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Flood Prediction In Nigeria Using Artificial Neural Network

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ABSTRACT: *Flooding has been a major problem both in urban and rural areas in Nigeria and globally. Hundreds of lives and millions dollars of properties are destroyed yearly due to flooding. This research work is based on flood prediction using ANN. These factors of which temperature and rainfall were the most significant were used to develop an ANN model for the prediction of flooding in Nigeria using deep feed-forward neural network. The network has three hidden layers sandwiched between an input layer. It accepts two input features (i.e. temperature and rainfall) and outputs the predicted Standard Precipitation Index (SPI). Two-third (67%) of the dataset was used to train the network using the back propagation algorithm. Adam's algorithm was used as an optimizer while the loss function used was categorical cross entropy. One-third (33%) of the total dataset was used to test and validate the network during training. From the confusion matrix, the average accuracy of the model on the test set was 76% which although may not be seen as high but will be sufficient for our prediction.*

Keywords *-Data Mining, Flooding prediction, Modeling, Neural networks, Wetin App.*

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I. INTRODUCTION

In many parts of Nigeria, flooding continue to be an increasing problem, catching individuals and communities by surprise in a repeatedly exasperating way and causing disruption of social activities, damage of infrastructures and even death of people and livestock. In 2003, severe flooding resulting from dam failure submerged farmlands in Zamfara state. In Taraba State the extreme flood which occurred in October 2012 affected 111,255 people. About 28,511 persons were internally displaced with 29 Internally Displaced Persons (IDPs) camp in different parts of the state. The floods also destroyed about 83,722 farmlands and 11,178 houses. The flood was so much that the Lagdo dam which was constructed on the River Benue in the Republic of Cameroon could not control it. Consequently, the dam had to be opened to release some water from the excess impoundment that is capable of collapsing the dam. The release of water from the Lagdo dam upstream of the River Benue led to the flooding of the entire length and breadth of the downstream catchment of the basin. All the settlements (both rural communities and townships) along the River Benue were flooded. In southern urban and coastal areas in Nigeria flooding continue to pose a major risk to many of the inhabitants of the low-lying coastal areas [1].

Flood is one of the most important water-related natural disaster causing damages of properties and loss of lives [2]. Floods are the prominent cause of natural disaster deaths globally and were responsible for 6.8 million deaths in the 20th century. Asia is the most flood-affected region, accounting for nearly 50% of flood-related fatalities in the last quarter of the 20th century.

Several factors can cause flooding and is consistently preceded by heavy rainfall. The other causes of flooding are moderate to severe winds over water, unusual high tides and tsunamis due to undersea earthquakes, breaks or failures of dams, retention ponds or lakes etc. Flooding can be intensified by impervious surfaces or by other natural and man-made hazards which destroy soil and vegetation that can absorb rainfall. After a heavy rainfall, some of the water is retained on the soil and may form ponds. Some of the water penetrates into the soil, some evaporates, and any excess water moves along the land surface as surface runoff. Flooding occurs

when the soil, stream channels and manmade reservoirs cannot absorb or contain all the water. A flood that occurs abruptly, with little or no prior signs is called a flash flood and is due to intense rainfall over a relatively small area.

Flooding is inevitable, resulting from the natural rainfall-runoff process or might be due to natural or man-made factors. It is a natural phenomenon and the magnitude of floods is periodic. The periodicity of flood implies that every year some area surrounding the river (on both sides) is flooded. Every other period, (two, five, ten, fifty, one hundred and even a thousand years) is associated with increasing areas around the river which gets flooded [3]. Several anthropogenic factors have contributed to the incidence of flood. Among these factors is the encroachment of development to flood prone areas. The intrusion into such areas have being progressive until now because of unprecedented urbanization and industrialization which has undoubtedly resulted into large scale massive deforestation, loss of surface vegetation and farmlands [4].

Flooding is a yearly occurrence in Nigeria and is expected to increase due to climate change. The Federal Government of Nigeria failed to heed early warnings by relevant agencies and was unprepared to manage the 2012 flood which was one of the most devastating in the country [5].

According to Elsafi [6], flood forecasting and prediction capabilities evolved slowly during the 1970s and 1980s. However, recent technological advances have had a major impact on forecasting methodologies. For instance, hydrological models use physical detection systems to forecast flood conditions based on predicted and/or measured parameters. River flow models are used as components in actual flood forecasting schemes, where forecasts are required to issue warnings and to permit the evacuation of populations threatened by rising water levels.

The basis of such forecasts is invariably observation and/or predictions of rainfall in the upper catchment area and/or river flows at upstream points along main rivers or tributaries. Forecasts about the discharge are obtained in real-time, by using the model to transform the input functions into a corresponding discharge function time. The repeated occurrence of catastrophic flood around the country, particularly in southern and urban areas in Nigeria, justifies the need for the development and implementation of a flood prediction system to warn against the event of flood disaster in the country. Although there is a flood prediction application (Wetin App) launched by the Ministry of Agriculture, however the application does not function correctly and thus cannot predict flood occurrence. There is therefore, a gap or need to develop using neural network a flood prediction model that will use historical data about flood occurrence to make future flood prediction accurately.

II. BACKGROUND

An Artificial Neural Network (ANN) is a computing system that is made of an extremely interconnected set of simple information processing elements, analogous to a neuron, called units. The neuron collects inputs from both a single and multiple sources and produces output in accordance with a predetermined non-linear function. An ANN model is created by inter-connection of many of the neurons in a known configuration. The primary elements characterizing the neural network are the distributed representation of information, local operations and non-linear processing [7].

A comparison of ANN model with a conventional method like auto-regression, suggests that ANN provides better accuracy in forecasting. Other studies have also shown that ANNs are more accurate than conventional methods in flow forecasting and drainage design. Furthermore, the ANN method was used extensively for the prediction of various variables (stream flow, precipitation, suspended sediment, etc.) in the water resources field and water quality modeling [8]. ANN represents a mathematical model inspired by the structure and functions of biological neural networks. They consist of an interconnected group of artificial neurons and provide information using a connectionist approach to the computation. The advantage of artificial neural networks is the fact that they can simulate processes without the incorporation of physical laws in the mathematical form. On the other hand, neural networks are often susceptible to overtraining, which occurs when a training data set reduces error and increases the errors of the test data set[9].

[10] used Artificial Neural Network to predict weekly discharge rate of the underlying hydrometric station. They also reported that Artificial Neural Networks are known as the sort dynamic, complex and intelligent systems. The importance of the neural networks is in simulation of processes in which usually there isn't clear and comprehension definition for them. Artificial Neural Networks have been applied in prediction tool of various field of science especially in hydrology science and water management affairs. They also stated that in spite of many good news mentioned about the Artificial Neural Networks, danger of getting stuck into local minima is an undeniable problem of Artificial Neural Network from which makes researchers to be concern about their results.

Sarkar and Kumar [7] developed models for event-based rainfall-runoff using Artificial Neural Networks and parameters such as the magnitude of the peak discharge and the time to peak discharge. The developed ANN models were able to predict event-based rainfall-runoff with great accuracy.

[6]developed a model to forecast the River Nile flow at Dongola Station in Sudan using Artificial Neural Network (ANN) as a modeling tool and validated the accuracy of the model against actual flow. The ANN model was formulated to simulate flows at a certain location in the river reach, based on flow at upstream locations.

[11]worked on a neural network-based algorithm for predicting the atmosphere for a future time and a given location. Back Propagation Neural (BPN) Network for initial modeling was used. The results obtained by BPN model are fed to a Hopfield Network. The performance of their proposed ANN-based method (BPN and Hopfield Network based combined approach) tested on 3 years' weather data set comprising 15000 records containing attributes like temperature, humidity and wind speed. The prediction error is found to be very less and the learning converges very sharply.

[12]reported that flood is one of the most destructive natural hazards in the world, claiming lives and properties more than any other natural phenomena. Flooding happens when natural or man-made water bodies cannot adequately transport or hold excess water generated by storms or other sources, thereby overflowing their normal beds to flood the nearby lands. Mitigation of flood disaster can be successful only when comprehensive information is gotten about the vulnerability of the people, buildings, infrastructure and economic activities in a potentially dangerous area. One way to relieve the effects of flooding is to ensure that all areas that are susceptible are documented and adequate precaution is taken to ensure adequate awareness, effective response, quick recovery and effective prevention.

[13]stated that flood is a natural reaction of a river, stream or drainage valley/canal that has too much water to handle. It is one of the most widespread, disastrous and frequent natural disaster of the world which is triggered by factors that are partly or entirely climatological in nature, but human activity often escalates the frequency and severity of the floods. Flood arises due to accumulation of water especially from rainfall across an impermeable surface and cannot rapidly dissipate or evaporate. It can affect the social, economic and political wellbeing of people.

According to [4], the causes of flood include natural and man induced cause. Flood is caused naturally by heavy rainfall. Man induced flood is caused due to dumping of waste material and refuse into water channels, non-functional drainage and encroachment of buildings on flood plains.

[14]reported that flooding is the most common environmental hazard in Nigeria which is not a recent phenomenon in the country, with high destructive propensities. Severe flood calamities have happened in Ibadan (1985, 1987 and 1990), Osogbo (1992, 1996, 2002), Yobe (2000) and Akure (1996, 2000, 2002, 2004 and 2006). The coastal cities of Lagos, Port Harcourt, Calabar, Uyo, Warri among others have experienced flood disaster which claimed many lives and assets worth millions of dollars. Floods occur in Nigeria in three main forms: coastal flooding, river flooding and urban flooding. Coastal flooding occurs in the low-lying belt of mangrove and fresh water swamps along the coast. River flooding occurs in the flood plains of the larger rivers, while sudden, and brief flash floods are linked with rivers in the inland areas where sudden heavy rains can change them into destructive torrents within a short period. Urban flooding on the other hand occurs in towns, on flat or low-lying terrain especially where little or no provision has been made for surface drainage, or where existing drainage has been blocked with public waste, refuses and eroded soil sediments.

[15]acknowledged that blocked drains, houses on flood plains, heavy rainfall, absence of drainages, nature of terrain, type of soil, poor heeding to predictions, land reclamation and non-compliance with regulations are also some common causes of flood.

[16] stated that the causes of flooding are due to the following;

- Severe sea storms, or as a result of another hazard (e.g., Tsunami or hurricane).
- Significant and unexpected event e.g., dam breakage, or as a result of another hazard (e.g., earthquake or volcanic eruption).
- Accidental damage by workmen to tunnels or pipes.
- Climate change: Climate change is an attributed cause of flooding because warmer climate leads to heavy rainfall and rise in sea level.

According to [17], some of the measures that could be adopted to limit the menace of flood in Nigeria are:

- Flood plain management such as prohibition of certain types of buildings or activities in flood high risk zones, elevate or flood proof buildings that are allowed on the legally defined flood plains.

- The National Inland Waterways Authority (NIWA) of Nigeria should urgently take steps to desilt waterways and tributaries which are sited and taken over by shrubs to allow for channels and easy flow of water to curb the ravaging flood in the coastal communities.
- In developed countries of the world particularly in America and Europe, there is always a standing taskforce that is set up to deal with the problem of snow once winter is approaching. In the same way, the Nigerian government needs to be proactive by setting up standing taskforce that will tackle the issue of flood once the rainy season is approaching.
- Town planning laws should be properly enforced and strictly adhered to as this will go a long way to curbing the menace of floods. The Nigerian government should always plan ahead of the population so as to avert the occurrences of unplanned houses and cities. This is necessary because deviation from the original master plan by prospective town developers do facilitate the occurrence of floods as investigations has shown that a lot of houses built today in Nigeria are erected on natural drainage channels/courses which are often firsts and filled by land developers before erecting their structures. The resultant effect of this practice is that these natural drainage channels/courses have been blocked will afford storm water no channels/courses to pass through and thus the inundation of the areas that are liable to flooding.
- All roads should be constructed with adequate drainage facilities provided.
- Drainage systems should be regularly inspected and monitored to take note of any failure with a view of effecting repairs. Also sedimentation and littering of the drainage systems should be guided against while vegetation like trees whose rooting system tends to or are likely to distort, break or undermine the drainage system should be removed.
- There should be adequate sensitization of people who are often affected by flood menace towards adopting environmental best practices.

III. METHODOLOGY

The flood prediction system was designed using a deep feed-forward neural network. The back propagation algorithm was used to train the neural network to predict the severity of flood in Nigeria. Since flood occurs in some part of Nigeria each year, it was not right to predict whether or not flood would occur. Therefore, it was more appropriate to frame the problem as a multiclass classification problem where each class represents the wetness or dryness for the year. The neural network has three hidden layers sandwiched between an input and output layer. It accepts two input features (i.e. temperature and rainfall) and outputs the predicted Standard Precipitation Index (SPI) shown in figure 4.

Dropout layers (with dropout probability of 0.2) were included after each hidden layer to avoid overfitting. The optimum configuration of the network was gotten through iteration and shown in table 1.

Layer	**Number of Neurons**	**Activation Function**	**parameters**
Input Layer	2		
Hidden Layer 1 (dense)	128	ReLU	384
Dropout	128		0
Hidden Layer 2 (dense)	64	ReLU	8256
Dropout	64		0
Hidden Layer 3 (dense)	64	ReLU	4160
Dropout	64		0
Output	7	Softmax	455
Total Parameters	13,255		
Trainable Parameters	13,255		
Non-trainable Parameters	0		

Table 1: Structure of the Model

A. Training and Testing the Network

Two-third (67%) of the dataset was used to train the network using back propagation algorithm. Adam algorithm (Kingma and Ba, 2015) was used as the optimizer, while the loss function used was categorical cross entropy. One-third (33%) of the total dataset was used to test it. Also, 33% of the training dataset was used to validate the network during training. The graphs below show the results of the training process on the training and validation data. The model accuracy shown in figure 1 and the model loss is shown in figure 2.

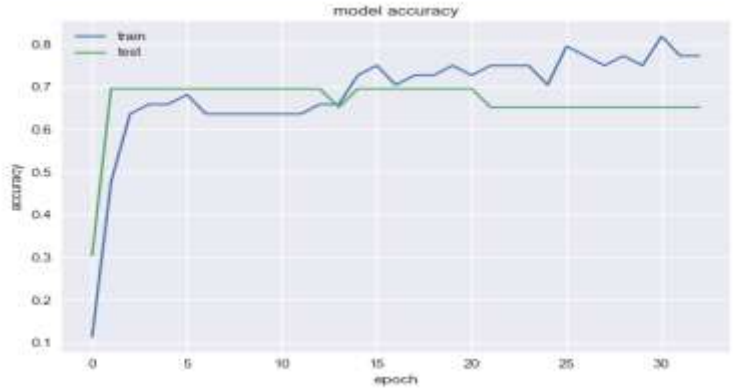

Figure 1: Model accuracy

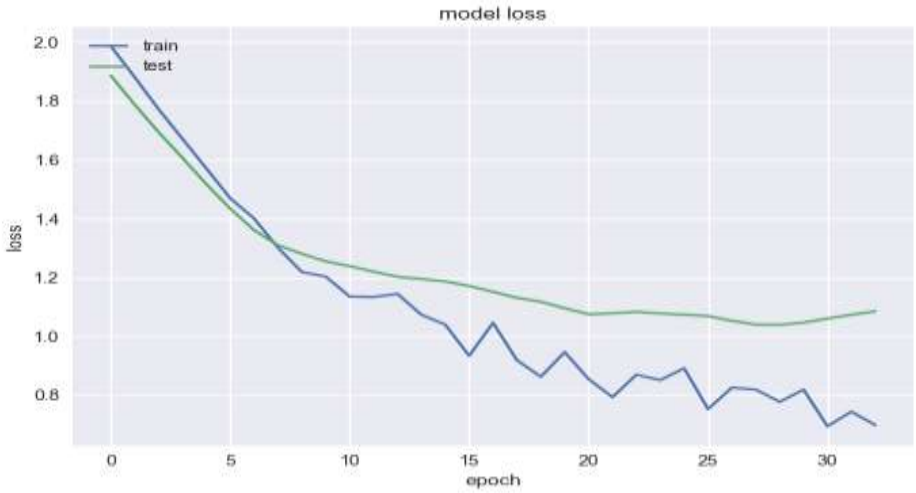

Figure 2: Model loss

IV. RESULTS AND DISCUSSION

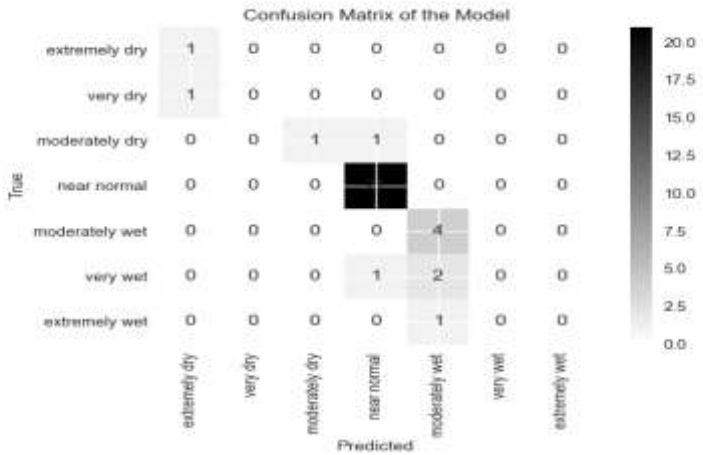

Figure 3: Confusion matrix

The model was tested with the test dataset. The confusion matrix in figure. 3 shows the result of the test. The average accuracy of the model on the test set was 76%.
In this work, we had access to only temperature and rainfall data for 100 years yet it was able to predict with high accuracy. With more input features, I believe the network will do better.

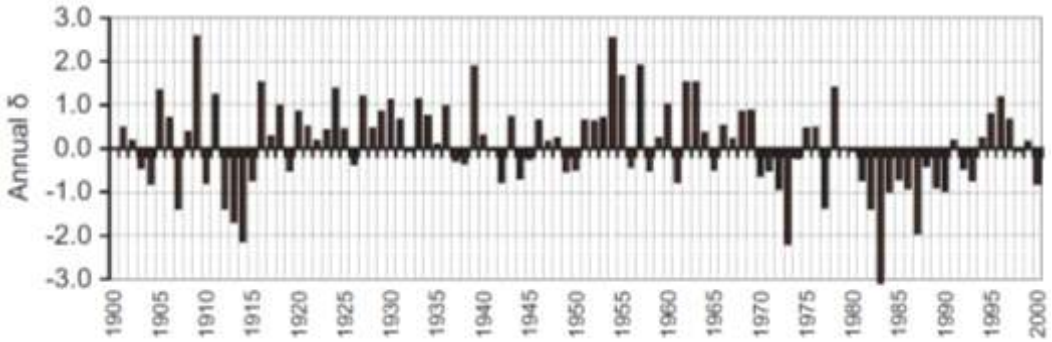

Figure 4: Standard Precipitation Index

Standard Precipitation Index	Label	Value
Below -2.0	Extremely dry	0
-1.99 to -1.5	Very dry	1
-1.49 to -1.0	Dry	2
-0.99 to 0.99	Near normal	3
1.0 to 1.49	Wet	4
1.5 to 1.99	Very wet	5
Above 2.0	Extremely wet	6

Table 2: Standard Precipitation Index

V. CONCLUSION

Flooding has affected lots of places in Nigeria. The problems associated with flooding have caused the Federal Government and the people to be at alert in case of sudden flood disaster. A flood prediction system will be very useful in tackling the effects of flood because it would enable the populace to prepare against the dangers of flood which would further help in the reduction of the effects of flooding. The researcher used ANN to develop a flood prediction system using data such as temperature and rainfall. The work provides an effective flood prediction model which shows how possible it is to accurately predict flood using ANN and to create flooding awareness thereby reducing the impacts of flooding.

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