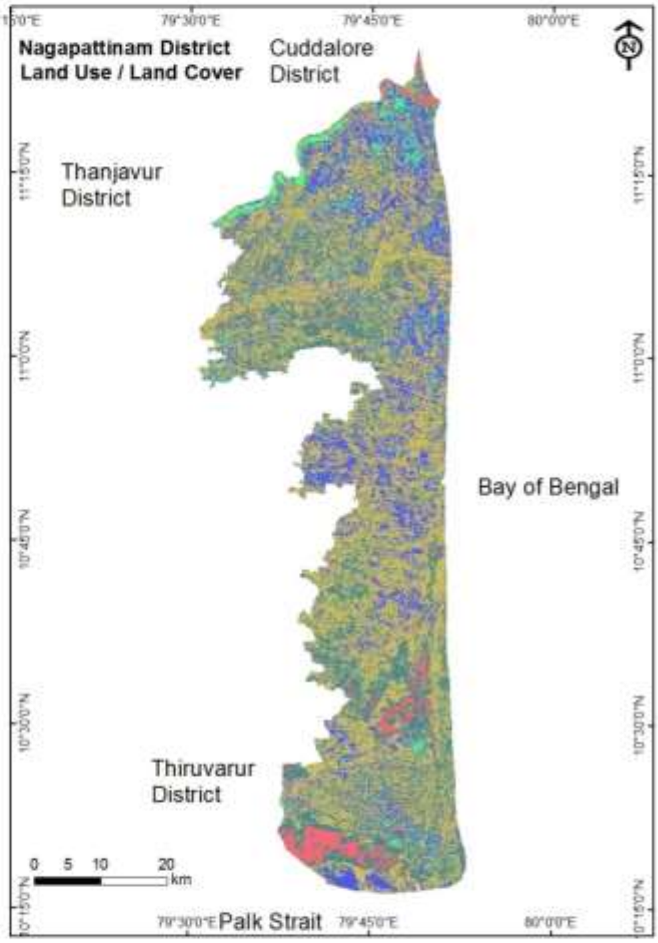

Figure 7 Urban land uses in the study area

3.2Weight and ranking calculation

In the weight and ranking calculation step, the pairwise comparison matrix and the factor maps are used. The principal eigenvector of the pairwise comparison matrix is figured out to produce a best fit to the weight set. Weight values represent the priorities which are absolute numbers between zero and one. Using a weighted linear combination, it implies that the weights sum to 1. A summary of the flood causative factors or variables development showing the various factors, their respective weights and how they are ranked according to their influence to flood events in the study area is presented in Table 1. Table 1 shows how the three-level hierarchical structure is decomposed, and how ranking decision is derived for the subsequent vulnerability and risk mapping. A higher weight value of the factors represents more priority or more impact than others within the study. From the factor weights found for this study area, it is clear that the soil cover, characterized by infiltration, have the highest weights, implying that they have more contribution to flooding in the area as compared to the other factors or elements. This factor not only affects the bare soil surfaces, but the general material the covers a given area.

Table 1Weighted flood hazard ranking for the case study

Factors	Class	Rank	Weight	Score
Land Use / Land Cover	Agricultural land	3	18	54
	Built-up land	5		90
	Current fallow land	2		36
	Grass land	1		18
	Water bodies	5		90
Soil Order	Alfisols	5	14	70
	Entisols	4		56

	Vertisols	3		42
	Inceptisols	2		28
	Reserved Forest	1		14
	Pondicherry	1		14
	Swamp	5		70
Drainage density (km/sq.km)	Very low (0-0.23)	1	12	12
	Low (0.23-0.63)	2		24
	Moderate (0.63-1.05)	3		36
	High (1.05-1.62)	4		45
	Very high (1.62-3.09)	5		60
Rainfall (Rf) in mm	827-1017	1	32	32
	1017-1099	2		64
	1099-1177	3		96
	1177-1279	4		128
	1279-1493	5		160
Elevation	0	5	12	60
	0-2	4		48
	2-7	3		36
	7-13	2		24
	13-27	1		12
Slope (degree)	0-0.49	5	12	60
	0.49-1.04	4		48
	1.04-4.25	3		36
	4.25-89.35	2		24
	89.35-89.71	1		12

3.3Urban Flood Risk Mapping

Flood vulnerability mapping is the process of determining the degree of susceptibility of a given place to flooding. The process involves the selection of bio-physical and/or socio-economic factors of an area; the combination of the selected factors with the decision maker's preferences allows a user to create a composite suitability index. This process results into a multi-criteria and multi-parametric decision making problem. To solve such problems, Boolean overlay and modeling approaches such as neural networks and evolutionary algorithms are recently developed methods for performing flood risk mapping in a GIS environment. However, these approaches lack a well-defined mechanism for incorporating the decision maker's preferences into the GIS procedures. This disadvantage can be solved by integrating GIS and MCE methods, hence producing an effective tool for multiple criteria decision making.

The advantage of MCE is on the integration of a number of choice possibilities in the light ofmultiple criteria and multiple objectives. An integration of GIS and MCDA can help Tourism planners and managers to improve decision making processes when it comes to flood vulnerability analysis. This is because GIS enables the computation of assessment factors, while MCE aggregates them into a flood vulnerability index. In this study, GIS was used in the creation of the criteria maps and data layers, spatial analyses and weighting of the AHP evaluated data sets (Fig.8). This is due to the ability of GIS algorithms to input, store and retrieve, manipulate and analyze, and output spatial and attribute data. As depicted in Figure 8, six different predictor maps were used as structurally represented in the hierarchical structure

$$LC = \frac{1}{n}\sum_{i=1}^{n} D_i W_i \qquad (6.6)$$

where*LC* = linear combination; *Di* = decision parameter; *Wi* = weight; *n* = numbers of parameters.

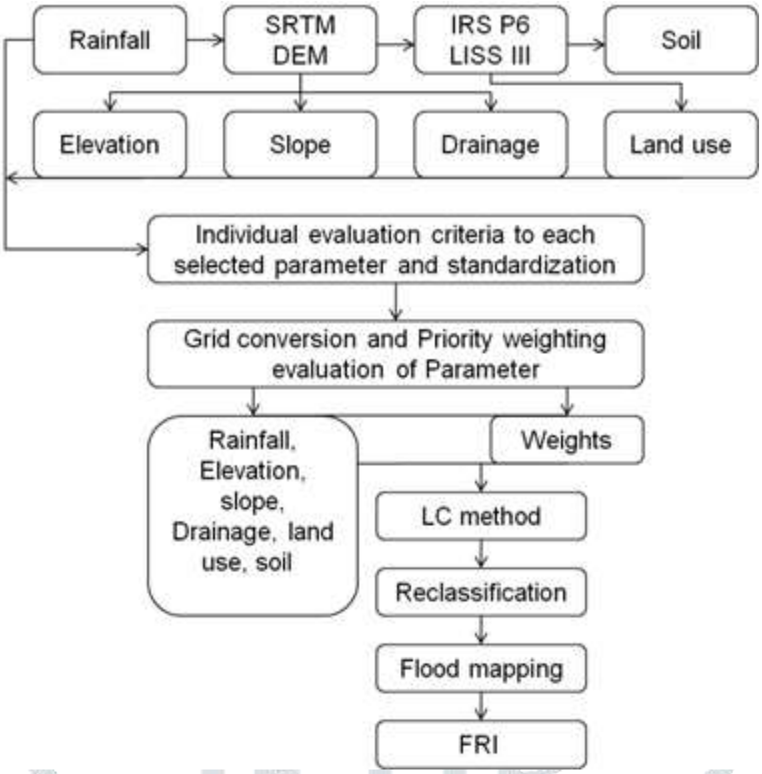

Figure 8Flow chart based flood mapping and flood risk analysis

The most logical and reliable consequence in constructing the vulnerability map was evaluated by the parameters of the study area which are related to given data. In the application of AHP-GIS schema, the parameters concerning the flood risk in the study area have been evaluated and weighted by using the fundamental scale for pairwise comparisons where intensities of 2, 4, 6 and 8 are used to express intermediate values (Table 1). Theoretically, the values which are close to one have the minimum risk and, similarly, the maximum risky areas have values close to nine. Since the effects of the parameters that are related to disasters are in different proportions, each of them has different input values. The next step involves the determination of the Relative Importance Weight (*RIW*) for each hierarchy element by normalizing the eigenvector of the decision matrix. Finally, an flood risk index (FRI) is computed using GIS overlay analysis as in Equation:

$$FRI = Rf_{wt}Rf_{Nr} + El_{Wt}El_{Nr} + dd_{wt}dd_{Nr} + So_{wt}So_{Nr} + Ulu_{wt}Ulu_{Nr} + Sd_{wt}Sd_{Nr} \quad (1)$$

4. Results and Discussion

In the present study, to derive the flood vulnerability map, a weighted linear combination (LC) overlay of the decision factors according to Equation. The result is a flood vulnerability or hazard map showing the most vulnerable areas to flooding within the city. The results show that almost a fifth of the total municipal area was prone to “high” and or “very high” flood hazards. These areas are those that are close to the rivers and generally laying at low elevations within the settled/paved regions. Conversely, four-fifths of the study area was prone to “very low” to “moderate” level of flood hazards. Most of these areas tended to be on the higher grounds and further away from the high drainage density areas. Significantly, the results in Figure 10 depict the fact that Nagapattinam district is prone to “moderate” flooding vulnerability. This is due to the fact that despite the study area having drainage networks, most of them are clogged and coupled with the fact that the urban paved surfaces hinder water infiltration of runoff, these areas are prone to flooding events during heavy rainfall occurrences. As the multi-parametric and multi-criteria analysis forms a single map from the combination of all analyzed map, then the final output will represent the desired result for flood prediction map for the duration of study.

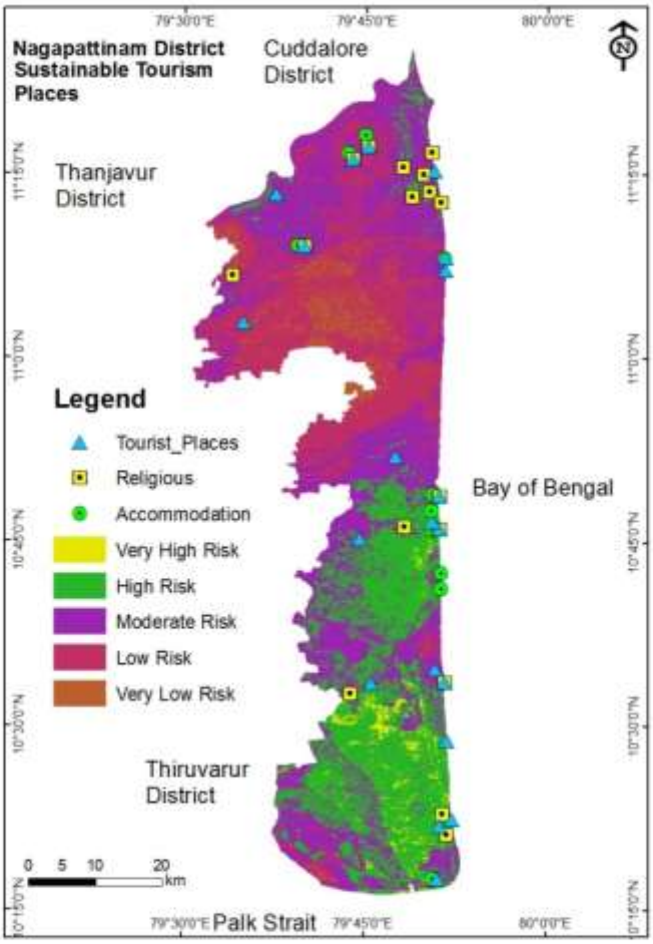

Figure 6.9Flood risk map of the Nagapattinam district for tourism management

The accommodation, religious and tourist places were plotted into the flood hazard zonation map (Table 2). The significant places were placed under high to very high flood hazard zones are revealed that the particular places are monitored for sustainable development of tourism management in the Nagapatinam District.

Table 5 Flood hazard zones verified with the tourism places

Sl. No.	Flood Hazard Zone	Area in Sq.km	Area in %	Tourist Places	Religious Places	Accommodation
1	Very Low Risk	92.96	3.38	5	4	4
2	Low Risk	733.96	26.49	4	4	3
3	Moderate Risk	1112.80	40.47	7	6	2
4	High Risk	764.66	22.81	3	2	4
5	Very High Risk	45.59	1.66	1	0	0
	Total	2749	100	20	16	11

5. Conclusions

In presents an empirical approach for mapping vulnerability to flooding in areas through the integration of remote sensing and GIS techniques. The proposed approach can aid decision and policy makers in the rapid assessment and evaluation of flooding phenomenon in Nagapattinam district. The derived flood risks indices (FRI) can be used for decision making towards planning for flood management. In overall, the study results show that the GIS based category model is effective in flood risk zones. The results revealed that the immediate action taken during rainy seasons to avoid tourism and flood risk for the public for maintain sustainable environment in theNagapattinam district. The flood mapping is very helpful for present and future context sustainable urban bus stop development activities in the Nagapattinam district.

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