Flood susceptibility mapping using MCDM-AHP approach and geospatial techniques – a study of Hyderabad District, Telangana, India

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Abstract: Recently, humans have been susceptible to a growing number of natural hazards, the most severe and frequent of which is flooding. This study aims to prepare flood hazard risk zone maps of Hyderabad District based on MCDM-AHP method and RS-GIS tools. Various parameters like physiographic, climatic, LULC and pedological were used and thematic maps were prepared from various sources, which were integrated into the ArcGIS software to identify flood hazard zone based on weighted overlay method. Each parameter has given a relative weightage depends on their significance, and sub-class of each parameter was given ranking from 0 to 5. The resultant flood risk map is classified into low, moderate and high-flood risk zone and the result was verified further using past flood events occur in the area. This study can be useful to the planners and local authorities in developing flood prevention and mitigation strategies in Hyderabad District.

Keywords: flood susceptibility zones; analytic hierarchy process; AHP; weighted overlay analysis; WOA; geographical information system; GIS; remote sensing.

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1 Introduction

In the era of climate change, mapping and assessment of flood risk is very much important for flood management effectively (Sahana and Patel, 2019). The probability of the existence of a potentially harmful event over a fixed amount of time and space is referred to as the hazard (Varnes, 1984). Flood danger, is the likelihood of a flood occurrence of a certain magnitude occurring in a given location within a certain time frame. Identification and assessment of flood susceptible areas along with flood management and mitigation are essential, since absolute flood protection is not possible (Vojtek et al., 2021). Flood vulnerability analysis is an essential part of flood-prone land use planning. It generates, charts and maps that are easy to interpret and quickly available, allowing managers and planners to locate areas of concern and prioritise mitigating efforts. Floods are one of the world's most recurrent, widespread, disastrous, and constant natural disasters. Natural disasters such as earthquakes, tsunamis, landslides, tropical storms (hurricanes, cyclones, and typhoons), coastal inundation, and floods affect large areas of the world; however, many countries are also vulnerable to man-made hazards (Li et al., 2012). Although, floods are a common natural hazard, prevention and mitigation of it can be facilitated by flood susceptibility mapping (Msabi and Makonyo, 2021).

India, a nation with varied hypsographic and climatic environments, has 85% of its land area exposed to a variety of natural hazards, with 22 states classified as multi-hazard states. India is one of the most flood-affected countries in the world, ranking second, and accounts for one-fifth of all flood-related deaths worldwide. During the monsoon season (June–September), India receives 75% of its moisture. As a result, almost all rivers flood during this time, causing sediment accumulation, drainage congestion, and infiltration into the main field. Floods impact over 8 million hectares of land in India per year. This means, that almost 32 million Indians are affected by deluge-related disasters. According to the Central Water Commission report, nearly 37 million hectares (nearly one-eighth of

India’s geographical area) of fertile land are vulnerable to flooding at any point during the monsoon season (Valdiya, 2004).

While floods are not as extreme in the Hyderabad District as they are in the Indo-Gangetic plains, they are becoming more regular and severe. The main contributor to the intense flooding in the state is the continuous presence of high intensity rainfall for a few days. Other considerations include inappropriate land use policies and poor control of water supply and forestry. Human interventions that contribute to flood issues are mostly likely to take the form of reclamation of wetlands and water sources, changes in land use patterns, the development of dense networks of roads, the creation of more and more cities, deforestation in upper catchments, and so on. Flood losses increase as floodplain occupancy increases. Flooding in cities is caused by clogged or insufficient storm sewers as well as rapid urbanisation. A series of extreme flood incidents that happened during the past century and caused significant harm to life and property demonstrate the importance of adequate flood control initiatives in the district. With continuing floodplain occupancy and reclamation of water sources and wetlands, flood issues are expected to intensify.

Rachna and Joisy (2009) created a flood vulnerability map for the Vamanapuram River Basin, taking into account a variety of contributing factors such as annual rainfall, watershed size, slope, gradient of river and stream, drainage density, form of soil, land usage, communication lines, and infrastructures. Saini and Kaushik (2012) used GIS to determine the danger and vulnerability of flood hazards in the Ghaggar Basin, India. The research attempted to develop a Flood Risk Index (FRI) based on hydrology, slope, soil composition, drainage density, landform, and land usage. Thilagavathi et al. (2011) and Punithavathi et al. (2011) have performed flood risk assessment or flood hazard zonation studies based on different parameters.

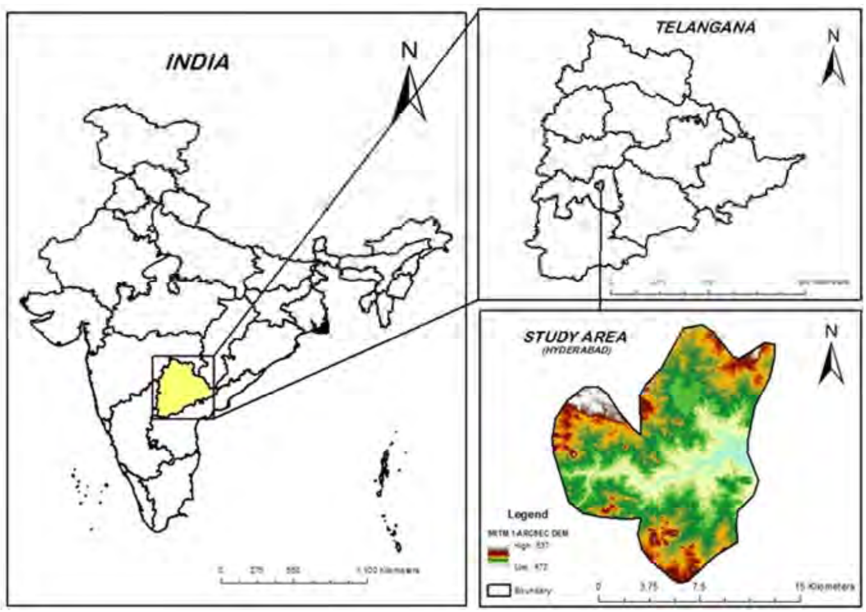
Recent trends and advancements in geospatial technologies for monitoring flood-prone areas have provided leverage to track, measure, and reduce the risk posed by floods. Geographical information system (GIS) and remote sensing (RS) data include a range of techniques such as stream channel, watershed delineation, and elevation information. GIS has been used by the decision makers for implementing strategy in the flood prone areas (Sar et al., 2015). The RS methodology contributes significantly to flood visualisation and risk management. RS and GIS are easier and more efficient, providing the best ability to record, preserve, aggregate, process, recover, analyse, and view information for determining possible threat areas. This study utilises an ensemble approach to show the effectiveness of GIS-based food modelling. The weighted overlay analysis (WOA) technique was paired with RS and GIS to predict flood probabilities.

The main objective of this study, is to investigate the use of RS, geographic information systems (GIS), and the WOA methodology for flood susceptibility analysis and mapping in the Hyderabad District. The aim, of the research is to mapping and identifying the flood hazard zones in the Hyderabad District. Various datasets, in terms of thematic layer are generate here that can be used as input into the weighted overlay to categorise possible flood prone areas, to create a food vulnerability map of the Hyderabad District, and to conduct impact analysis that will be helpful to local authority officials, analysts, and planners in developing food reduction strategies.

2 Study area

The study area, Hyderabad District (Figure 1), is a physiographic region of Telangana, covering roughly around 178 square kilometres. The Hyderabad's latitude and longitude can be projected as 17°22′31″ N and 78°28′27″ E. Hyderabad district is located in the Indian State of Telangana and is part of the Hyderabad metropolitan area. In 1978, the Hyderabad region was divided into two parts: the Hyderabad urban area and the Hyderabad rural area. The rural area of Hyderabad was later called Rangareddy District. The Hyderabad metropolitan area is now known as Hyderabad District. The city, is located on the Deccan Plateau at a height of about 500 meters above sea level.

Figure 1 Location map of the study area (see online version for colours)



Greater Hyderabad Municipal Corporation, Secunderabad Cantonment, Lalaguda, and Osmania University are all included in the Hyderabad District. In Hyderabad, mandals (or tehsils) are the 16 administrative districts. Amberpet, Asifnagar, Shaikpet, Bahadurpura, Bandlaguda, Marredpally, Charminar, Ameerpet, Golconda, Khairtabad, Saidabad, Secunderabad, Musheerabad, Khairtabad, Saidabad, Secunderabad, Musheerabad, Khairtabad, Saidabad, Secunderabad, Musheerabad Himayathnagar, Nampally and Trimulgherry According to 2011 census, the population of Hyderabad was 3,943,323, ranking it 57th in India (out of a sum of 640). The population density in the city is 18,480 people per square kilometre (47,900 people per square mile). Its population grew at a 4.71% annual rate from 2001 to 2011. Hyderabad has a gender ratio of 943 females per 1,000 males and an 80.96% literacy rate.

3 Materials and methods

3.1 Datasets used

For this study, preparation of various thematic maps, such as elevation, slope, drainage density, annual rainfall, flow accumulation, distance to drainage network, aspect, NDVI, LULC and soil types were prepared for the generation of flood hazard map. Arc GIS 10.4 software tools were used to generate thematic maps. The Landsat 8 image of 2020 was used to produce the land use/land cover map (LULC) and the normalised differential vegetation index (NDVI) map. Landsat 8 with a spatial resolution of 30 m was downloaded from USGS website, where path/row number is 144/48 and date of acquisition was 2 May 2020. Land use and landcover (LULC) map was produced by using supervised classification technique using maximum likelihood classification (MLC) algorithm. the elevation, slope, drainage density, flow accumulation, distance to drainage network, aspect were prepared from shuttle radar topographic mission (SRTM) digital elevation model (DEM) image. The SRTM DEM with a spatial resolution of 90 m was also obtained from the USGS website (https://earthexplorer.usgs.gov). The rainfall map, was generated with Arc GIS spatial analyst software and the IDW process. The IMD rainfall data was used to prepare the rainfall map. The soil data downloaded from soil grids website (https://soilgrids.org/) and map was prepared using ArcGIS 10.4 software.

3.2 Analytical hierarchy process

The AHP method was used to generate a pairwise matrix of conditional variables. The AHP method is a well-known method for solving complex problems. Different researchers have used pairwise rating methods in flood risk studies to capture the significance and contributions of each conditional element in flood mapping. Both flood susceptibility factors, were ordered hierarchically in this approach to allow pairwise comparison. In this analysis, we assessed the relative significance of susceptibility factors using a comparative scale suggested by Saaty (1987), which consists of integer numbers ranging from 1 to 9, with 1 indicating that the factors are similarly relevant and 9 indicating that they are significantly more important than others. Table 1 shows a 10 * 10 pairwise reference matrix of diagonals, it compares the value of each unit, elements are equal to 1. The remaining values in each row reflect the relative significance of the remaining variables.

The pairwise comparison matrix (Table 1) for thematic layers (elevation, slope, drainage density, annual rainfall, flow accumulation, distance to drainage network, aspect, NDVI, LULC and soil types) and their parameters was created by using the scale given by Satty. The effect percentage of thematic layers and the rank for its parameters were determined using the pairwise comparison matrix, the relative weight matrix, and the normalised principal eigenvector. The pairwise comparison for the ten layers were, focused on the similarity of the layers and their relative value to flood hazard prospects, and a 10 * 10 matrix was established.

Figure 2 Methodology for the preparation of flood susceptibility map

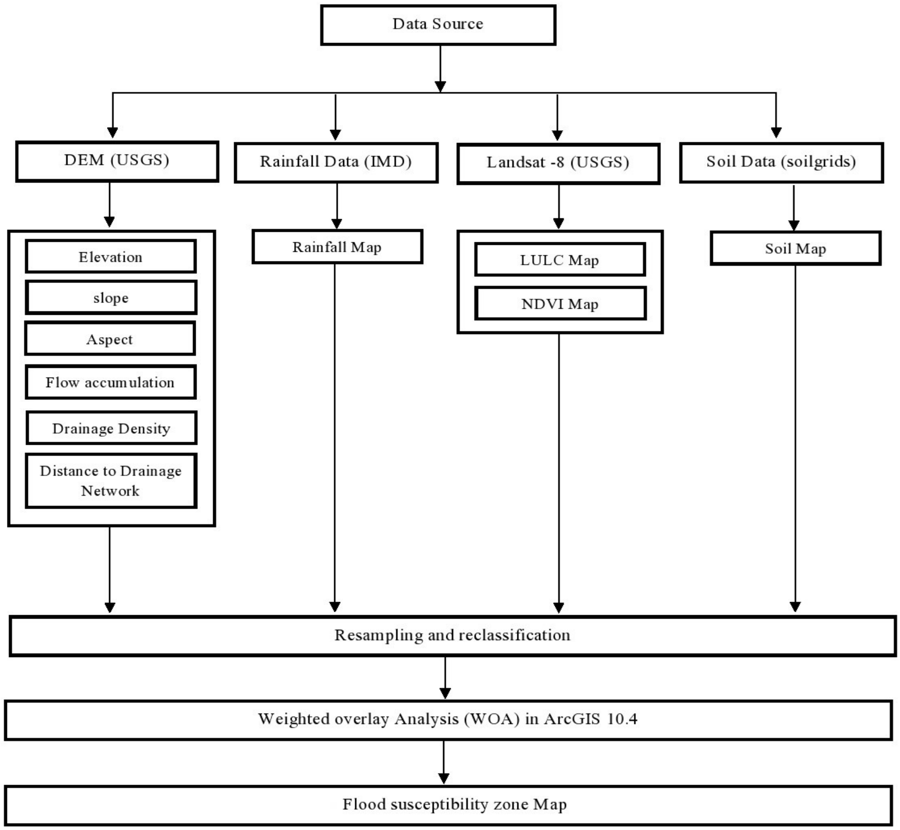


Table 1 Pairwise comparison matrix – thematic layers

Thematic layers	*L1*	*L2*	*L3*	*L4*	*L5*	*L6*	*L7*	*L8*	*L9*	*L10*
L1	1	1/3	1/2	1	4	3	4	1	3	1
L2	3	1	2	1/2	4	1/2	2	5	6	1/3
L3	2	1/2	1	2	5	3	5	2	3	5
L4	1	2	1/2	1	1/3	3	1/2	1	2	1/2
L5	1/4	1/4	1/5	3	1	1/2	1/4	1	1/4	3
L6	1/3	2	1/3	1/3	2	1	1/4	1/3	1/3	1/4
L7	1/4	1/2	1/5	2	4	4	1	4	4	1/3
L8	1	1/5	1/2	1	1	3	1/4	1	1	4
L9	1/3	1/6	1/3	1/2	4	2	1/4	1	1	2
L10	1	3	1/2	2	1/3	4	3	1/4	1/2	1
Total	10.16	9.95	5.76	13.33	25.66	24	16.5	16.58	21.25	17.41

Table 2 Relative weight matrix – thematic layers

Thematic layers	*L1*	*L2*	*L3*	*L4*	*L5*	*L6*	*L7*	*L8*	*L9*	*L10*
L1	0.10	0.03	0.08	0.07	0.16	0.13	0.24	0.06	0.14	0.06
L2	0.30	0.10	0.34	0.04	0.16	0.02	0.12	0.30	0.28	0.02
L3	0.20	0.05	0.17	0.15	0.19	0.13	0.30	0.12	0.14	0.29
L4	0.10	0.20	0.08	0.07	0.01	0.13	0.03	0.06	0.09	0.03
L5	0.02	0.02	0.03	0.23	0.04	0.02	0.02	0.06	0.01	0.17
L6	0.03	0.20	0.06	0.02	0.08	0.04	0.02	0.02	0.02	0.01
L7	0.02	0.05	0.03	0.15	0.16	0.17	0.06	0.24	0.19	0.02
L8	0.10	0.02	0.08	0.07	0.04	0.13	0.02	0.06	0.05	0.23
L9	0.03	0.02	0.06	0.04	0.16	0.08	0.06	0.06	0.05	0.11
L10	0.10	0.30	0.03	0.15	0.01	0.17	0.18	0.02	0.02	0.06
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3 Normalised principal eigenvector – thematic layers

Thematic layers	*Normalised principal eigenvector*
L1	0.11
L2	0.17
L3	0.17
L4	0.08
L5	0.06
L6	0.05
L7	0.11
L8	0.09
L9	0.06
L10	0.10

Table 4 Influence percentage for thematic layers

Thematic layers	*Influence percentage*
L1	11
L2	17
L3	17
L4	8
L5	6
L6	5
L7	11
L8	9
L9	6
L10	10

In the comparison matrix (Table 1), L1 – elevation, L2 – slope, L3 – flow accumulation, L4 – drainage density, L5 – soil types, L6 – annual rainfall, L7 – aspect, L8 – distance to drainage network, L9 – LULC and L10 – NDVI. The following steps were taken to quantify the normalised principal eigenvector based on the comparison matrix. The column values were summed. Then, each column unit was divided by its corresponding column sum to form the relative weight matrix (Table 2). The normalised principal eigenvector by averaging across the rows (Table 3) and then the effect percentage for each thematic layer based on the normalised principal eigenvector were calculated (Table 4).

To check the accuracy of the relation, a consistency ratio (CR) of less than or equal to 0.1 implies an appropriate reciprocal matrix, whereas a ratio greater than 0.1 indicates that the matrix should be modified (Yahaya et al., 2010). The accuracy ratio is determined as follows:

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI} \tag{1}$$

where CI is the consistency index and RI is the random consistency index.

$$\mathrm{CI} = \lambda\,\mathrm{max} - \mathrm{n}/\mathrm{n} - 1 \tag{2}$$

where λ max is the principal eigenvalue and n is the number of comparisons.

Based on the random consistency value, the accuracy reviewed for thematic layers is max = 10.312, n = 10, RI = 1.49, CI = 0.034, and CR = 0.023, all of which are smaller than the threshold value of 0.1.

3.3 Weighted overlay analysis

The WOA is an easy, simple, and sufficient approach for evaluating possible flood hazard areas. Ten environmental factor maps, were used in this analysis to determine flood vulnerability mapping. In order of significance, those factors were given a numerical proportional rating on a 1–5 scale (Table 5). The classes of the factor were also allocated weights (Table 5) and grades, with higher weightage and ranks showing a greater impact on flood occurrence. To create the flood hazard zone map, these factors were overlaid as thematic layers in Arc GIS using the weighted overlay method (WOM). The prepared risk map was divided into three zones: low, moderate, and high hazard zone.

The WOA was run using the procedures given below.

3.3.1 Choosing an evaluative scale

To perform the analysis, each cell from each map layer must be reclassified into a common preference scale, such as 1–5 and then adding the input raster.

3.3.2 Setting scale values

The estimation scale is used to assign values to the call values for each input raster in the study. It is, now possible to perform arithmetic operations on raster that previously contained different types of values. The values assigned may also be adjusted depending on their suitability or significance.

Table 5 Assignment of ranking and weightage values of different thematic layers

SI no.	*Parameters*	*Weightage (%)*	*Classes*	*Rank*
1	Elevation	11	472–505	5
			505–538	4
			538–571	3
			571–604	2
			604–637	1
2	Slope (%)	17	0–6	5
			6–12	4
			12–18	3
			18–24	2
			24–30	1
3	Flow accumulation	17	0–85.92	1
			85.92–64,919.2	2
			64,919.2–97,378.8	3
			97,378.8–129,838.4	4
			129,838.4–162,298	5
4	Drainage density (km/km^2)	7	0–3.06	1
			3.06–6.12	2
			6.12–9.18	3
			9.18–12.24	4
			12.24–15.31	5
5	Soil type	6	Arenosols	1
			Cambisols	4
			Fluvisols	2
			Leptosols	3
			Solonetz	4
			Luvisols	2
			Vertisols	2
6	Annual rainfall (mm/year)	6	53–65	1
			65–77	2
			77–89	3
			89–101	4
			101–113	5
7	Aspect	11	Flat (–1)	1
			North (0–22.5)	1
			Northeast (22.5–67.5)	2
			East (67.5–112.5)	3
			Southeast (112.5–157.5)	3
			South (157.5–202.5)	5
			Southwest (202.5–247.5)	4
			West (247.5–292.5)	4
			Northwest (292.5–337.5)	2

Table 5 Assignment of ranking and weightage values of different thematic layers (continued)

SI no.	*Parameters*	*Weightage (%)*	*Classes*	*Rank*
8	Distance to drainage network (m)	9	100	5
			200	4
			300	3
			400	2
			500	1
9	LULC	6	Forest	1
			Agriculture	2
			Built up areas	3
			Water bodies	5
10	NDVI	10	–0.20—0.01	5
			–0.01–0.19	4
			0.19–0.39	3
			0.39–0.58	2
			0.58–0.78	1

3.3.3 Adding weights to the input raster

Flow accumulation and slope layer were given the most weightage in this analysis for flood risk zone analysis since it was deemed to be the most significant parameter.

3.3.4 Finally running the weighted overlay tool in ArcGIS software

Each input raster's weighted is multiplied by the corresponding cell values of each input raster. To perform the WOA, all of the layers were reclassified, modified to raster, and resampled. This means that all pixels are the same size and are label equally. This research was carried out in ArcGIS using the weighted overlay tool (WOT). The ten of the input layers, were used as data for the overlay analysis. This research uses the mathematical equation given below

$$RI = \sum W_i R_j \tag{3}$$

where W denotes the weightage assigned to each layer and R, denotes the rank assigned to each theme within a layer. The i represents the number of layers, and the 'j' represents the number of themes within each layer.

$$\begin{aligned} RI = {} & W1*R1 + W2*R2 + W3*R3 + W4*R4 + W5*R5 \\ & + W6*R6 + W7*R7 + W8*R8 + W9*R9 + W10*R10 \end{aligned} \tag{4}$$

where

$W1 \times R1$ weight and rank of elevation layer

$W2 \times R2$ weight and rank of slope layer

$W3 \times R3$ weight and rank of flow accumulation layer

W4 × R4 weight and rank of drainage density layer

W5 × R5 weight and rank of soil type layer

W6 × R6 weight and rank of annual rainfall layer

W7 × R7 weight and rank of aspect layer

W8 × R8 weight and rank of distance to drainage network layer

W9 × R9 weight and rank of LULC layer

W10 × R10 weight and rank of NDVI layer.

These weighted factor maps were incorporated into a GIS platform and WOM analysis was used to create a flood hazard zonation map (Figure 2). By collecting the historical data from recent flood incidents and overlaying it on the hazard zone map to verify the results.

4 Result and discussion

In the present examination an attempt has been made for flood hazard zonation of the Hyderabad District based on the analysis of the ten parameters via elevation, slope, drainage density, flow accumulation, soil type, annual rainfall, aspect, distance to drainage network, LULC and NDVI. The summary, of each parameter extracted and the maps generated are provided below as details:

4.1 Elevation and slope

For any geographic analysis, the slope and elevation of the land is a significant geospatial parameter. A 30 m resolution SRTM DEM dataset was analysed [Figure 3(a)] using ArcGIS 10.4 to create the slope map [Figure 3(b)], which included filling sinks and extracting continuous flat regions to establish flow consistency. The vulnerability, of any region to flooding is influenced by two main factors: elevation and slope. The elevation differential, between two points are separated by a unit distance is referred to as slope. The majority of flood-prone areas have low surface slopes and are situated in low-elevation districts. In the other hand, how high a region’s elevation is in comparison to neighbouring regions’ elevations, and how it can be classified based on past flood events. In different parts of Hyderabad District, the slope and elevation values are different.

4.2 Flow accumulation

Flow accumulation, is one of the most important variables in the evaluation of hydrological problems, and it has been extensively calculated and used in various studies. This factor, represents the total flow obtained from upstream areas to a particular point within the catchment. A higher flow accumulation value means a greater chance of water accumulation, and therefore a greater chance of flooding. Flow accumulation [Figure 3(c)] values are categorised into five classes in this study, ranging from very low (0–85.92 pixels) to very high (129,838.4–162,298 pixels) flow accumulation.

Figure 3 Susceptibility factors used in this study, (a) DEM (b) slope (c) flow accumulation (d) drainage density (e) soil type (f) annual rainfall (g) aspect (h) distance from the drainage network (i) land use/cover (j) NDVI (see online version for colours)

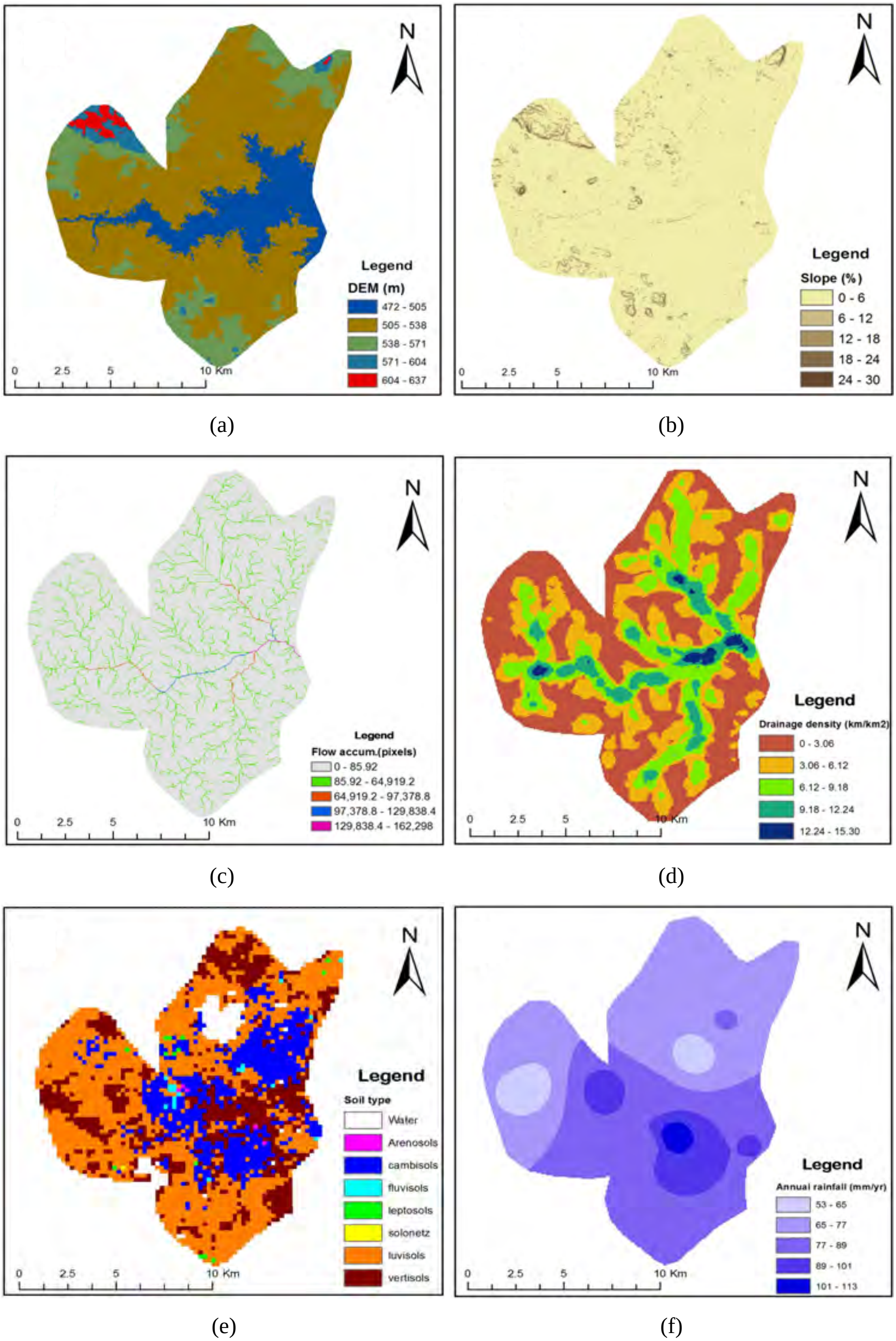
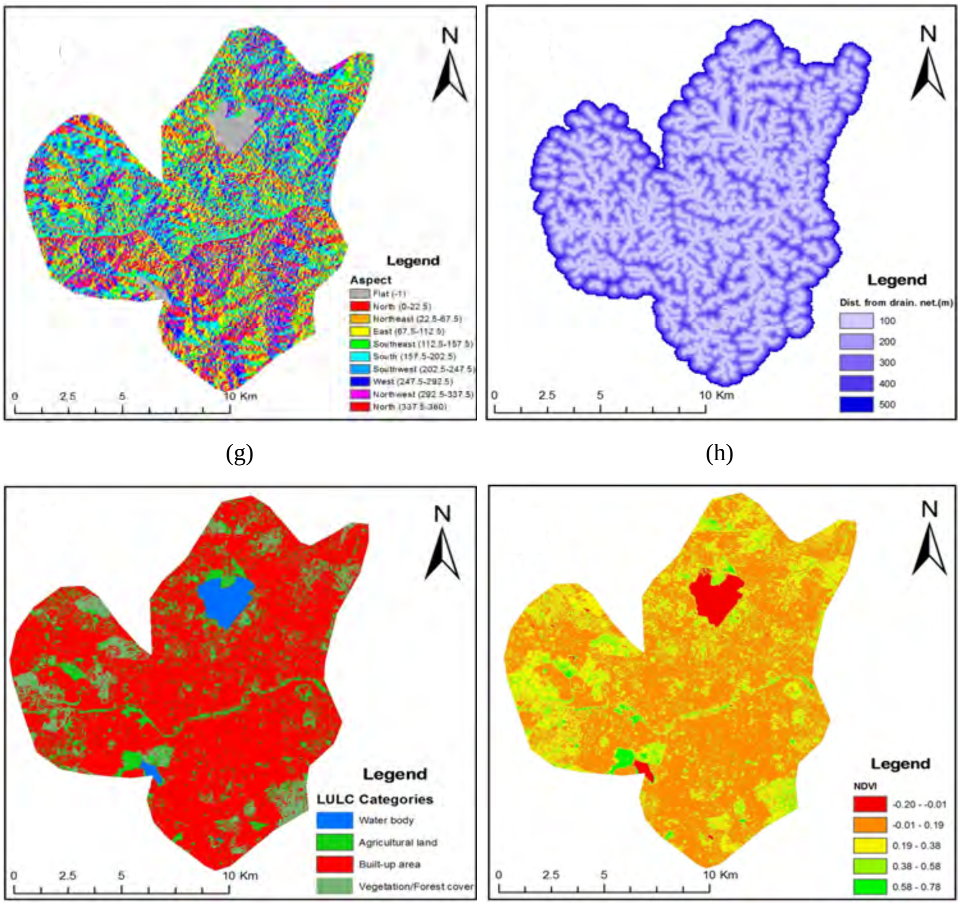


Figure 3 Susceptibility factors used in this study, (a) DEM (b) slope (c) flow accumulation (d) drainage density (e) soil type (f) annual rainfall (g) aspect (h) distance from the drainage network (i) land use/cover (j) NDVI (continued) (see online version for colours)



(g) (h)

(i) (j)

4.3 *Drainage density*

Drainage, is a critical habitat for hazard management because its densities indicate the condition of the soil and its geophysical properties. The drainage density has a major impact on floods. The drainage network was used to measure the drainage density map of the study area. The drainage density values are divided into five categories [Figure 3(d)]. The classes are 0–3.06, 85.92–64,919.2, 64,919.2–97,378.8, 97,378.8–129,838.4 and 129,838.4–162,298. Ranks were allocated to each class depending on their influence in causing the flood. The rank 1, indicates that the area has little influence and is not vulnerable to flooding. Rank 2, indicates a less affecting and less vulnerable to flooding zone. Rank 3, indicates a moderately affecting and moderately vulnerable to flooding zone. Rank 4, indicates that the area is highly influential and vulnerable to flooding. Rank 5, indicates a high level of influence and a high risk of flooding. The drainage density class rating of 0–3.06 falls under rank 1. Rank 2 includes the drainage density class value distribution of 85.92–64,919.2. The rating levels 64,919.2–97,378.8 are found in rank 3. The rating for rank 4 ranges from 97,378.8 to 129,838.4 and for rank 5 the value ranges 129,838.4–162,298.

4.4 Annual rainfall

One of the primary sources of flooding is, heavy rainfall. Floods are synonymous with precipitation extremes; all water that cannot quickly seep into the earth runs down the slope as runoff. The information, is gathered from the Meteorological Department. Rainfall amounts are also divided into five categories [Figure 3(f)]. The classes are 53–65 mm, 65–77 mm, 77–89 mm, 89–101 mm and 101–113 mm. The rank 1, indicates that the area has a little influence and is not vulnerable to flooding. Rank 2, indicates a less affecting and less vulnerable to flooding zone. Rank 3, indicates a moderately affecting and moderately vulnerable to flooding zone. Rank 4, indicates that the area is highly influential and vulnerable to flooding. Rank 5, indicates a high level of influence and a high risk of flooding. The greater the rainfall, the greater the chance of flooding. Rank 1, is assigned to ranges between 53–65 mm. Rank 2, includes the 65–77 mm class value set. The rating levels 77–89 mm are found in rank 3. The rating for rank 4 ranges from 89–101 mm and for rank 5, the value ranges 101–113 mm.

4.5 Soil types

The soil types in a region, are important because they regulate the amount of water that can infiltrate into the soil and therefore the amount of water that flows. The research region contains seven different varieties of soil. The soil forms observed are as follows: arenosols, cambisols, fluvisols, leptosols, solonetz, luvisols and vertisols. The majority of the area is covered with luvisols soil [Figure 3(e)].

4.6 Aspect

Aspect, regulates a slope segment’s exposure to wind direction, rainfall, sunshine, regulating vegetation growth, evapotranspiration, and soil moisture retention, which determines its infiltration-to-runoff ratio and direction. The aspect values are divided into nine categories [Figure 3(g)]. The classes are flat (–1), north (0–22.5), northeast (22.5–67.5), east (67.5–112.5), southeast (112.5–157.5), south (157.5–202.5), southwest (202.5–247.5), west (247.5–292.5) and northwest (292.5–337.5).

4.7 Distance to drainage network

The distance from the drainage network has a significant impact on the spread of a riverine flood event. A possibility of lower flooding is experienced, in regions far from streams. At the same time, areas near rivers experience periodic floods. For example, considered areas within 100 m of the drainage network have high flood susceptibility, while areas greater than or equal to 500 m have very low flood vulnerability. According to Pradhan (2009), areas situated within 90 metres of the drainage network have a high flood risk. Similar to research that follow the approach, regions closer to the drainage network are much more likely to flood, so flood-prone zones of the study area are delineated accordingly. Distance to drainage network values are categorised into five classes [Figure 3(h)] in this study, ranging from very low (100 m) to very high (500 m).

4.8 LULC

The land-use pattern of a region, has a considerable influence, surface runoff, infiltration rate, and evapotranspiration are also characteristics of hydrological processes. As a result, in flood susceptibility mapping, this is considered as one of the critical parameters. The 2020 Landsat 8 imagery was used to determine land use and land cover. The spatial resolution of those imagery is 30 m. ArcGIS 10.4 was used for the study, and a supervised classification using the MLC algorithm. The main land uses in the study area are as follows: forest, agriculture, built up areas and water bodies [Figure 3(i)]. The MLC, showed good overall accuracies, with evaluations of 90% and Kappa accuracies of 88%. The accuracy study, showed that the verification rates for years 2020 were more than 85%, suggesting an excellent accuracy match. Forest areas come under rank 1. Agriculture land is found in rank 2. The build-up areas are a significant determining factor and classified in rank 3. The water bodies classified in rank 5.

4.9 NDVI

In this study, the vegetation cover map was collected using the NDVI index [Figure 3(j)] and a Landsat ETM+ image from the 2020 year in ArcGIS 10.4 software. The Normalized Difference Vegetation Index (NDVI) is a vegetation index that measures plant greenness or photosynthetic activity. It is, among the most widely used vegetation indices. Greenness, can be determined by taking the ratio of red and near infrared bands from a remotely sensed image and converting it into an index of vegetation. The NDVI is certainly the most widely used of these vegetation ratio indices:

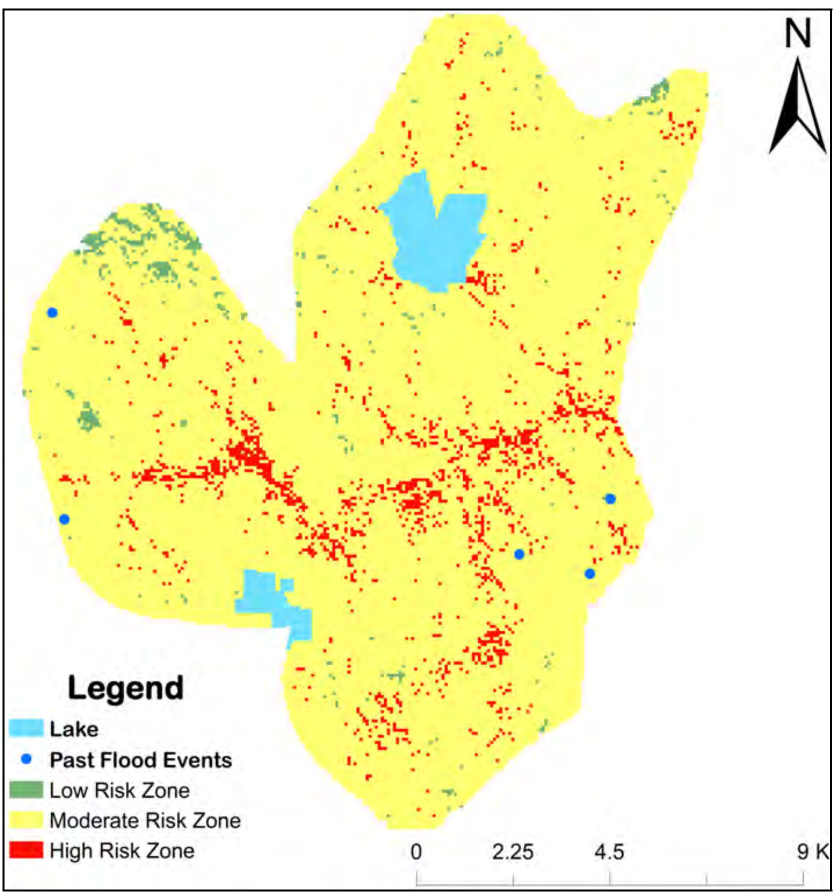
$$\text{NDVI} = \text{NIR} - \text{RED} / \text{NIR} + \text{RED}$$

where NIR is a near infrared band value and RED represents the red band value. NDVI can be computed for any image with a red and near-infrared band. The digital number (DN) values of NDVI images range from –1 to +1, with –1 representing very deep water and +1 representing fully dense vegetation cover. As a result, the investigation of vegetation cover density would only look at positive values (Myneni et al., 1995).

4.10 Flood hazard zone map

Flood hazard zonation assessment, is very crucial for rational management of watershed (Stefanidis and Stathis, 2013). Flood risk zonation map (Figure 4) was prepared by weighted overlay index (WOI) approach with ranking on GIS platform. The ranking and weightage values of different thematic layers are given table. Flood hazard zone map was classified into three areas of flood susceptibility: low-risk zone, moderate-risk zone, and high-risk zone. Low prone to flood category about 2 sq.km areas. Moderately prone to flood is about 161 sq.km. High-risk zone is about 8 sq.km. Flood susceptibility map may help to take proper flood measures to reduce the risk and vulnerability (Das and Gupta, 2021). The obtained findings were considered to be very close to the general conception of flood-prone regions in the study field. 93% of the total area, comes under the moderate risk zone and 5% under high-risk zone. Only 2% of the area is in a safe condition. The regions which are highly susceptible to flood are Afzail Nager, Daruishifa, Rahnimpura, Hasan Nager, Saleh Nager, Bholakpur and part of Shaali Banda, these are areas were around Musi River. This shows that the approach introduced in the current study with a limited number of variables can be used to estimate flood susceptibility in a consistent manner. For the study region, the most influential factors for flood incidence were defined as slope, drainage pattern, and LULC. However, soil and rainfall conditions play an important role in flood incidence. Data from past Flood events obtained from the Google search engine were used to verify the accuracy of the Flood hazard zonation map produced. As a result, the WOA in ArcGIS was useful in creating a flood risk zone map. Changing the percent effect or weighted for the considered may produce a different production map. The above weightage and ranks, however, is allocated based on the field of evidences, some logics, and discussions with the corresponding field experts. Flood susceptibility map is an important tool for flood risk management and priority areas are defined for detailed studies (Amaya et al., 2021).

Figure 4 Flood susceptibility zonation map of Hyderabad District (see online version for colours)



5 Conclusions

This perspective illustrates the relevance and role of RS and GIS techniques in flood hazard zonation mapping. The WOA is an easy, simple, and sufficient approach for evaluating possible flood hazard areas. It has allowed to combine voluminous datasets despite their differences. The majority of the dangers are determined by a number of quality plan. To forecast such complex phenomena, a systematic multi-criteria evaluation is required, so that reduction and managing of such dangers may be made easier. AHP is one such multi-criteria technique that yields accurate predictions, and it is used in our study. GIS tools and research are useful in a variety of areas. This has been used for visualisation, modelling and study of a wide range of emergency relief applications at different levels and ranges. Floods are a natural occurrence that cannot be avoided. Human action, on the other hand, is leading to a rise in the probability and severity of major flood events. For example, the magnitude and frequency of floods are expected to increase as a result of climate change would result in increased rainfall rate and increasing sea levels, as well as poor river maintenance and development in flood plains, reducing their ability to contain flood waters. Second, the number of residents and economic properties in flood-prone areas is increasing. The research, suggests a quick and cost-effective method of using a GIS to create a flood threat map from an existing data base. An effort was made in this analysis to create a flood threat map by using ArcGIS software tools. Flood prone areas can be detected by using the flood hazard map, which can aid in the proper preparation of construction works to prevent flooding in the future. The map created in this study will definitely assist disaster managers, planners, and local authorities in better understanding flood susceptibility in the region. It is, also predicted that the flood-susceptible map created in this study would assist various agencies in the region in guiding practical measures for flood risk reduction.

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