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Decision Support System for Flood Disaster Mitigation

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ABSTRACT
The catastrophic effects of past flooding such as the 2012 flood that occurred in Nigeria have underlined the importance of making timely mitigation decisions in advance of a catastrophic Events. Decision Support System (DSS) help users settle on compelling decisions in flood disaster mitigation and prevention. Decision Support Systems are computer based systems that are aimed at assisting decision-makers in making productive, agile, innovative and reputable decisions. The work presents a decision support system using Fuzzy logic, the wind speed and temperature data were obtained from Nigerian Meteorological Agency (NIMET) and Climate_Data are classified into very low, low, normal, high, very high, and extremely high to denote the amount of rainfall. The input data were used in DSS model to test the system in order to evaluate the amount rainfall so that predictions can be made. The results were promising indicating the amount of rainfall that can cause severe flooding.

General Terms
Fuzzy Logic**,** Decision Support System

Keywords
Decision Support System; Flood Mitigation; Disaster Management; Fuzzy logic.

1. INTRODUCTION
For the most part, Decision Support System (DSS) covers computer-based systems that are created to help decision-makers make decisions. Basically, DSS helps decision-makers to settle choices that are increasingly beneficial, dexterous, inventive and reputable, DSS are a particular class of information system that underpins business and organizational decision-making activities. A properly-designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions. DSS includes computer reasoning, human computer interaction, research on databases and the programming and simulation of technology and telecommunications. (Jin, 2007). Decision support system for disaster management is a system that has been designed to deal with the disaster situations with all emergency management plans and decision. Disaster management is a collective term that incorporates all parts of anticipating and responding to disasters, including both pre and post-catastrophe activity namely, prevention and mitigation, preparedness, response and recovery which are the four phases of Disaster management. It might allude to the management of both the risk and consequences of disasters".

1.1 Statement of the Problem / Research Objectives
The past flood events that occurred in Bayelsa, Rivers State, Calabar and Delta State in 2012 highlighted the significance of mitigation and prevention ahead of a catastrophic event. However, the events also had difficulties that resulted from the multifaceted aspects of the problems that officials have to face in making the mitigation and prevention plans, these difficulties are:

1. The difficulty in predicting accurate flooding has made it hard for decision makers to make right decisions.
2. Decision-making is often difficult for decision-makers because of uncertain and inadequate data
3. The impact of making wrong decisions can be severe and can lead to loss of life, damage to vehicles, submersion of structures and economic loss.

Based on the problem, the aim of this research is to develop an efficient Decision Support System (DSS) model to help users make effective decisions in flood disaster mitigation and prevention and its objectives are;

i. Analyze GIS rainfall data gotten from NIMET.
ii. Identify areas that are prone to flooding using data gotten from NIMET.
iii. Explore the use of fuzzy logic in rainfall prediction
iv. Develop a Decision Support System Model that will be used to anticipate the amount of Rainfall.
v. Test and Evaluate the Decision Support System model.

2. RELATED WORKS

2.1 Overview of a DSS
A definition for a DSS helps us understand and enables the review of the DSS theory and practice, it also assist the users and developers to design, plan and develop an effective DSS. Because the concept of DSS is very broad with a lot of definition from various researchers depending on the author’s point of view. (Gory & Morton, 2000) characterized a DSS as a framework for decision making of unstructured and semi-organized choice by administrative decision makers. The DSS was classified a framework for managers to make decisions on unstructured or semi-structured issues (Gory & Morton in 2000). The key words in this definition were support and unstructured (or semi-structured). Barbosa and Hirko (1980) also found that the DSS is used primarily to deal with semi-structured or unstructured problems. Notwithstanding, any problem they viewed as unstructured, on the off chance that it

was excessively costly or tedious to characterize the structure of the problem before building up the solution, were characterized uniquely in contrast to what was characterized as non-structure issues (McCleod 1995).

In decision making–school management in the planning of a training system–examined the consequences for students functioning. These applications demonstrate the intensity of DSSs in addressing the complex problem DSS has been characterized by (Ginzberg & Stohr, 1992) as a data-based computer-aided system that helps decision makers in situations where the automated system is unrealistic or not attractive. The DSS was defined as an information computer-based system to settle semi-organized questions by Silver (1991). Sprague & Watson (1996) trusted that computerized DSSs help decision makers defy unorganized issues by cooperating directly with data and models.

A prominent framework to solve difficult problems is Decision Support Systems. The general welfare assessment was conducted by (Bracke *et al*., 2001). The model of the DSS-based GIS was depicted by Johnson (2001) for use by government housing managers. (Vassilakis, 2002) has developed the DSS for the diagnosis and grouping of children suffering from epilepsy disorder using artificial intelligence. Kalay & Chen (2002), by coordination of DSS

Ahmad & Simonovic, (2006) built up an intelligent decision support system (DSS) to help decision makers amid various periods of flood management. The DSS is created as a virtual planning tool and can address both engineering and non-engineering issues identified with flood management. The DSS can anticipate the pinnacle flows with 2% error and uncovers that with modified working rules of Assiniboine River to the flooding of Winnipeg city can be altogether decreased. The decision support environment condition permits various "what if" type inquiries to be posed and replied, along these lines, numerous decisions can be attempted without managing the genuine outcomes.

Kaviani *et al*., (2015) built up an Intelligent Disaster Decision Support System (IDDSS) to give a platform to coordinating a huge scope of street arrange, traffic, geographic, financial and meteorological information just as unique disaster and transport models. It has various highlights for supporting homogenous data collection, control and representation that can be utilized to research a wide scope of disaster management issues. An application of the IDDSS including the management of road network amid bushfire and floods scenario is exhibited to outline a portion of its capabilities.

3. METHODOLOGY

The system adopted the constructive research approach (CRA) as its methodology because it develop scientifically based solutions that can solve real - world problems (Flooding), thus establishing an appropriate link between theory and practice by the constructive research methodology, reinforcing the relevance of academic research, object oriented design (OOD) was adopted as its design methodology to make system elements more modular, thus aiming to improve system performance and system analysis and design productivity. The architecture of the system has been designed and is presented in Figure-1.

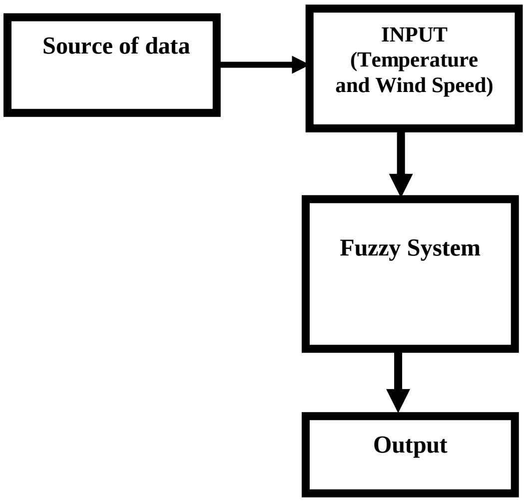

Fig 1. Architecture of the Proposed System

3.1 Sources of Data

Data was sourced through interview with officials of National Emergency Management Agency (NEMA) and Nigeria Meteorological Agency (NIMET), The secondary data was sourced from books (2012 – 2017) Seasonal Rainfall Prediction (SPR)) gotten from NIMET, journals and annual rainfall data collected from (NIMET) and (NEMA). The system uses wind speed and temperature data gotten from NIMET and Climate_Dara for a period of 2 years (2017 - 2018) to test the system.

3.2 Input Variables

Weather is generally considered at any given location as the state of the atmosphere that are visible and affect human activities. The parameters of the environment used are temperature (℃ *or* ℉) which ranges 0℃ - 25℃ and wind speed (km/h) which ranges from 0 km/h - 10 km/h, these parameters are the major causes of rainfall. Table -1 shows the linguistic labels of the input variables

Table 1. Linguistic Labels

S/N	Parameters	Linguistic Values
1	Temperature	Very High, High, Normal, Very Low, Low
2	Wind Speed	Very High, High, Normal, Very Low, Low

3.2.1 Wind Speed (km/h)

Wind is characterized by its direction and speed. Wind speed at a given location varies with time, it needs to be expressed as an average over a given time interval. The wind speed ranges from 2 - 10 km / h. The table below produces the membership value for any wind speed value.

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Table 2. Shows the membership value for wind speed

S/N	RANGE	Linguistic Values
1	$Wind\ speed \leq 10$	Extremely High
2	$8 \leq Wind\ speed \leq 10$	Very High
3	$6 \leq Wind\ speed \leq 8$	High
4	$4 \leq Wind\ speed \leq 6$	Normal
5	$2 \leq Wind\ speed \leq 4$	Low
6	$0 \leq Wind\ speed \leq 2$	Very Low

3.2.2 Temperature

Temperature is the degree of coldness and hotness of a place. The temperature ranges from $5^{\circ}C - 25^{\circ}C$.

Table 3. Shows the membership value for temperature.

S/N	RANGE	Linguistic Values
1	Temperature $\leq$ 25	Extremely High
2	20 $\leq$ Temperature $\leq$ 25	Very High
3	15 $\leq$ Temperature $\leq$ 20	High
4	10 $\leq$ Temperature $\leq$ 15	Normal
5	5 $\leq$ Temperature $\leq$ 10	Low
6	0 $\leq$ Temperature $\leq$ 5	Very Low

3.3 Fuzzy Logic (FL)

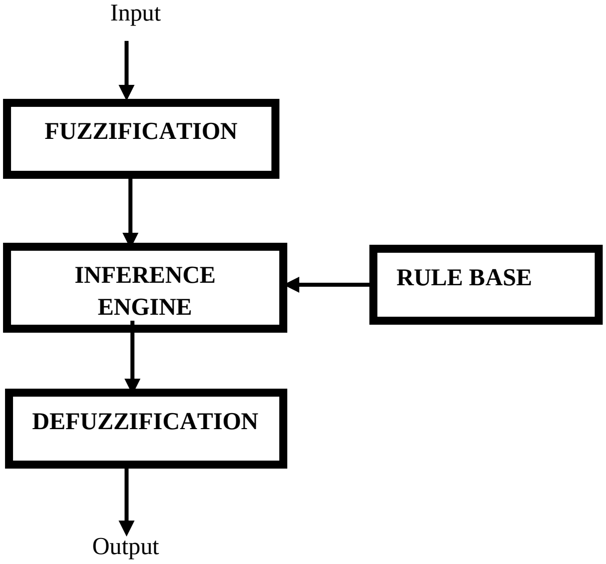

Fig 2. General Structure of a fuzzy System

Fuzzy System basically has four segments, rule base, fuzzy inference engine, and defuzzification. Fuzzification converts input data (temperature and wind speed) by looking up on the different membership function to degrees of membership function, a membership function that expects comprehensive values of 0 and 1, can numerically describe the partial membership of a set. The fuzzy rule base contains rules that incorporate all conceivable fuzzy input and output relationships. These rules are expressed in the format of IF-THEN. The fuzzy inference engine takes all the fuzzy rules in the rule base into account and learns how to convert a series of inputs into the relevant outputs. Defuzzification is a phase by which a solution set becomes a single, crisp value. The fuzzy logic solution set is a function that relates the value of the result to the membership level. In the fuzzy solution set the entire range of possible solutions can be included. Defuzzification is also a process for extracting an easy-to-understand solution from the set.

Fuzzy rules for wind speed

IF ($0 \leq Wind\ speed \leq 2$)

Then

{

$M_1 = 0$;

}

Else if ($2 \leq Wind\ speed \leq 4$)

Then

{

$M_2 = 0.2$;

}

Else if ($4 \leq Wind\ speed \leq 6$)

Then

{

$M_3 = 0.4$;

}

Else if ($6 \leq Wind\ speed \leq 8$)

Then

{

$M_4 = 0.6$;

}

Else if ($8 \leq Wind\ speed \leq 10$)

Then

{

$M_5 = 0.8$;

}

Else ($Wind\ speed \geq 10$)

{

$M_6 = 1$

}

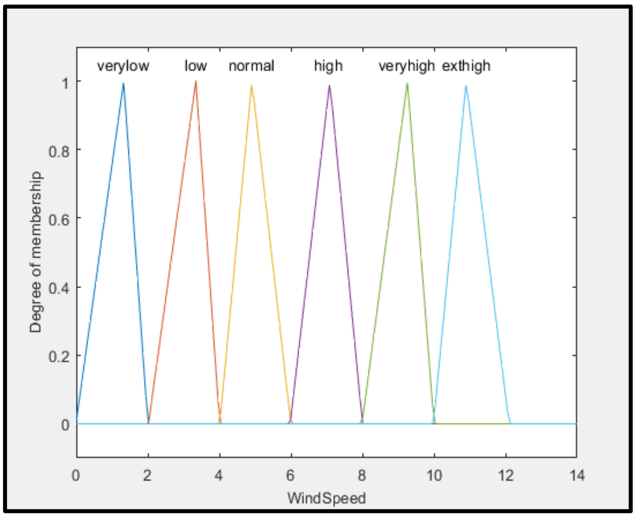

Fig 3. Membership function for wind speed

Fuzzy rules for temperature

IF ($0 \leq Temperature \leq 5$)

Then

{

$M_1 = 0$;

}

Else if ($5 \leq Temperature \leq 10$)

Then

{

$M_2 = 0.2$;

}

Else ($10 \leq Temperature \leq 15$)

Then

$M_3=0.4$;

}

Else if ($15 \leq Temperature \leq 20$)

Then

{

$M_4 = 0.6$;

}

Else if ($20 \leq Temperature \leq 25$)

Then

{

$M_5=0.8$;}

Else $Temperature \geq 25$)

Then {

$M_6 = 1$

}

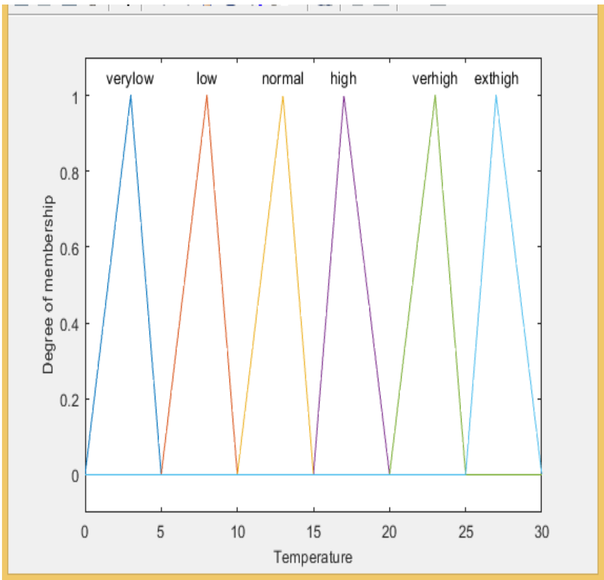

Fig 4. Membership function for temperature

3.4 Output

The output variables depend on the category that the temperature and the wind speed falls in. They can either be of very low, low, normal, high and very high as shown in Table 4. The table shows how we can get our final output (amount of rainfall) at different category of the output variable.

Table 4. Output Variable

TEMPERATURE AND WIND SPEED	MEMBERSHIP FUNCTION	LINGUISTIC VALUES
0 – 20	0 – 0.2	Very low
20 – 40	0.2 – 0.4	Low
40 – 60	0.4 – 0.6	Normal
60 – 80	0.6 – 0.8	High
80 – 100	0.8 – 1	Very high

4. RESULTS AND DISCUSSION

This research made use of 2 years (2017 - 2018) wind speed and temperature data gotten from NIMET and Climate_Data, the data gotten was used to test the Decision Support System to anticipate the amount of rainfall. The rainfall amount and label are shown below, table 5 and 6 shows the amount of daily rainfall for June 2018 gotten from NIMET and Climate _Data respectively.

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Table 5. Daily rainfall amount (June 2018, NIMET)

DAYS	WIND SPEED	TEMPERATURE	RAINFALL	LABEL
1.	7	27.2	90	Very high rainfall (Flood)
2.	5	28	79	High rainfall
3.	5	28.4	79	High rainfall
4.	7	29.2	90	Very high rainfall (Flood)
5.	5	27.3	79	High rainfall
6.	8	27.9	94	Very high rainfall (Flood)
7.	3	27.6	69	High rainfall
8.	4	29.1	70	High rainfall
9.	8	29.2	94.1	Very high rainfall (Flood)
10.	6	28.4	89.4	Very high rainfall (Flood)
11.	6	27.5	89	Very high rainfall (Flood)
12.	6	27.3	89	Very high rainfall (Flood)
13.	12	27.2	96	Very high rainfall (Flood)
14.	7	26.7	90	Very high rainfall (Flood)
15.	4	28.8	69.9	High rainfall
16.	5	28.3	79	High rainfall
17.	4	25	60	High rainfall
18.	2	25.8	75.3	High rainfall
19.	6	28.4	89	Very high rainfall (Flood)
20.	4	26.3	69	High rainfall
21.	4	26.2	69	High rainfall
22.	7	27.6	90	Very high rainfall (Flood)
23.	5	27.8	79	High rainfall
24.	4	26.8	69.4	High rainfall
25.	5	25.7	79	High rainfall
26.	5	27.6	79	High rainfall
27.	5	27.6	79	High rainfall
28.	5	26.9	79	High rainfall
29.	4	27.4	69.2	High rainfall
30.	9	25.0	73.5	High rainfall

Table 6. Daily Amount of Rainfall [June, 2018], (Source: CLIMATE_DATA)

DAYS	WIND SPEED(Km/h)	TEMPERATURE (◦c)	RAINFALL(mm)	LABEL
1	1	5	15	No rainfall
2	3	14	33	No rainfall
3	10	5	55.3	Drizzle
4	5	25	75	High rainfall
5	8	29	94.1	Very high rainfall (flood)
6	5	10	50	Drizzle
7	3	7	25.2	No rainfall
8	9	7	50	Drizzle
9	4	25	68.3	High rainfall
10	6	5	37.8	No rainfall
11	7	7	38	No rainfall
12	8	15	70.4	High rainfall
13	6	23	77.1	High rainfall
14	7	26	90	Very high rainfall (flood)
15	5	7	30	No rainfall
16	5	10	50	Drizzle
17	10	13	68.3	High rainfall
18	7	23	72.4	High rainfall
19	3	35	55.6	Drizzle
20	7	27	90	Very high rainfall (flood)
21	7	25	80.2	Very high rainfall (flood)
22	6	26	89	Very high rainfall (flood)
23	9	29	96	Very high rainfall (flood)
24	4	17	48	Drizzle
25	3	16	35.5	No rainfall
26	5	28	79	High rainfall
27	5	15	55.5	Drizzle
28	10	28	98	Very high rainfall (flood)
29	4	15	48	Drizzle
30	10	22	75.2	High rainfall

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Table 7. Comparison between NIMET and Climate_Data Amount of Rainfall [June, 2018]

DAYS	AMOUNT OF RAINFALL(mm) (NIMET)	AMOUNT OF RAINFALL(mm) (CLIMATE DATA)
1	90	15
2	79	33
3	79	55.3
4	90	75
5	79	94.1
6	94	50
7	69	25.2
8	70	50
9	94.1	68.3
10	89.4	37.8
11	89	38
12	89	70.4
13	96	77.1
14	90	90
15	69.9	30
16	79	50
17	60	68.3
18	75.3	72.4
19	89	55.6
20	69	90
21	69	80.2
22	90	89
23	79	96
24	69.4	48
25	79	35.5
26	79	79
27	79	55.5
28	79	98
29	69.2	48
30	73.5	75.2

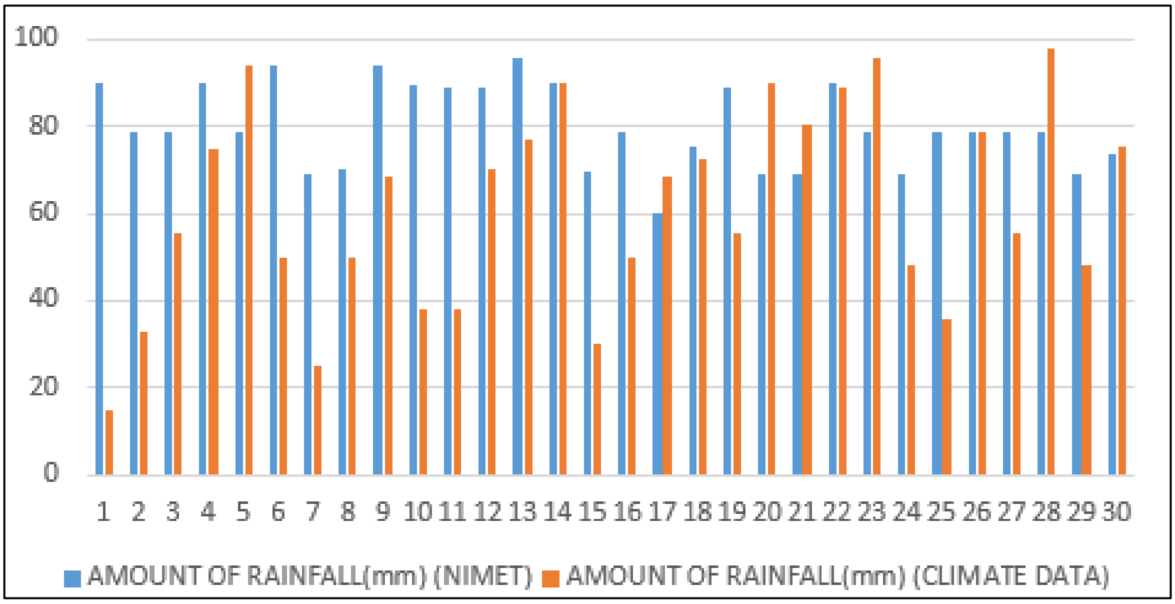

Fig 5. A graph showing comparison between NIMET and Climate_data amount of rainfall [June, 2018]

Wind Speed and Temperature data from NIMET produced high amount of rainfall in day (2, 3, 5, 7, 8, 15, 16, 17, 18, 20, 21 to 30) and very high amount of rainfall in other days. However, Wind Speed and Temperature from Climate data varies between very low, low, normal, high and very high amount of rainfall. There were high amount of rainfall in day (4,9,12,13,14,17,18,26,30) and very high amount of rainfall in day (5,20,21,22,23,28). Thus, tested climate data performed better than NIMET data due to the fact that their wind speed and temperature value varies between very low, low, normal, high and very high. The proposed Decision Support System is efficient as data from different sources were tested and produces "No rainfall", "Drizzle", "High rainfall" and "Very high rainfall". Thus, very high rainfall leads to flooding.

5. CONCLUSION

Decision Support System was developed that could mitigate flood disaster using fuzzy logic. The rule base is one of the main components in decision support system. The rules were calibrated for accurate result of amount of rainfall, which can be used for the prediction of the flood in Brass, Bayelsa State. From the research, human perception about rainfall level can be represented by using fuzzy logic. The results of this study indicates that the design of the system with fuzzy method is very effective, more responsive in providing information about the amount of rainfall. Most research work done on flood mitigation are statistical work, in this research Decision support system was applied in flooding in other to minimize the adverse effects of flood. It is beneficial to use parameter as atmospheric condition for flood mitigation. Mostly this parameter can be very useful in rainy season to determine the rainfall amount and according to that we can mitigate flood precisely using the amount of rainfall to avoid these flood situations. However using only two parameters wind speed and temperature, efficient flood mitigation cannot be obtained and hence more parameters can be added such as, humidity, wind direction, water level and flow rate for efficient flood mitigation.

The proposed Decision Support System was tested with data from different sources (NIMET and CLIMATE_DATA), result shows that tested data from Climate performs better than NIMET data due to the fact that their wind speed and temperature value varies between very low, low, normal, high and very high and produces "No rainfall", "Drizzle", "High rainfall" and "Very rainfall". Thus, very high rainfall leads to flooding.

6. RECOMMENDATION

The application of this fuzzy methodology as decision support can be associated with a GIS to improve crisis management in the case of severe disasters threatening people's lives. A decision support System for Flood disaster mitigation using Geographical Information System is expected to be developed in the future on the basis of our proposal.

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