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MCDM MODELING FOR FLOOD RISK ZONING USING FUZZY LOGIC

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Abstract: Risk is a combination of factors that determine people's vulnerability and exposure prospects to a hazard. The estimation of flood extents and the identification of vulnerable factors aid in determining high-risk flood zones in advance, allowing for effective and efficient mitigation actions. This study investigates how effectively flood risk can be assessed using a fuzzy approach, taking into account the study location's frequent flooding. Twelve factors were selected for the case study in India's East Godavari District to construct the flood risk assessment model using a fuzzy logic approach and Arc GIS. This study found that extremely high, very high, high, medium, and low risk zones are distributed throughout the study area. Meanwhile, the percentage area under various levels of flood risk in the East Godavari district is calculated and displayed in a bar chart, as is the magnitude of flood risk calculated by estimating flood hazard, flood vulnerability, and flood risk at various locations throughout the study area.

Index Terms **– Disaster Management, Fuzzy logic, Hazard, Vulnerability, Risk, Arc GIS.**

1.0 INTRODUCTION

Rivers all over the globe are subjected to floods due to heavy rainfall that occurs in the river's catchment. Floods when exceed a certain stage will not only interrupt with the normal activities in the region, but also cause damage to life and property in the area where they occur. Such a flood causing is considered as a potential flood hazard. Depending on the conditions that prevail in the area where flood hazard is present risk due to flood will depend on the extent to which the region is vulnerable to the flood. Thus the risk due to flood depends on the magnitude of the flood hazard in a location and the degree of vulnerability of that region to the hazard.

A timely assessment of flood risk enables mitigation of the possible damage and safeguard property and life. This very significance of flood risk assessment has attracted the attention of the research community all over the globe for developing risk assessment models and identifying the flood risk zones.

Numerous methods, models, and software have come into existence for flood risk assessment. In recent days, techniques based on Multi-Criteria Decision Making (MCDM) models have been identified to be very effective in flood risk analysis. There are two types of such studies and they are: (i) the Analytical Hierarchy Process (AHP) method and (ii) the Fuzzy Logic Approach. Basically, both methods consider the effect of a number of parameters that affect a particular system through ranking them in a particular manner. In other words, the relative influence of the parameters on the occurrence of an event to a certain degree will be estimated. In the present study Fuzzy logic based MCDM model has been developed for flood risk assessment for any region and the model developed is applied to a selected study area.

The concept of Multi-Criteria Decision Making is to identify all the possible criteria that affect any system that needs a decision, assign membership functions followed by the generation of rules for the decision-making process. Membership function is nothing but dividing the entire range of the numerical value associated with a criterion that forms a part of the decision making process. In the present study, a Fuzzy Information System (FIS) has been developed for flood risk analysis, considering the criteria that are hazardous with respect to the occurrence of floods in an area and the criteria that decide the extent of vulnerability of that area. The fuzzy information system flood risk assessment (FISR) developed in the present study involves at the outset the development of two separate fuzzy information systems, one for hazard (FISH) and another for vulnerability (FISR). These two systems in turn are generated by grouping the pertinent criteria belonging to the hazard and vulnerability based on their nature. The FIS for hazard

(FISH) is effectuated through three sub FIS of hazard. Similarly, the FIS for vulnerability is developed through two sub FIS of vulnerability. The details of these groups are given in the next section which deals with the information related to the factors that are responsible for flood risk.

2.0 FACTORS CAUSING FLOOD RISK

As indicated already, risk due to floods is caused by such factors that are responsible for occurrence of hazard scenario and the susceptibility i.e., vulnerability of any area due to the presence of such a hazard. Several factors cause hazard and vulnerability while only some of them are most significant. In the present study 12 parameters are considered to be significant in creating a hazardous situation w.r.t. floods and vulnerability of the location under such a hazard for causing flood risk of varying level. Table 1 given below Table 1 shows the decision criteria (parameters) considered in the present study that influence the hazard, vulnerability. The grouping of these parameters for developing the sub FIS for hazard (FISHR, FISHS and FISHT) and sub FIS for vulnerability (FISVL and FISVA) is also shown in that table.

Table 1: Decision Making Criteria (Parameters) for Flood Hazard and Flood Vulnerability

Flood Risk (FISR)				
Flood Hazard (FISH)			Flood Vulnerability (FISV)	
Hazard Group 1 (FISHR)	Hazard Group 2 (FISHS)	Hazard Group 3 (FISHT)	Vulnerability Group 1 (FISVL)	Vulnerability Group 2 (FISVA)
Rainfall Intensity	Sediment Transport Index	Topographic Wetness Index	LULC	Altitude
Rainfall Frequency	Stream Power Index	Slope	Distance to Stream	Temperature
Drainage Density			Population Density	

3.0 METHODOLOGY

The overall methodology followed in the present context is divided in to three parts. They are: (i) Data collection and Generation of Basic Data Layers, (ii) Fuzzy Logic Model Development in MATLAB and (iii) Model Application to a particular selected area. Data related to climatic and topographical parameters are in general available in the form of digital data or in the form of maps in various authentic web sites. In the present study information related to most of the parameters is gathered starting from the basic Digital Elevation Map (DEM) of the study area. From the DEM the basic layers are developed using various functions available in the Arc GIS toolbox. Generation of the base maps enable in identifying the range of variation of each of the parameters which is required for forming Membership Functions for the parameters. The details of the parametric ranges of all the twelve parameters considered here in the model generation are presented later in the section on the study area and data. Once the data is made available, the next step is the development of FIS in MATLAB. This is accomplished either using the FIS toolbox of MATLAB or directly writing MATLAB code in the command prompt. In this study the model is built by writing the relevant code, which was later compared with the toolbox model. The FIS modeling is done in the following steps:

(i) Membership Function Generation for the decision criteria (parameters).
(ii) Linguistic Rule Formulation for decision making on the combined influence of the criteria under consideration,
(iii) Coding for FIS model formulation and
(iv) Output Generation.

The first three steps are referred as Fuzzification and the last step is known as Defuzzification. Defuzzification is performed using the data set corresponding to the location of interest at which the risk level is required to be determined. As there are a number of systems and sub-systems in the present case, the above steps are repeated for each of the systems and sub-systems. Figure 1 shows the overall flowchart of the methodology followed in the present study. The study area considered for applying the model is the district of East Godavari in the State of Andhra Pradesh, India. The DEM of this area which is fundamentally required for all subsequent map generations is obtained from USGS web site which is covered in four different tiles. Figure 1 shows these tiles and the DEM developed there from using Arc GIS software.

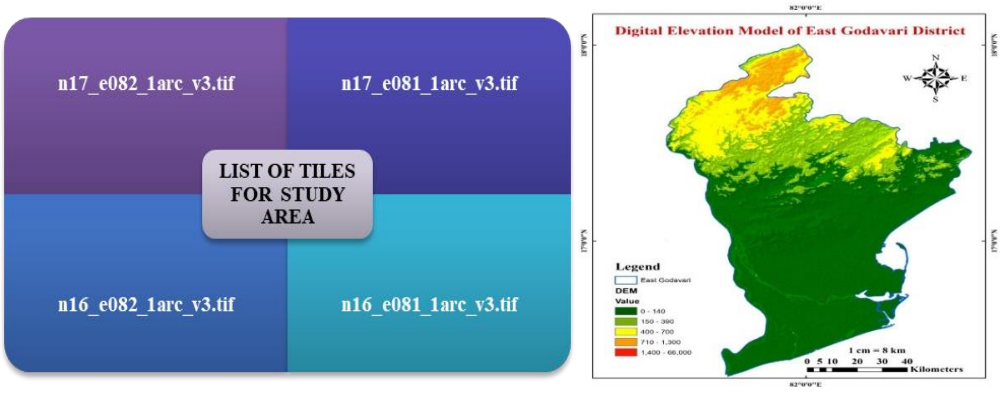

Figure 1: DEM of Study Area - East Godavari District.

4.0 STUDY AREA AND DATA

The study area considered in the present context is the East Godavari district of Andhra Pradesh, India extending between 16° 30' to 17° 00' N Latitude to 81° 30' to 82° 30'E Longitude. Through this district the river Godavari which is one of the major rivers of Indian Peninsular flows before joining in to the Bay of Bengal. Due to heavy flows in the river, this district is often affected by floods in various parts of the district. The district is spread over 10,807 sq.km in a total of 59 mandals. Figure 3 shows the study area map. As indicated earlier, data related to majority of the parameters is generated from the DEM of the area. However, data related to a few parameters such as the rainfall intensity, rainfall frequency, population density and temperature are obtained from other sources. Table 2 shows the sources of all the data used in the present study.

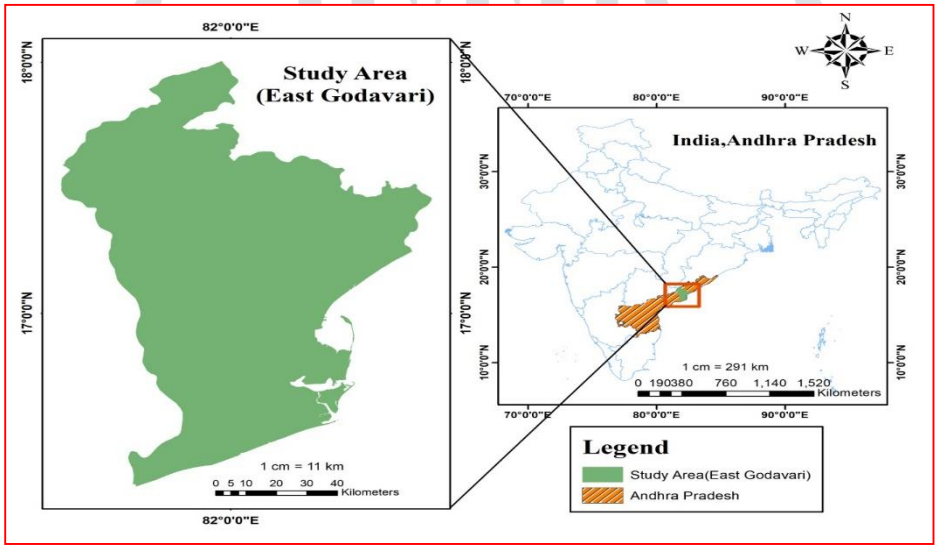

Figure 2: Geographical Location Map of the East Godavari District.

Table 2: Data Collection Sources.

S.no.	Variable	Source of data	Source Address
1	Rainfall Intensity	CRU data	https://crudata.uea.ac.uk/cru/data/hrg
2	Rainfall Frequency	Take a promising data	———
3	Drainage density	USGS DEM	https://earthexplorer.usgs.gov
4	Sediment Transport Index(STI)	USGS DEM	https://earthexplorer.usgs.gov
5	Stream power Index(SPI)	USGS DEM	https://earthexplorer.usgs.gov
6	Topographic Wetness Index(TWI)	USGS DEM	https://earthexplorer.usgs.gov
7	Slope	USGS DEM	https://earthexplorer.usgs.gov
8	Land use & Land cover(LULC)	Sentinel-2A(10 m) satellite online data	https://scihub.copernicus.eu
9	Distance to stream	USGS DEM	https://earthexplorer.usgs.gov
10	Population density	From census data-E.G	https://eastgodavari.ap.gov.in/census
11	Altitude	Using DEM	https://earthexplorer.usgs.gov
12	Temperature	CRU data	https://crudata.uea.ac.uk/cru/data/hrg

4.1 PARAMETRIC MAPS

Membership function ranges are collected from this map of study area. This data used in Fuzzy decision for specified location to plot Risk map in Arc GIS. This Risk Map contain levels from Extremely High to Low. Fuzzy rules are created according to Extraction data from Arc GIS maps. Output risk map depending upon each individual factor of hazard. Flood Hazard is composed of seven factors based on available study area data. Except rainfall frequency from flood hazard factors, this is not available because of hypothesized data for this factor. From these hazard factors, the rainfall intensity map is generated using the Cru dataset and the remaining factors are generated using Dem data.

Flood Vulnerability is composed of five factors based on available study area data. From this, land use and land cover are collected from Sentinel-2A (10 m) satellite online data, distance to stream data collected from Dem file, population density data collected from Census 2011, temperature data collected from Cru dataset and altitude data collected from Dem file.

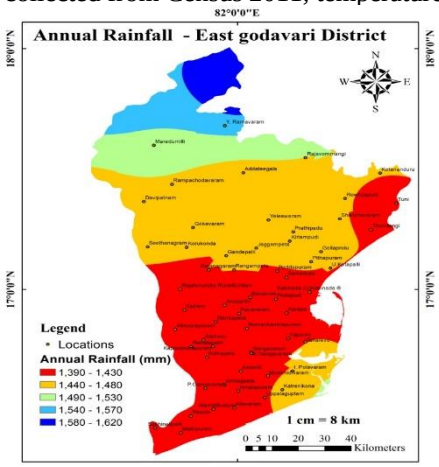

Figure 3: annual Rainfall Map of Study Area (From Cru Dataset)

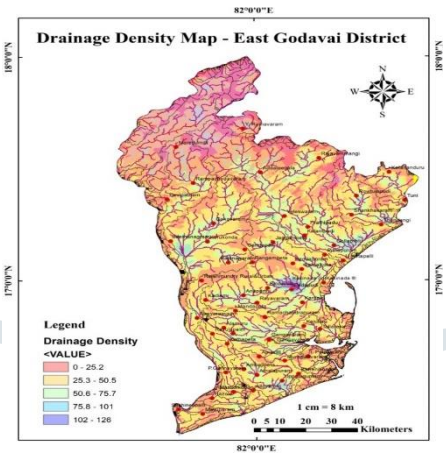

Figure 4: Drainage Density Map of Study area (From Dem map)

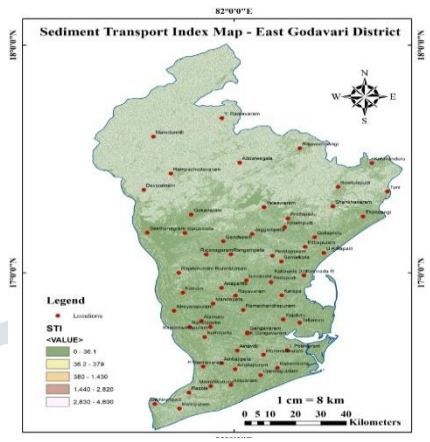

Figure 5: Sediment Transport Index Map of Study Area (From Dem map)

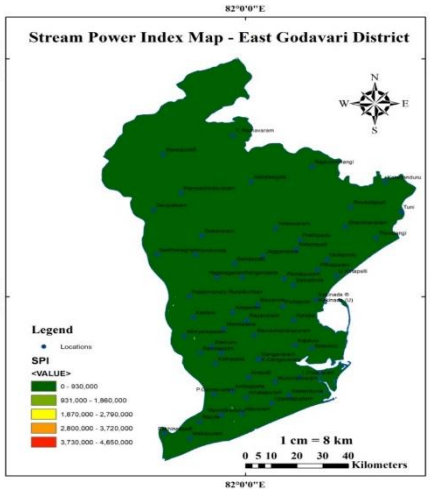

Figure 6: Stream Power Index Map of Study area (From Dem map)

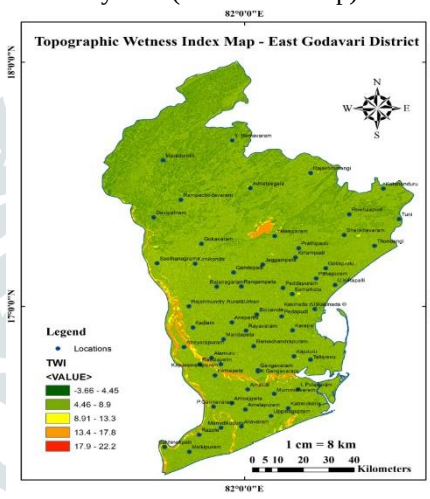

Figure 7: Topographic Wetness Index Map of Study area (From Dem map)

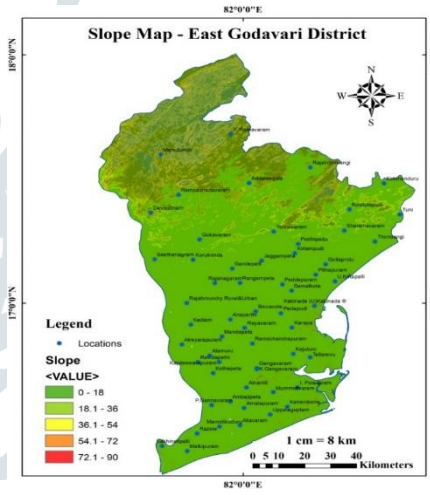

Figure 8: Slope Map of Study area (From Dem map)

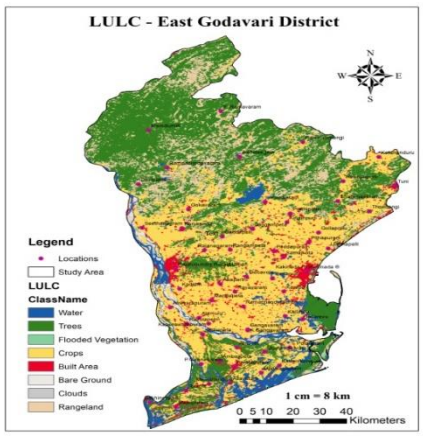

Figure 9: LULC Map of Study area (From Sentinel-2A)

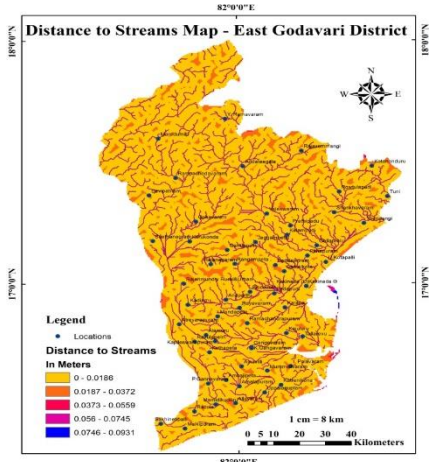

Figure 10: Distance to Streams Map of Study area (From Dem map)

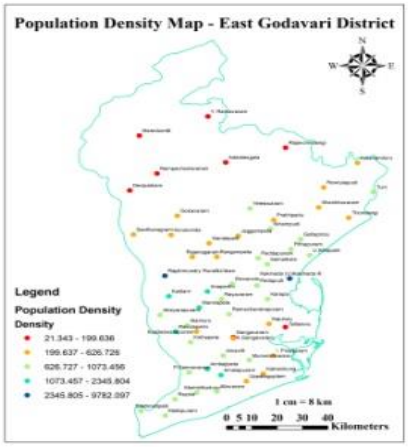

Figure11: Population Density Map of Study area (From Census data)

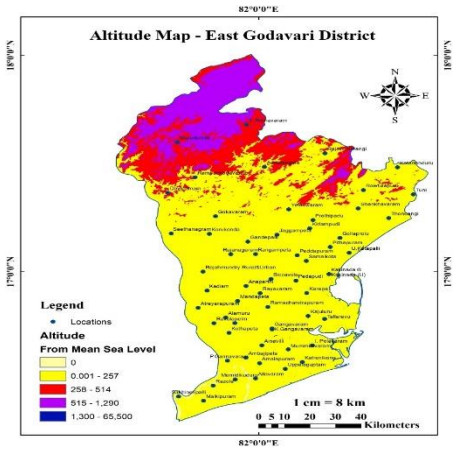

Figure 12: Altitude Map of Study area (From Dem map)

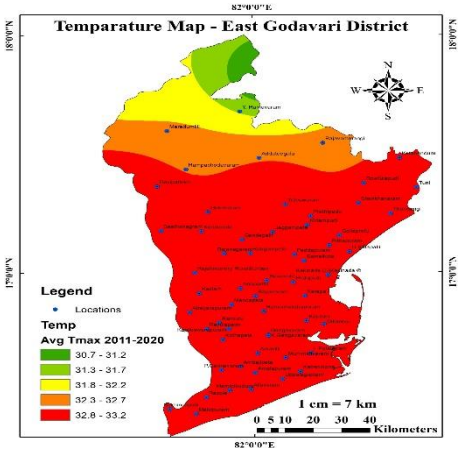

Figure 13: Temperature Map of Study area (From Cru dataset)

5.0 FUZZY BASED MCDM MODEL

It is challenging to quantify vulnerability, hazard, and risk since so many factors (such as rainfall intensity, slope, LULC, etc.) may have complex interactions with these variables. Usually, little is known about these components. In addition, vulnerability, hazard, and risk may have nonlinear relationships with these elements. Therefore, in the assessment of risk due to floods, hazard and vulnerability aspects were considered fuzzy. In this chapter discuss development of fuzzy interface system according to factors available in study area and involves fuzzification and fuzzy interface.

5.1 FUZZIFICATION

This entails employing membership functions to translate propositions into numeric values. Take the statement, "If Drainage density is high, hazard is high," as an example. In binary logic, levels like "high" and "low" are given crisp bounds, however in fuzzy logic, non-sharp (or fuzzy) boundaries can be given. The membership functions defined in a fuzzy model describe the "degree of belief" of a specific value of an input factor, as shown in Figure. Illustrates how a drainage density of, say, 20 m/km value need not be assigned to a "Low" or a "Medium" hazard group, but can instead be a member of both categories. (20% Low as well as 75% Medium Hazard). For each criterion, fuzzy membership types should be set in order to assign a level of risk and determine the best layout. Fuzzy memberships should be chosen based on the attributes of the data, especially how those factors affect the risk of flooding.

Membership functions come in a variety of shapes, such as triangles, trapezoids, Gaussian waveforms, bell-shaped waveforms, sigmoidal waveforms, S-curve waveforms, and more. According to earlier research, using a triangle or trapezoidal waveform is preferable when a system exhibits a significant dynamic variation over a short period of time.

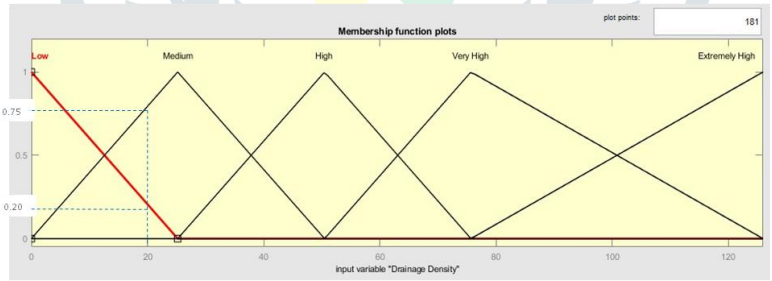

Figure 14: Membership Function for Drainage Density.

5.1.1 MEMBERSHIP FUNCTIONS

These East Godavari mandals were categorized into five hazard zones into five equal intervals, as recommended by research papers. The hazard areas were named as a Low hazard zone for $0 < \text{Hazard} \leq 20$, a Medium hazard zone for $20 < \text{Hazard} \leq 40$, a High hazard zone for $40 < \text{Hazard} \leq 60$, a Very High hazard zone for $60 < \text{Hazard} \leq 80$ and an Extremely High hazard zone for $80 < \text{Hazard} \leq 100$. According to this analysis, the study area has different hazard zone levels.

These East Godavari mandals were categorized into five vulnerability zones into five equal intervals, as recommended by research papers. The vulnerability areas were named as a Low vulnerability zone for $0 < \text{Vulnerability} \leq 20$, a Medium vulnerability zone for $20 < \text{Vulnerability} \leq 40$, a High vulnerability zone for $40 < \text{Vulnerability} \leq 60$, a Very High vulnerability zone for $60 < \text{Vulnerability} \leq 80$ and an Extremely High vulnerability zone for $80 < \text{Vulnerability} \leq 100$. According to this analysis, the study area has different vulnerability zone levels.

These East Godavari mandals were categorized into five risk zones into five equal intervals, as recommended by research papers. The risk areas were named as a Low risk zone for $0 < \text{Risk} \leq 20$, a Medium-risk zone for $20 < \text{Risk} \leq 40$, a High risk zone for $40 < \text{Risk} \leq 60$, a Very High-risk zone for $60 < \text{Risk} \leq 80$ and an Extremely High-risk zone for $80 < \text{Risk} \leq 100$. According to this analysis, the study area has different risk zone levels.

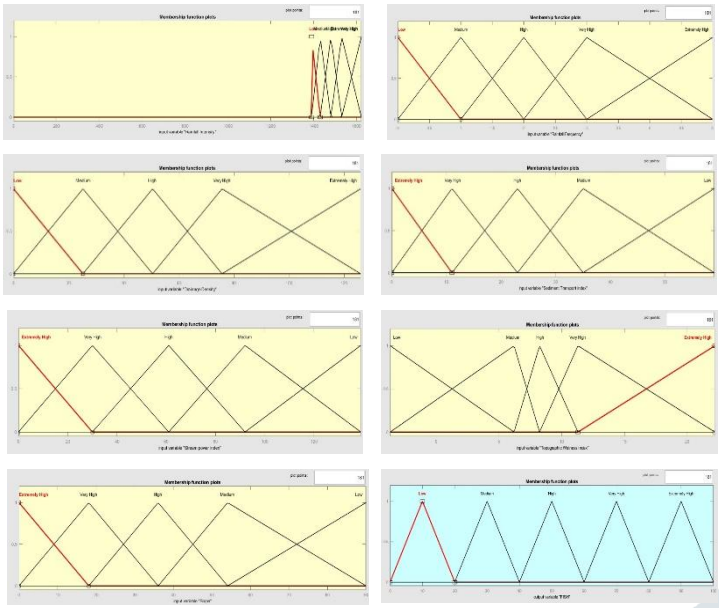

Figure 15: Membership Functions Used to Fuzzification the Hazard.

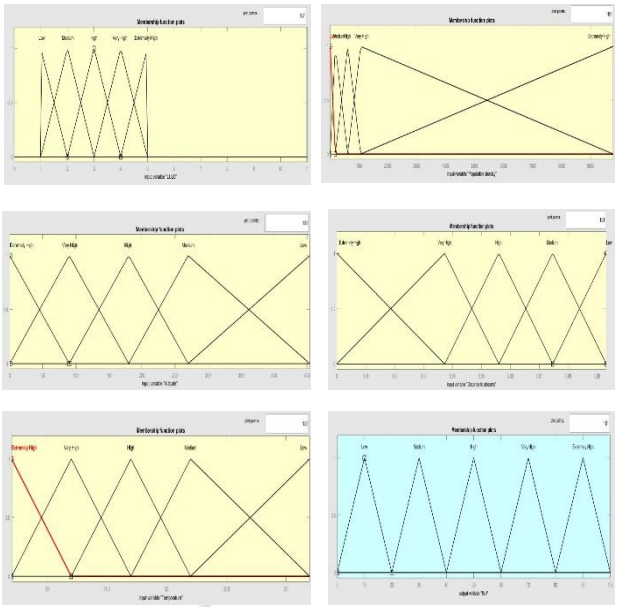

Figure 16: Membership Functions Used to Fuzzification the Vulnerability Factors.

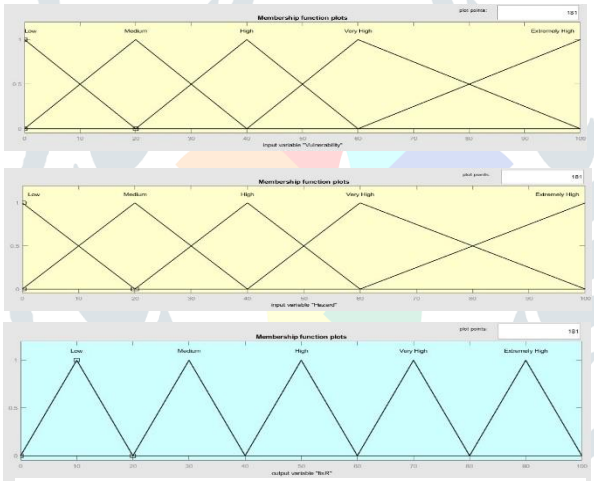

Figure 17: Membership Functions Used to Fuzzificaiton the Risk Factors.

5.1.2 LINGUISTIC RULES

Using normalizing, the fuzzy linguistic rules are generated for the most generalized model. Where there are 125 possible combinations for three input variables and for two input variables, 25 combinations are generated. These linguistic statements are noted as suitable for output.

S.no	Linguistic Rules for 2 Input Values				
	column 1	column 2	column 3	column 4	column 5
1	1	1	1	1	1
2	1	2	1	1	1
3	1	3	1	1	1
4	1	4	1	1	1
5	1	5	1	1	1
6	2	1	1	1	1
7	2	2	1	1	1
8	2	3	1	1	1
9	2	4	2	1	1
10	2	5	2	1	1
11	3	1	1	1	1
12	3	2	1	1	1
13	3	3	2	1	1
14	3	4	3	1	1
15	3	5	3	1	1
16	4	1	1	1	1
17	4	2	2	1	1
18	4	3	3	1	1
19	4	4	4	1	1
20	4	5	4	1	1
21	5	1	1	1	1
22	5	2	2	1	1
23	5	3	3	1	1
24	5	4	4	1	1
25	5	5	5	1	1

Table 2: Linguistic rules for 2 input

- **Above, tables are formatted and arranged using the following steps:**
- **Use five column values for two input factors, and three input factors with an additional input column.**

Column 1 - Index of membership function for first input
Column 2 - Index of membership function for second input
Column 3 - Index of membership function for output
Column 4 - Rule weight (from 0 to 1)
Column 5 - Fuzzy operator (1 for AND, 2 for OR)

5.2 FUZZY INTERFACE

A rule system with knowledge-based logic connects the fuzzified variables to one another. For every feasible pairing of the categories of all factors or variables, a declaration regarding the new variable must be stated. Assume the model has three components: population density, rainfall frequency, and rainfall intensity. If each of these variables has five states (for example, "Low," "low," "High," "Very High," and "Extremely High"), then the output variable must be described by 125 rules (say, the Flood Hazard). The output statement is given by normalizing the rule weight of each individual. Similar rules write for hazard, vulnerability and risk in this work. The system's rules may include the following:

A rule base, or expert rules, is a fairly large set of rules in which a solution to a problem is described in words. The rules are written in an appropriate sequence for ease of understanding, but the sequence is not required in the process. The rules are linked together by the conjunction "or," which is frequently ignored. Each rule is made up of factors that are commonly connected with the conjunction "and."

Rule 1: If Rainfall intensity is Low and Rainfall Frequency is Low and Drainage Density is Low, then the Hazard (HR) is Low.
Rule 2: If Rainfall intensity is Low and Rainfall Frequency is Low and Drainage Density is low, then the Hazard (HR) is Low.
Rule 3: If Rainfall intensity is Low and Rainfall Frequency is Low and Drainage Density is high, then the Hazard (HR) is Low.
Rule 4: If Rainfall intensity is Low and Rainfall Frequency is Low and Drainage Density is high, then the Hazard (HR) is Low.
……
Rule 125: If Rainfall intensity is Extremely High and Rainfall Frequency is Extremely High and Drainage Density is Extremely High, then the Hazard (HR) is Extremely High.

The input variables are converted into the output variables by these rules. A membership function must also be used to define the output variable, which in this case is the hazard, vulnerability, and risk. These functions are typically Low, Medium, High, very high, and Extremely High hazard, as shown in Figure. The number of membership functions taken into account for the input and output variables will determine the number of rules to be considered. Based on such linguistic rules, there are two typical approaches to deductive inference for fuzzy systems: (1) Mamdhani systems, and (2) Sugeno models. The **Mamdhani system**, the earliest inference method, was utilized as the study's fuzzy inference system because it is the most widely used in practice (Mamdhani and Assilian, 1975, as referenced in Ross, 2004).

5.2.1 BUILD FUZZY INFERENCE SYSTEM

The basic concept of FIS for flood risk assessment is illustrated in figure 3.4. For the generation of this FIS Fuzzy Design tool of the MATLAB software is used. The following are the steps involved in the development of the FIS. Example for three input variables is FIS HR group and for two input variables refers FIS HS.

Using the Fuzzy Logic Designer app, you can construct a FIS entirely from the command line.

FIS HR Group:

- **First, create a "Mamdani FIS", specifying its name.**
  fisHR = mamfis('Name',"fisHR");
- **Add the first input variable for the "Rainfall Intensity" using adds Input.**
  fisHR = addInput(fisHR,[0 1622],'Name', "Rainfall Intensity");
- **Add membership functions for each of the "Rainfall Intensity" using add MF, Add five triangular membership functions**
  fisHR = addMF(fisHR,"Rainfall Intensity","trimf",[1390 1390 1430],'Name',"Low");
  fisHR = addMF(fisHR,"Rainfall Intensity","trimf",[1390 1430 1480],'Name',"Medium")
  fisHR = addMF(fisHR,"Rainfall Intensity","trimf",[1430 1480 1530],'Name',"High")
  fisHR = addMF(fisHR,"Rainfall Intensity","trimf",[1480 1530 1622],'Name',"Very High");
  fisHR = addMF(fisHR,"Rainfall Intensity","trimf",[1530 1622 1622],'Name', "Extremely High");
- **Add the second input variable for the "Rainfall Frequency", and add five triangular membership functions.**
  fisHR = addInput(fisHR,[0 5],'Name', "Rainfall Frequency");
  fisHR = addMF(fisHR,"Rainfall Frequency","trimf",[0 0 1],'Name',"Low");
  fisHR = addMF(fisHR,"Rainfall Frequency","trimf",[0 1 2],'Name',"Medium");
  fisHR = addMF(fisHR,"Rainfall Frequency","trimf",[1 2 3],'Name',"High");
  fisHR = addMF(fisHR,"Rainfall Frequency","trimf",[2 3 5],'Name',"Very High");
  fisHR = addMF(fisHR,"Rainfall Frequency","trimf",[3 5 5],'Name',"Extremely High");
- **Add the third input variable for the "Drainage Density", and add five triangular membership functions.**
  fisHR = addInput(fisHR,[0 126],'Name', "Drainage Density");
  fisHR = addMF(fisHR,"Drainage Density","trimf",[0 0 25.2],'Name',"Low");
  fisHR = addMF(fisHR,"Drainage Density","trimf",[0 25.2 50.5],'Name',"Medium");
  fisHR = addMF(fisHR,"Drainage Density","trimf",[25.2 50.5 75.7],'Name',"High");
  fisHR = addMF(fisHR,"Drainage Density","trimf",[50.5 75.7 126],'Name',"Very High");
  fisHR = addMF(fisHR,"Drainage Density","trimf",[75.7 126 126],'Name',"Extremely High");
- **Add the output variable for the "FISHR", and add five triangular membership functions.**
  fisHR = addOutput(fisHR,[0 100],'Name',"fisHR");
  fisHR = addMF(fisHR,"fisHR","trimf",[0 10 20],'Name',"Low");

```
fisHR = addMF(fisHR,"fisHR","trimf",[20 30 40],'Name',"Medium");
fisHR = addMF(fisHR,"fisHR","trimf",[40 50 60],'Name',"High");
fisHR = addMF(fisHR,"fisHR","trimf",[60 70 80],'Name',"Very High");
fisHR = addMF(fisHR,"fisHR","trimf",[80 90 100],'Name', "Extremely High");
```

- **Specify the following three rules for the FIS as a numeric array**
  If (Rainfall is Extremely High) and (Rainfall Frequency is Extremely High) and (Drainage Density is Extremely High) then (FISHR is Extremely High)
  If (Rainfall is Very High) and (Rainfall Frequency is Very High) and (Drainage Density is Very High) then (FISHR is Very High)
  If (Rainfall is High) and (Rainfall Frequency is High) and (Drainage Density is High) then (FISHR is High)
- **Each row of the array contains one rule in the following format.**
  Column 1 - Index of membership function for first input
  Column 2 - Index of membership function for second input
  Column 3 - Index of membership function for output
  Column 4 - Rule weight (from 0 to 1)
  Column 5 - Fuzzy operator (1 for AND, 2 for OR)
- **For the membership function indices, indicate a NOT condition using a negative value.**
- **For more information on fuzzy rule specification, see add Rule.**

```
ruleList = [1 1 1 1 1 1;
            1 1 2 1 1 1;
            1 1 3 1 1 1]; and so, on up to 125.
```

- **Add the rules to the FIS.**

```
fisHR = addRule(fisHR,ruleList);
```

- **Evaluate Fuzzy Inference System**
- **To evaluate the output of a fuzzy system for a given input combination, use the evalfis command. For example, evaluate fis using input variable values of 1, 2 and 3.**

```
evalfis(fis,[1  2  3])
        ans = 1x1
```

- **You can also evaluate multiple input combinations using an array where each row represents one input combination.**

```
inputs = [3 5 1;
          2 7 2;
          3 2 1];
inputs = inputHR
evalfis(fisHR,inputHR)
ans = 3×1
ans =ansHR
```

5.2.2 RULES VIEWER OF FIS

The Rules Viewer option when activated will display all the rules generated. If any rule is to be edited or deleted, the same operation can be performed in this window. Below figures shows the FIS rules for flood hazard and flood vulnerability respectively. Both the hazard and vulnerability are assigned a range of 1 to 100 and this range is classified in to 5 intervals as “Low”, “Medium”, “High”, “Very High”, and “Extremely High”.

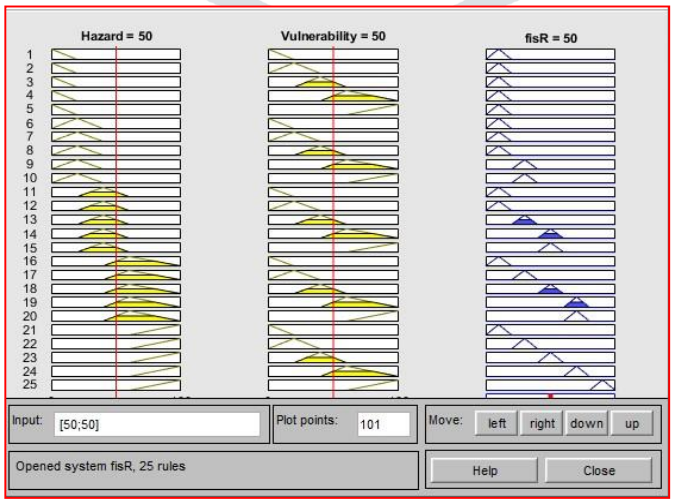

Figure 18: Rules Viewer for Risk.

5.2.3 DEFUZZIFICATION

The outcomes of each rule must be combined into a single result in this last step of the fuzzy inference system. Although there are a number of mathematical techniques for defuzzification, the analysis employed the 'center of gravity' method, which is the most used technique. As a result, the procedure followed involved these steps: (1) utilizing the fuzzification technique to convert input indicators into fuzzy numbers, (2) using fuzzy inference to connect the input indicators and output index, and (3) using

defuzzification to convert the fuzzy index into a crisp value, which is then used as the research area's flood risk. The methods outlined are employed to produce the flood risk fuzzy variables, which are then utilized to determine a fuzzy measure of risk. The fuzzy computations were carried out using the MATLAB software's fuzzy toolbox.
Using the study area's hazard, vulnerability, and risk data, we created maps in Arc GIS that show the level of risk on a scale of 0 to 100. Find these FH, FV, and FR at any location and at any time using the most generalized flood assessment model. In this chapter, we discussed the study area's output maps (East Godavari).

Table 3: FLOOD RISK IN STUDY AREA

S.no	East Godavari District							
	Y-Latitude	X-Longitude	Address (Mandals)	Risk (5)	Risk(4)	Risk(3)	Risk(2)	Risk(1)
1	17.5983355	81.7135475	Maredumilli	15.70	15.70	10.00	10.00	10.00
2	17.6797658	81.956891	Y. Ramavaram	20.81	14.94	14.83	10.00	10.00
3	17.4839322	82.0202304	Addateegala	10.00	10.00	10.00	10.00	10.00
4	17.546866	82.233202	Rajavommangi	10.00	10.00	10.00	10.00	10.00
5	17.4825114	82.4888124	Kotananduru	14.91	15.72	14.91	10.00	10.00
6	17.3573261	82.544292	Tuni	15.58	15.58	15.58	15.58	15.58
7	17.24783	82.4576741	Thondangi	10.00	10.00	10.00	10.00	10.00
8	17.1561749	82.2861382	Gollaprolu	37.90	37.90	37.70	17.95	12.04
9	17.2922225	82.3506142	Shankhavaram	10.00	10.00	10.00	10.00	10.00
10	17.23855535	82.1910932	Prathipadu	10.00	10.00	10.00	10.00	10.00
11	17.2882648	82.1063568	Yeleswaram	26.13	26.28	21.24	17.58	11.62
12	16.7382218	82.04742377	Gangavaram	10.00	10.00	10.00	10.00	10.00
13	17.436699	81.7759679	Rampachodavaram	10.00	10.00	10.00	10.00	10.00
14	17.3644905	81.6795209	Devipatnam	10.00	10.00	10.00	10.00	10.00
15	17.1766571	81.6925246	Seethanagram	17.15	17.35	17.15	10.00	10.00
16	17.1747003	81.8262498	Korukonda	38.46	38.25	33.20	26.56	21.04
17	17.2563226	81.848391	Gokavaram	22.51	22.51	20.55	16.36	10.00
18	17.171159	82.0644394	Jaggampeta	23.48	23.48	17.54	15.60	10.00
19	17.2005349	82.1795209	Kirlampudi	18.55	19.15	18.55	10.00	10.00
20	17.0756673	82.1360026	Peddapuram	21.44	21.54	21.44	20.10	20.10
21	17.1145559	82.2521517	Pithapuram	27.85	28.29	27.85	24.01	24.01
22	17.0878025	82.3187355	U.Kotapalli	20.23	20.27	20.23	15.29	15.29
23	16.9890648	82.2474648	Kakinada ®	23.70	23.70	23.70	23.70	23.70
24	16.9890648	82.2474648	Kakinada (U)	30.00	30.00	30.00	30.00	30.00
25	17.0500453	82.1679386	Samalkota	23.47	23.47	23.47	23.47	23.47
26	17.081637	81.9889323	Rangampeta	10.32	10.42	10.32	10.00	10.00
27	17.1391865	81.961664	Gandepalli	10.00	10.00	10.00	10.00	10.00
28	17.0806322	81.9017706	Rajanagaram	13.93	14.63	11.93	11.46	10.00
29	17.0005383	81.8040345	Rajahmundry Rural&Urban	23.21	23.21	23.21	23.21	23.21
30	16.9135908	81.8182663	Kadiam	30.00	30.00	30.00	30.00	30.00
31	16.8652942	81.9261999	Mandapeta	23.80	23.80	23.80	23.80	23.80
32	16.9340866	81.9555307	Anaparthi	36.19	37.13	36.19	30.00	30.00
33	16.9665505	82.043438	Biccavole	15.06	15.23	15.06	10.00	10.00
34	16.95903248	82.13120142	Pedapudi	13.76	13.89	13.76	10.00	10.00
35	16.9018262	82.1693237	Karapa	24.70	25.18	24.70	15.80	15.80
36	16.7819278	82.2325227	Tallarevu	10.00	10.00	10.00	10.00	10.00
37	16.7958224	82.1740826	Kajuluru	10.00	10.00	10.00	10.00	10.00
38	16.8372408	82.0325401	Ramachandrapuram	30.00	30.00	30.00	30.00	30.00
39	16.9006109	82.0052883	Rayavaram	10.00	10.00	10.00	10.00	10.00
40	16.7629766	81.91638316	Kapileswarapuram	10.00	10.00	10.00	10.00	10.00
41	16.7889753	81.8838931	Alamuru	23.52	23.52	23.52	23.52	23.52
42	16.8334169	81.7869042	Atreyarapuram	14.20	14.40	14.20	10.00	10.00
43	16.762483	81.8423198	Ravulapelm	23.84	23.84	23.84	23.84	23.84
44	16.7338867	82.0475242	K.Gangavaram	10.00	10.00	10.00	10.00	10.00
45	16.71768014	81.89576	Kothapeta	23.85	23.85	23.85	23.85	23.85
46	16.5891247	81.8905145	P.Gannavaram	19.33	19.33	19.33	19.33	19.33
47	16.60335746	81.9554518	Ambajipeta	30.00	30.00	30.00	30.00	30.00
48	16.6600657	82.0114209	Ainavilli	14.55	14.55	14.55	14.55	14.55
49	16.6414998	82.1042955	Mummidivaram	15.98	15.98	15.98	15.98	15.98
50	16.6602506	82.189037	I. Polavaram	10.00	10.00	10.00	10.00	10.00
51	16.5828372	82.1536851	Katrenikona	15.24	16.09	15.24	10.00	10.00
52	16.5513219	82.0938189	Uppalaguptam	20.84	20.49	20.84	10.00	10.00
53	16.5774798	82.0031455	Amalapuram	43.51	42.64	43.51	30.00	30.00
54	16.5078455	81.9889323	Allavaram	10.00	10.00	10.00	10.00	10.00
55	16.5028955	81.9173312	Mamidikuduru	19.32	19.32	19.32	19.32	19.32
56	16.4743259	81.8401957	Razole	22.81	22.81	22.81	22.81	22.81
57	16.4043328	81.806039	Malkipuram	19.87	19.87	19.87	19.87	19.87
58	16.4242668	81.7185253	Sakhinetipalli	30.00	30.00	30.00	30.00	30.00
59	17.3772505	82.3689165	Rowtulapudi	15.50	15.50	15.62	15.02	10.00
Note : Risk value for different rainfall frequency from (1) to (5)								

5.2.4 FLOOD HAZARD, VULNERABILITY, RISK MAPS IN STUDY AREA

Below figures show the final hazard, vulnerability and risk results; These flood maps are generated in five scenarios because the variable of rainfall frequency factor is Vary from 1 to 5. Hazard, vulnerability values vary from 1 to 100 on a scale with respect to risk. These maps represent only for scenario 5 because it gets more risk values.

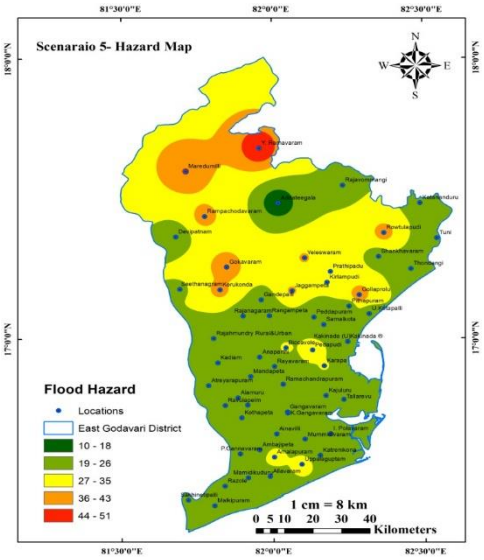

Figure 19: Hazard Map in Study Area for Scenario 5 (Frequency Of Rain = 5 Per Year)

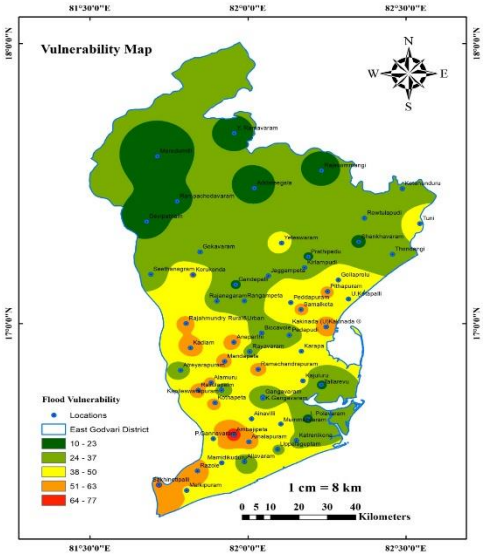

Figure 20: Vulnerability Map in Study Area.

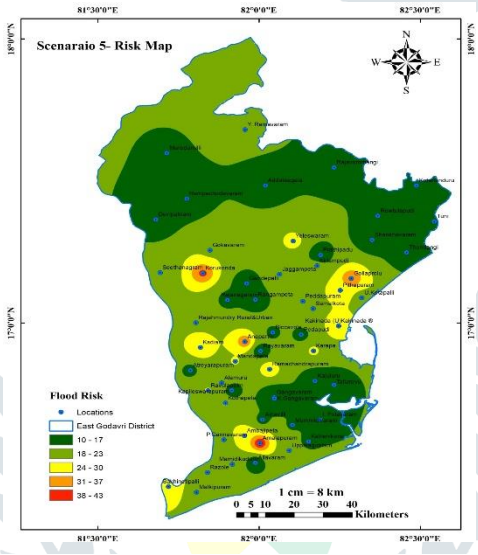

Figure 21: risk map in study area for scenario 5 (frequency of rain = 5 per year)

6.0 CONCLUSION

Over the past few decades, rapid urbanization and climate change have significantly raised the risk of flooding in metropolitan areas. Future risk management will be greatly aided by the identification of regional flood risk levels through flood risk assessment. In this study, an MCDM model based on fuzzy logic was built and used to estimate risk in the East Godavari district. Flood risk levels are distributed spatially throughout the E.G. district area according to GIS maps.

A fair distribution of risk has been obtained as a result of the fuzzy logic-based technique, which successfully identified the levels of indicator parameters, hazards, and vulnerability variables. This increases the likelihood that the fuzzy approach will be successful in risk assessment. Due to the fact that the input and output membership functions are always on a scale of 0-100, the fuzzy approach does not require standardization.

A study is taken up to assess the flood risk for some selected locations in the east Godavari district of the state of Andhra Pradesh. Flood Hazard and Flood Vulnerability criteria are considered to generate the FIS for the flood risk. The flood hazard and flood vulnerability are considered to be influenced by different set of criteria. From the study carried out the FIS-FR, Fuzzy Information System for Flood Risk is generated and the level of flood risk at the selected locations is determined and Flood Risk Map in Mandals level of Study area (E.G) is generated.

REFERENCES

[1] A.K. Gorai, S. A. Hasni and Jawed Iqbal (2014) "Prediction of ground water quality index to assess suitability for drinking purposes using fuzzy rule-based approach".

[2] Brito M De and Evers M, 2016 "Multi-criteria decision-making for flood risk management: a survey of the current state of the art" Nat. Hazards Earth Syst. Sci., 16, 1019–1033.

[3] Chitsaz N., Banihabib M.E, 2015., "Comparison of Different Multi Criteria Decision-Making Models in Prioritizing Flood Management Alternatives". Water Resour Manage. DOI 10.1007/s11269-015-0954-6.

[4] Dragan Pamucar1, Darko Bozanic, Nenad Komazec Military Academy, University of Defense in Belgrade, Serbia "Flood Hazard Assessment by Application of Fuzzy Logic" Conference Paper - October 2014.

[5] Hemalie Nandalal, Uditha Ratnayake (2011) "Flood risk analysis using fuzzy models", Article in Journal of Flood Risk Management · April 2011
[6] Hoggan D.H. ,1996, "Computer-assisted floodplain hydrology and hydraulics", McGraw- Hill.
[7] Kerkez M., Gajovic V., Puzic G.,2017, "Flood risk assessment model using the fuzzy analytic hierarchy process"., Progress in Economic Sciences Nr 4.
[8] Kim Y., Chung E.-S., 2013, "Fuzzy VIKOR approach for assessing the vulnerability of the water supply to climate change and variability in South Korea" Applied Mathematical Modelling 37, 9419– 9430.
[9] Lee G., Jun., K. S., and Chung E.-S., 2015, "Group decision-making approach for flood vulnerability dentification using the fuzzy VIKOR method", Nat. Hazards Earth Syst. Sci., 15, 863–874.
[10] Nandalal H.K. and Ratnayake U.R. "Flood risk analysis using fuzzy models" J Flood Risk Management 4 (2011) 128–139.
[11] O. Sonmez and H. Bizimana (2018) "Hazard risk evaluation using fuzzy logic and weightage-based combination methods in geographic information system" Department of Civil Engineering, Sakarya University, 54187 Sakarya, Turkey.
[12] Opricovic S., 2011, "VIKOR with an application to water resources planning", Fuzzy Expert Systems with Applications 38, 12983–12990.
[13] R. Bakhtyar , A. Ghaheri , A. Yeganeh-Bakhtiary , T.E. Baldock "Longshore sediment transport estimation using a fuzzy inference system" - Civil Engineering Department, Iran University of Science and Technology, Tehran, Iran.
[14] S.S. Ahmad and S.P. Simonovic, Delcan Corporation, Ottawa, ON, Canada, "A three -dimensional fuzzy methodology for flood risk analysis" Department of Civil and Environmental Engineering, The University of Western Ontario, London, ON, Canada.
[15] Saaty R.W., "The Analytic Hierarchy Process - What It Is and How It Is Used," Mathematical Modelling, 9, 161-176 (1987).
[16] Saaty T. L., 1980, "The Analytic Hierarchy Process". McGraw-Hill, New York.
[17] Siddayao G P, Vldez S E., Fernandez P L., 2014, "Analytical Hierarchy Process (AHP) in spatial Modelling for Flood Risk Assessment" International Journal of Machine Learning and Computing. Vol. 4. No. 5.
[18] Valentina Nikolova, Plamena Zlateva. (2016) "Assessment of Flood Vulnerability Using Fuzzy Logic and Geographical Information Systems" 1st International Conference on Information Technology in Disaster Risk Reduction (ITDRR), Nov 2016, Sofia, Bulgaria.
[19] Yang X., Ding J., Hou H., 2013 "Application of a triangular fuzzy AHP approach for flood risk evaluation and response measure analysis", Nat Hazards, 68: 657-674.
[20] Zadeh, L. A., 1965. "Fuzzy sets. Information and Control", 8, 338–353.
[21] Zou Q., Zhou J., Song L., Guo J., 2013, "Comprehensive flood risk assessment based on set pair analysis-variable fuzzy sets model and fuzzy AHP" ,2013 Stoch Environ Res Risk Assess 27: 525–546.