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Plan a Condensed Risk Model using Fuzzy Logic for Natural Disaster Management

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***Abstract*—The assessment of natural risk and similar meteorological phenomenon risk management is the prima facie for management of Chaotic features associated with the atmospheric phenomena in Bangladesh. This paper interprets a reduced risk model of natural calamities in respect of Bangladesh established on the application of fuzzy inference system. This paper intends to represent a condensed risk model for natural disaster management implemented by applying fuzzy inference system. A hierarchical fuzzy inference system is built aided with rule-based reasoning and fuzzy logic and designed as inputting four variables from a fuzzy set. The concluding output is the natural mapping process developed using the Fuzzy Logic Toolbox from the MATLAB. The accuracy and efficiency of the algorithm given by experimental analysis provide the forecasters of an invaluable opportunity to merge the system in effective disaster management systems and can be available tools in the form of desktop-based software (combined with the web) to the department of disaster management (DDM) in Bangladesh.**

Keywords*— Bangladesh, fuzzy logic, weather-forecast, natural hazards, risk assessment, evaluating risk

I. INTRODUCTION

Regardless of the advancement in science and technology, natural catastrophic events affect adversely the socioeconomic conditions of the all regions around the globe. From the most recent couple of decades negative effect of characteristic risks on human life, economy and condition is expanded radically [1]. Natural occasions, for example, tremors, avalanches, floods, Tropical storms, dry spells, tornadoes and so forth are regularly known as natural calamities. The checking of regular dangers, the assessment of their effect and the general hazard appraisal are the most essential strides on taking satisfactory defensive measures. Governments can propose various methodologies to moderate and decrease the antagonistic outcomes. [2]- [3].

The natural hazard assessment of catastrophic events is a significant concern for the trustworthy hazard management and the economical network improvement for our nation. Hence, there is have to propose coordinated ways to deal with the evaluation of common dangers. The accessibility of an appropriate evaluation of the total misfortune because of antagonistic natural phenomenon would help taking more well-educated choices for viable decisions from the risk management authority [13]-[17]. Then again distributed cloud computing is a developing business foundation and web-based cost-proficient platform where data can be retrieved from the internet by clients as indicated by their necessity [4]. The fuzzy logic technique is a basic instrument for chance evaluation. This technique permits the master information and unsure quantitative information handled viably [18]-[21].

The main aim of this paper is to use the structural fuzzy logic technique to determine the "Total Hazard" caused by natural calamities in Bangladesh using usable data and expert knowledge. Our proposed model, which is most likely implemented as part of a web-based information system, is primarily used for measuring natural disaster measurement using Cloud computing.

II. RELATED WORKS

The risk of occurring natural calamities such as earthquake, heavy rainfall, floods, etc. has risen steadily every day over the last few decades. But over this catastrophic threat we are not worried. Since the buzz of extreme natural disaster, we have already experienced so many, which also has a catastrophic impact on the life cycle of humans, national economy and even major environmental changes. In contrast to this harsh world of nature, we people aren't really useless in figuring out any way, in figuring out how we can reduce some natural disaster loss to make us especially post-

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concerned. In this sense, we cannot make ourselves Hundred per cent pre-concerned because our Almighty is totally running and managing these things. Only he will save us from this curse. Scientifically it is a natural phenomenon which depends on some climatic parameter. Yet the chance of natural disaster can still be reduced. Many researchers are already doing their work trying to construct an effective decreased risk model, occurring natural disaster is not a predetermined occurrence, so using the Fuzzy logic method, they perform their calculation and recommendation. They collect available information from various sources and the expert expertise in one paper [21]. They then apply a fuzzy logic method to sort out the outcome and proceed to integrate with information system. Another paper [22] "Fuzzy Logic Model for Natural Risk Assessment in SW Bulgaria" authors take identical vulnerable area of Bulgaria in associated risk order with respect to degree of complex natural risk and then Matlab fuzzy logic toolbox as well as Simulink for computing fuzzy data and projected performance. This helps them in the efficiency of risk assessment and also it helps them make further effective decisions.

On another paper [23] they take various disasters types as an indicator, then collect previous statistics to integrate with their process to scope out minimal implications throughout the potential risk model. They also handle cloud technology in to get the danger circulated faster and much more effectively than it was before.

At long last, from another two papers [24]-[25] they likewise utilize the equivalent just info sets are not the same as different techniques.

E. Foroutan, J.Maleki combined GIS system with existing fuzzy logic scheme in their paper, this GIS system allows them to take more accurate decisions in residential zones. This model also has introduced a map of risk indicators for vulnerable areas.

III. METHODOLOGY

The fuzzy logic model is projected as a hierarchical system with restricted number of inputs with two intermediary outputs and one final output.These inputs related to the indicators as linguistic variables which depict the natural calamities being monitored. The final performance shows a complete natural disaster risk assessment which is also a complicated risk assessment. There are three fuzzy logic subsystems in our proposed framework.

There are different types of qualitative approaches, from them the fuzzy logic technique is rely mostly on subjective assessments about the comparative importance of the prediction about parameters of data and their different situations. In our analysis, four key parameters for the Bangladesh complete risk assessment are defined using the statistical data package, expert advice and also valid online compositional maps of recent times for the hazards of the earthquake, extreme temperature and rainfall [5]-[10]. The Fuzzy logic model indicators are source parameters of prototype fuzzy model. Inputs of Fuzzy model are defined as:

- Source 1: Intense temperature.
- Source 2: Intense rainfall.
- Source 3: Earthquake.
- Source 4: Density of population

The proposed Fuzzy logic framework is modeled as a Fuzzy hierarchical system with four inputs previously described. One fuzzy logic subunit is included in first step. There are also two fuzzy logic subunits with one intermediate variable and one input variable at second and third level. Here intermediate variable means the output from first two fuzzy logic subunits.

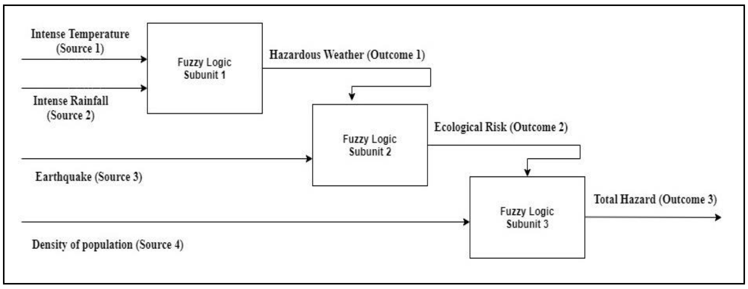

Fig.1. Proposed fuzzy logic system

The highest and lowest production value reflects the respective highest and lowest degree of risk [12]. Figure 1 indicates the three-level hierarchy fuzzy logic structure with four sources, with one final output.

The first fuzzy logic subunit in this system consists of two sources respectively "Intense temperature" and "Intense Rainfall," Which generates the geographical outcome parameter that stated as Intermediary variable 1 " Hazardous weather". Similarly, the next fuzzy logic subunit consisted of one "Hazardous weather" outcome parameter and the Input 3 "Earthquake" bring out the "Ecological risk" outcome parameter defined as Intermediary variable 2.

The third fuzzy logic subunit contains of two sources that are "Density of population" source 4 and "Ecological risk" output variable two, and the final output variable is specified as output 3 which is the "Total Hazard" of the entire system.

" Absolute risk" end product is the final production which indicates the level of risk depending on the membership function. The final production, which is called the "Total Hazard" gives the combined assessment of the risk caused by our country's natural calamities. The overall factor result value is optimal for the final calculation value at true risk.

The total output of the multi-tire, fuzzy logic systems is the value of the last fuzzy logic module. This final output variable provides a full threat assessment of natural disasters in Bangladesh comprised of four main indicators. Measuring the overall risk level is a practice for estimating the danger associated with the natural calamities that are being tracked.

Once we find the highest value it satisfies the higher risk parameter. With respect to the qualitative figure of measures, the linguistic variables are totally associated. What the value we derive from the relevant web links or previous measured mathematical values is, lets our program take final action according to the data and indication of previous steps. Through collecting knowledge of past preventive action and informed discussion of operation simply helps us manage the overall risk of identifying specific risk factor in natural

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disasters to trigger related portions of the program. The input linguistic variables are specified in this fuzzy logic scheme as "Small," "Medium," and "Strong."

On the basis of degree Celsius (Figure 2), first source (Intense temperature) is evaluated in our system in interval [0, 45].

Currently, intense temperature is an alarming climate risk problem. And the possibility of extreme temperatures in Bangladesh is also rising day by day. Extreme weather triggers drought, greenhouse effect, Tornadoes are stronger and more severe, and by 2100 the sea level will rise 1-4 feet. In last few decades the highest temperature recorded in Bangladesh was 42.4 degree Celsius on April 24, 2014 [26] that indicates a caution to our country. So, we have fixed the range of extreme temperature based on the last highest temperature record in our country.

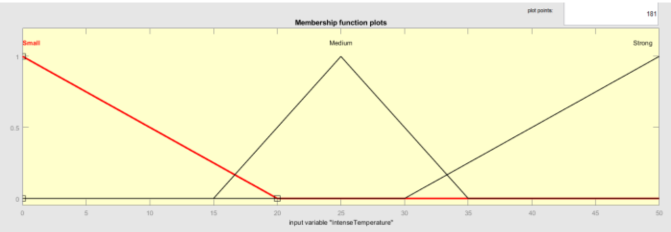

Fig. 2. (Intense temperature membership function)

The second input (Intense rainfall) is evaluated on the basis of millimeter (mm) at interval [0, 500] (Figure 3).

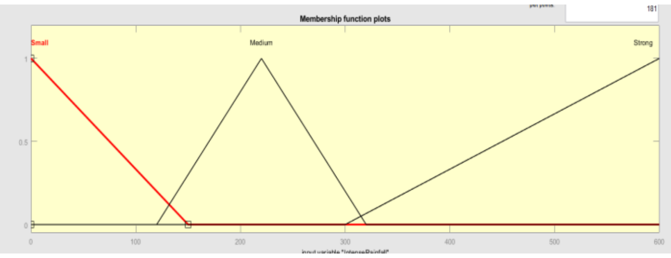

Figure 3. (Intense rainfall membership function)

Usually during the rainy season floods occur in our country. But the year of extreme rainfall, floods turn into severe type. During last few decades the remarkable floods occurred in our country in 1988, 1998, 2004, and 2010. About two thirds of our country remained submerge under water. And the extreme rainfall contributed a lot in these years. So, we have taken extreme rainfall as an input regarding climate risk for the fuzzy logic scheme. Here we have fixed the range of extreme rainfall based on some significant rainfall occurrence and the monthly average rainfall records of our country.

Here is the map which illustrates the flood affected areas in our country. From the figure 4 we can see that after heavy rainfall most of the regions of our country are submerged with flood water. For this reason, we select this as an input for our system.

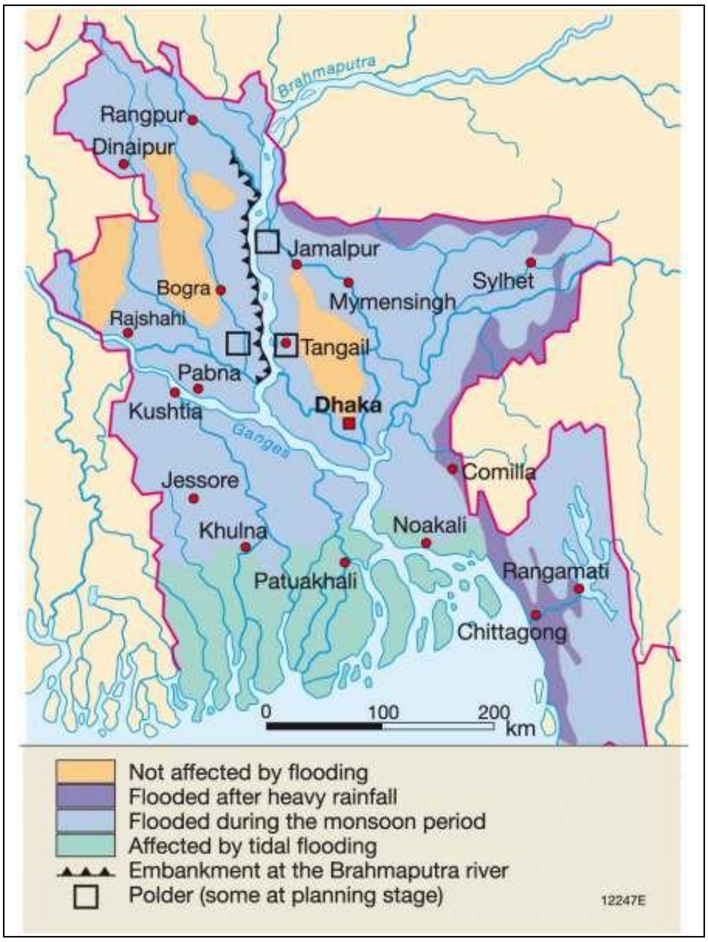

Fig. 4. (Flood area Map of Bangladesh)

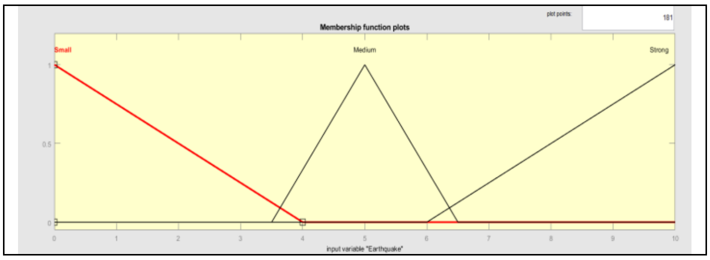

Figure 5. (Earthquake membership function)

Based on the Richter scale (Figure 5), the third source (Earthquake) is measured at interval [0, 10].

Bangladesh is the nation of over 160 million inhabitants, situated on the largest river delta in the world. Our nation is close to the sea level, which exposes it to tsunamis, and the risk that rivers will leap their banks when any earthquake occurs.

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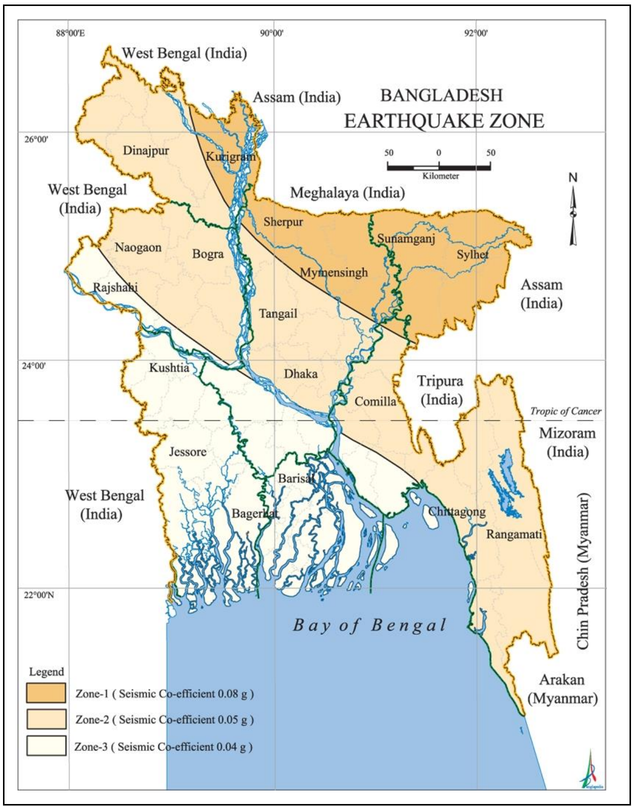

Figure 6. (Bangladesh Earthquake zone Map).

Many scientists now recognize Bangladesh as being at the intersection of many active continental plate borders, resulting in the 2004 Sumatra tsunami, which killed over 200,000 people and stretched over 1,300 miles south. Our capital, Dhaka, is one of the most earthquake-prone cities in the world, according to a new study by Michigan University. This is due to its unplanned urbanization. As shown in Figure 6, our country is located in a seismically active area, making the deadliest earthquakes a real possibility. Dhaka and Sylhet District, on the other hand, are in the moderate risk region, but the area is more vulnerable to destruction than any other part of Bangladesh due to other risk factors such as unplanned urban development, dense population, and a lack of open space.

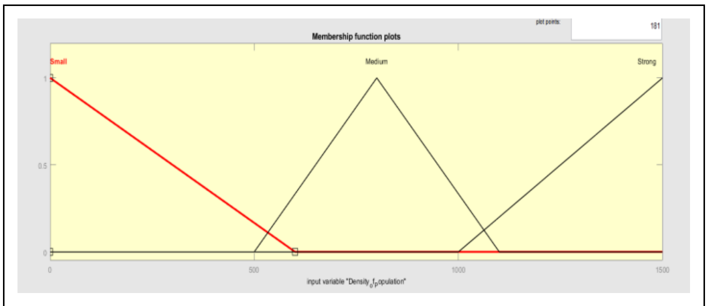

Fig. 7. (Density of population membership function)

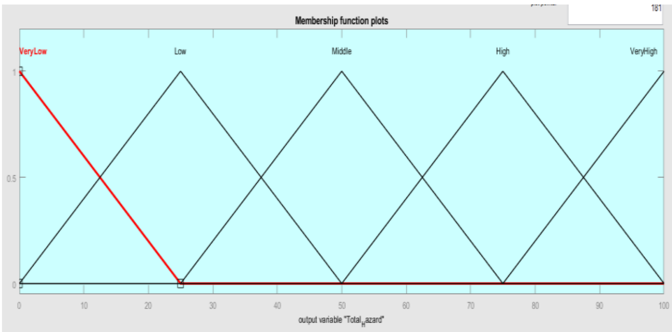

Fig. 8. (Total Hazard membership function)

The fourth source (population density) is estimated in terms of people per square in the range [0, 1500]. (Figure 7). According to the World Bank, Bangladesh's population density (people per square kilometer) was last estimated at 1,104.42 in 2019.Density of population means the mid-year population in square kilometers separated by land surface. Population including all inhabitants, regardless of legal status or citizenship-except for refugees who are not indefinitely living in the country of protection, who are generally considered part of their country of origin. Except for areas under offshore water bodies, national continental shelf claims, and exclusive economic zones, land area refers to a country's total area. The term "freshwater water bodies" typically refers to large rivers and lakes. Annual losses typically amount to billions of dollars and a significant number of lives lost. Triangular membership functions with three participation functions are used to produce all stimuli:

- Small
- Medium
- Strong

This fuzzy logic scheme's final performance (overall risk analysis) depicted by five fuzzy membership features given below:

- Very small
- Small
- Medium
- Strong
- Very Strong

Figure 8, shows how the triangular membership functions are used to estimate total hazard due to natural calamities in the range [0,100]. Mathematically this membership function of inputs and output are given below:

Source 1 (Intense temperature):

$$\mu_{LOW}\,(a) = -\frac{a}{20} + 1;\quad 0 \leq a \leq 20$$

$$\mu_{MIDDLE}\,(a) = \begin{cases} \frac{a}{10} - \frac{3}{2}\ ;\ 15 \leq a \leq 25 \\ -\frac{a}{10} + \frac{5}{2};\ 25 \leq a \leq 35 \end{cases}$$

$$\mu_{HIGH}\,(a) = \frac{a}{20} - \frac{3}{2}\ ;\quad 30 \leq a \leq 50$$

Source 2 (Intense rainfall):

$$\mu_{LOW}\,(b) = -\frac{b}{150} + 1\ ;\quad 0 \leq b \leq 150$$

$$\mu_{MIDDLE}\,(b) = \begin{cases} \frac{b}{100} - \frac{6}{5}\ ;\ 120 \leq b \leq 220 \\ -\frac{b}{100} + \frac{16}{5};\ 220 \leq b \leq 320 \end{cases}$$

$$\mu_{HIGH}\,(b) = \frac{b}{300} - 1\ ;\quad 300 \leq b \leq 600$$

Source 3 (Earthquake):

$$\mu_{LOW}\,(c) = -\frac{c}{4} + 1\ ;\quad 0 \leq c \leq 4$$

$$\mu_{MIDDLE}\,(c) = \begin{cases} \frac{c}{1.5} - \frac{7}{3}\ ;\ 3.5 \leq b \leq 5 \\ -\frac{c}{1.5} + \frac{10}{3}\ ;\ 5 \leq b \leq 6.5 \end{cases}$$

$$\mu_{HIGH}\,(c) = \frac{c}{4} - \frac{3}{2};\quad 6 \leq b \leq 10$$

Source 4 (Density of population):

$$\mu_{LOW}\,(d) = -\frac{d}{600} + 1\ ;\quad 0 \leq d \leq 600$$

$$\mu_{MIDDLE}\,(d) = \begin{cases} \frac{d}{300} - \frac{5}{3}\ ;\ 500 \leq b \leq 800 \\ -\frac{d}{300} + \frac{11}{3}\ ;\ 800 \leq b \leq 1100 \end{cases}$$

$$\mu_{HIGH}\,(d) = \frac{d}{500} - 2\ ;\quad 1000 \leq b \leq 1500$$

Final Output (Total Hazard):

$$\mu_{VERYLOW}\,(B) = -\frac{B}{25} + 1\ ;\quad 0 \leq B \leq 25$$

$$\mu_{LOW}\,(B) = \begin{cases} \frac{B}{25}\ ;\ 0 \leq B \leq 25 \\ -\frac{B}{25} + 2\ ;\ 25 \leq B \leq 50 \end{cases}$$

$$\mu_{MIDDLE}\,(B) = \begin{cases} \frac{B}{25} - 1\ ;\ 25 \leq B \leq 50 \\ -\frac{B}{25} + 3\ ;\ 50 \leq B \leq 75 \end{cases}$$

$$\mu_{HIGH}\,(B) = \begin{cases} \frac{B}{25} - 2\ ;\ 50 \leq B \leq 75 \\ -\frac{B}{25} + 4\ ;\ 75 \leq B \leq 100 \end{cases}$$

$$\mu_{VERYHIGH}\,(B) = \frac{B}{25} - 3\ ;\quad 75 \leq B \leq 100$$

The fuzzy logic scheme's inference rules are stated as a "IF - THEN" clause. For each of the sources and intermediate output variables, we set 9 rules based on fuzzy logic knowledge. The following are the rules:

IF “Intense temperature” is “Middle” and “Intense rainfall” is “Small” THEN “Hazardous weather” is “Medium”;

IF “Intense temperature” is “Strong” and “Intense rainfall” is “Medium” THEN “Hazardous weather” is “Strong”;

IF “Hazardous weather” is “Medium” and “Earthquake” is “Small” THEN “Ecological risk” is “Small”;

IF “Hazardous weather” is “Strong” and “Earthquake” is “Medium” THEN “Ecological risk” is “Medium”;

IF “Hazardous weather” is “Strong” and “Earthquake” is “Strong” THEN “Ecological risk” is “Strong”;

IF “Density of population” is “Small” and “Ecological risk” is “Medium” THEN “Total Hazard” is “Small”;

IF “Density of population” is “Medium” and “Ecological risk” is “Strong” THEN “Total Hazard” is “Medium”;

IF “Density of population” is “Small” and “Ecological risk” is “Small” THEN “Total Hazard” is “Very Small”;

IF “Density of population” is “Strong” and “Ecological risk” is “Strong” THEN “Total Hazard” is “Very Strong”;

Our proposed fuzzy logic scheme uses Fuzzy Logic Toolbox in MATLAB environment. Mamdani type fuzzy inference system is used in our fuzzy subsystems [11]. Finally, we obtained the Total Hazard as an output, as well as three inference surfaces for three fuzzy logic subunits.

IV. OUTCOME

We obtained the total performance (Total Hazard of Environmental Dangers) using three fuzzy logic subunits from the fuzzy logic toolbox. We used two inputs called Intense temperature [26] and Intense rainfall in the first subsystem to get the output (Hazardous weather).

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Rainfall in mm

St_name	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Dhaka	7.7	28.9	65.8	156.3	339.4	340.4	373.1	316.5	300.4	172.3	34.4	12.8
Mymensingh	10.0	20.5	35.8	128.6	356.9	394.3	436.3	318.1	335.3	190.9	17.5	8.7
Tangail	9.0	33.5	33.1	151.1	258.6	311.2	345.1	253.1	298.1	139.7	29.6	12.1
Faridpur	7.0	27.7	51.1	142.4	267.7	345.1	339.8	308.5	264.2	156.1	31.8	11.3
Madaripur	9.7	34.2	60.9	154.3	264.3	384.3	401.5	351.5	246.5	149.6	32.3	5.4
Chittagong	5.6	24.4	54.7	147.4	298.6	607.3	727.0	530.6	259.3	184.8	67.5	11.9
Sandwip	10.3	27.0	62.8	165.9	340.4	652.8	835.1	695.0	395.0	219.7	64.3	9.4
Sitakunda	5.6	19.6	91.9	184.5	351.0	548.4	726.8	545.6	316.4	240.3	54.2	7.9
Rangamati	5.1	24.3	62.1	147.9	319.7	504.8	572.6	435.2	259.6	152.2	55.7	9.5
Comilla	7.5	28.8	66.2	153.9	329.6	329.8	415.5	316.0	226.6	141.6	41.6	8.6
Chandpur	6.7	21.1	74.5	162.1	296.4	383.4	424.3	360.6	247.0	124.8	39.8	6.7
Maijdi Court	12.1	30.0	81.2	135.1	340.5	532.7	790.2	637.1	359.1	169.8	58.5	8.8
Feni	8.0	35.0	76.8	192.9	383.6	529.9	731.5	536.1	324.8	200.2	52.9	9.9
Hatiya	6.2	22.1	62.9	140.3	300.1	572.0	698.7	566.2	385.0	211.0	63.0	12.3
Cox's Bazar	4.1	17.0	34.7	121.8	286.8	801.9	924.6	667.1	330.1	213.6	109.4	13.0
Kutubdia	6.5	24.0	51.4	85.5	215.6	638.3	763.7	488.9	299.8	169.3	71.9	9.3
Teknaf	1.9	16.5	15.3	73.0	259.9	968.1	1029.7	898.9	402.1	207.4	75.7	5.9
Sylhet	9.4	36.2	155.3	375.6	569.6	818.4	819.2	612.6	535.9	223.9	30.4	9.4
Srimangal	5.0	31.3	84.1	216.1	449.9	449.7	339.4	299.3	278.5	150.0	40.3	11.2
Rajshahi	11.3	17.5	24.8	63.7	136.4	264.6	320.7	273.9	295.9	106.4	16.3	10.6
Ishurdi	8.1	21.5	30.8	95.0	206.3	288.6	335.6	261.2	282.8	98.1	17.4	10.8
Bogra	8.7	15.2	20.1	80.5	222.0	343.8	406.1	285.3	310.1	126.9	13.1	11.3
Rangpur	9.3	11.8	24.5	104.0	294.4	417.4	464.8	376.1	383.0	132.1	10.5	7.9
Dinajpur	12.3	10.5	11.3	67.1	232.5	335.3	433.6	387.7	383.8	115.1	7.0	10.2
Sayedpur	12.6	6.5	22.7	94.1	221.7	435.2	350.0	350.0	456.3	139.7	11.8	6.7
Khulna	13.3	44.4	52.1	87.5	200.0	335.6	329.8	323.5	254.7	129.8	32.1	6.6
Mongla	16.9	35.9	58.1	72.4	180.9	323.8	342.7	344.4	313.0	149.9	48.0	1.6
Satkhira	13.7	40.1	37.6	86.5	152.4	296.6	375.4	297.3	280.1	120.6	31.2	11.4
Jessore	14.8	26.1	44.6	75.4	169.9	298.7	304.1	291.8	236.9	107.9	29.0	15.8
Chuadanga	14.8	26.6	20.2	39.8	142.8	235.4	351.7	232.8	297.1	101.3	21.0	13.0
Barisal	8.9	27.0	57.1	132.3	232.9	408.4	407.3	371.3	259.4	158.6	52.4	12.6
Patuakhali	9.0	24.9	41.3	132.9	276.4	547.1	572.8	484.8	380.8	163.7	71.7	7.3
Khepupara	6.1	24.9	50.9	132.4	258.5	510.0	650.1	479.9	357.7	228.1	58.3	7.2
Bhola	10.3	32.7	63.4	129.7	274.0	465.2	444.5	395.5	264.2	155.3	52.0	10.6
Country	9.0	25.5	52.4	130.2	277.3	459.4	523.0	420.4	318.2	160.3	42.4	9.6

Bangladesh
Meteorological
Department

Fig. 9. (Rainfall data)

The Data for the intense rainfall is taken by considering the figure 9 and 10.

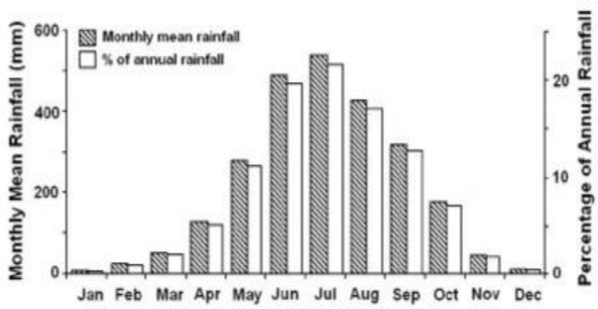

Fig. 10. (Monthly Rainfall)

We used two inputs, Hazardous weather and Earthquake, in the second subunit to get the output (Ecological risk). Figure 11 depicts the data collection we used for the Earthquake.

Date	Region	Tiefe	Magnitude	Deaths	Total damage
09/10/2010	Narayanganj	16 km	4.8	0	
01/12/2008	Rangamati, Bangladesh	47 km	5.0	0	
11/07/2007	Chittagong, Bandarban, Rangamati	21 km	5.1	0	
07/26/2003	Rangamati	17 km	5.7	2	
06/20/2002	Rangpur, Thakurgaon, Almanagar	43 km	4.5	0	
12/19/2001	Dhaka	7 km	4.5	0	
07/22/1999	Maheshkhali Island, Cox's Bazaar	11 km	4.2	6	
06/12/1989	Banaripara	9 km	5.1	1	
02/06/1988	Sylhet; India (Tipura-Assam)	45 km	5.8	2	

Fig. 11. (Yearly Earthquake information)

The third and final subunit is used to measure the risk (Total Hazard), which is based on two inputs: Ecological risk and Density of population. Figure 12 displays the data set we used to measure density of population.

Bangladesh - Historical Population Density Data

Year	Population Density	Growth Rate
2021	1,126.49	0.98%
2020	1,115.55	1.01%
2019	1,104.42	1.03%
2018	1,093.12	1.06%
2017	1,081.66	1.08%
2016	1,070.09	1.10%
2015	1,058.43	1.13%
2014	1,046.65	1.15%
2013	1,034.76	1.16%
2012	1,022.87	1.16%
2011	1,011.13	1.15%
2010	999.63	1.13%

Fig. 12. (Data set for Density of population)

We obtained the final output, which is referred to as the Total Hazard, after providing all sources.

Three separate inference surfaces are provided by three fuzzy logic subunits (3D). Figure depicts these surfaces numbered as 13, 14, and 15.

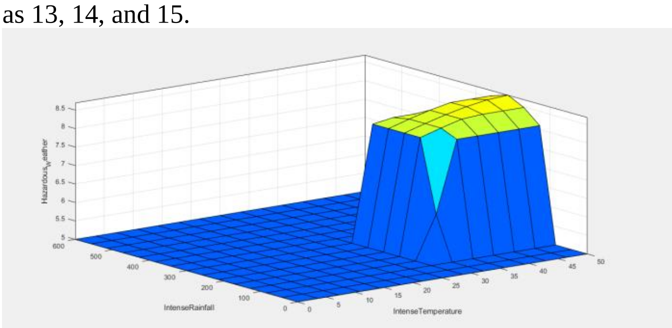

Fig. 13. (Hazardous weather's inferential floor)

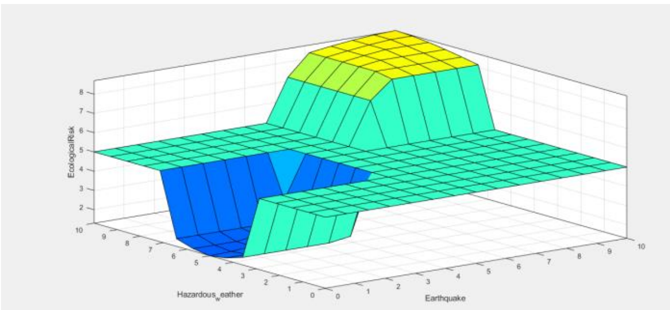

Fig. 14. (Ecological risk's inferential floor)

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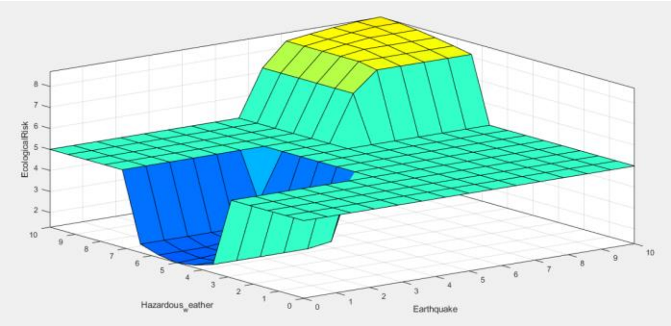

Fig. 15. (Total Hazard's inferential floor)

V. CONCLUTION

In this paper, we use a fuzzy logic scheme to suggest a reduced risk model for evaluating natural risk in Bangladesh. We are currently working on disaster management tools, which will include the knowledge obtained from the Fuzzy logic toolbox. By combining the performance (provided by the fuzzy logic scheme) with disaster management tools, we will be able to alert stakeholders, allowing them to make quicker decisions and reducing challenges and danger for Bangladesh.

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