

Development of a web-based Flood Early Warning System Prototype in Nigeria

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ABSTRACT

In order to disseminate flood alerts to people in Nigeria, a prototype of a web-based Flood Early Warning System (FEWS) was developed in this paper so as to send flood alerts to people especially those living in flood-prone remote areas. Records of flood occurrences in all the 36 states of Nigeria from 2000 to 2022 were extracted from the Emergency events Database of the Centre for Research on the Epidemiology of Disasters, Brussels, Belgium. The results were presented based on location as the Nigerian coastline states and six geopolitical zones. The emergency events database showed both the origin and location of the floods wherever possible. The web-based FEWS was hosted online and developed using HTML, JavaScript, PHP, and MySQL programming languages. A Short Message Service (SMS) gateway was also integrated into the website. This research work provided a FEWS prototype for information dissemination when a flood is imminent or already occurring limiting damage and loss of life in Nigeria.

Keywords

Flood Early Warning, Nigerian floods, natural disasters, NIMET, flood vulnerability, Nigerian geopolitical zones, flood alert, flood risks

1. INTRODUCTION

The World Meteorological Organization (WMO) theme for World Meteorological Day 2025 is “Closing the Early Warning Gap Together,” emphasizing the importance of cooperation and effective early warning systems to mitigate the impacts of extreme weather and climate events. On February 4, 2025 the Nigerian Meteorological Agency’s Seasonal Climate Prediction (a summary for policy makers) was held; the theme was “The Role of Early Warnings Towards A Climate-Resilient Aviation Industry for Sustainable Socio-Economic Development”.

Flooding is one of the most severe natural disasters globally [1]. Flooding is a general temporal state of partial or fully submersed inundation from overflows of inland or tidal waters or from infrequent and rapid accumulation of runoff [2]. Flooding is also the temporary inundation of all or part of the floodplain or temporary localized inundation occurring when surface water runoff moves via surface flow, gutters and sewers [3]. Climate change and the steady increase in the population as well as the urbanization, land use change, deforestation, sea level rise, population growth in the flood-prone area will increase the number of vulnerable people to flood disasters up to two billion in 2050 as the flood occurrence is going to increase in the future [4, 5, 6, 7]. While flash flooding is assumed to be the major issue in the urban areas, the flood stage conditions downstream the floodplain (i.e. varied catchment conditions e.g. slope and geology, varied drainage and flow routing systems) and in the coastal areas (i.e. tidal level,

earthquake conditions, flow routing from fresh water reservoirs upstream are considered multi-dimensionally [8]. Man-made causes of flooding like deforestation, urbanization in flood prone areas, and lack of effective flood control measures complement the natural causes like heavy rainfall, storms, soil nature and climate change effects, [9]. Some of the studies on the causes, effects or impacts of flooding in Nigeria include: [10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22]. Figure 1 shows the six geopolitical zones of Nigeria, whereas Figure 2 shows the flood prone areas and main flood occurrences in the country.

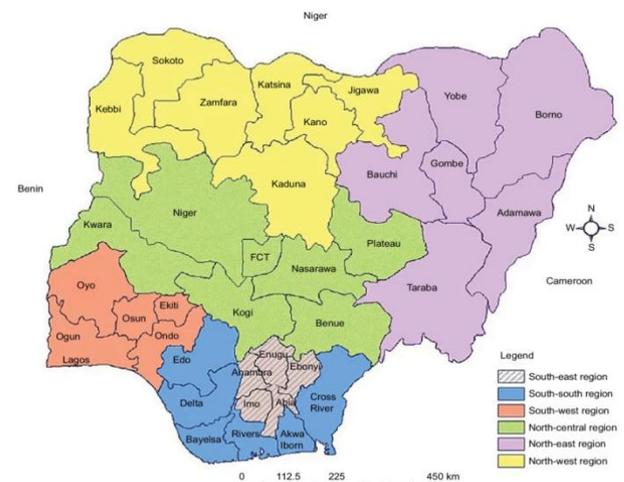


Figure 1. Map of Nigeria with the 6 geopolitical zones [23].

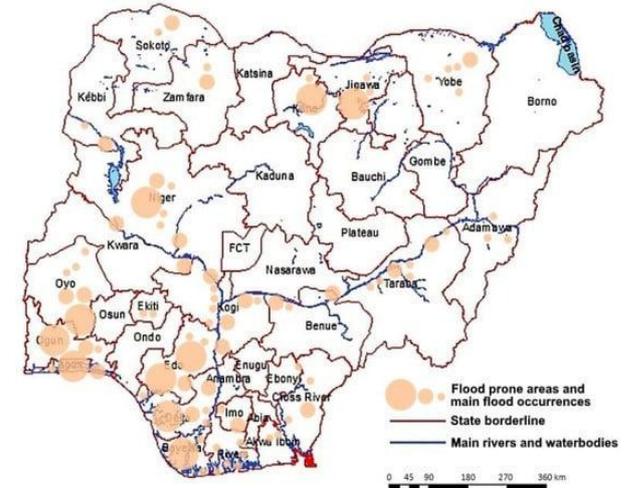


Figure 2. Map of Nigeria showing the flood prone areas and main flood occurrences superimposed over the main Nigerian waterways [24, 25].

2. CAUSES OF FLOODING IN NIGERIA

In Nigeria, the basic causes of floods are heavy and intense rainfall associated with high run-off. Other causes of floods in the country include dam breaks, blockages in river channels, population pressure as increasing number of people, especially the poor, are settling in flood-prone areas. In addition, some land use practices, some of which tend to favour increased runoff and decreased infiltration of rainfall into the soils, contribute significantly to the increasing trend of flooding in the country. Flooding has been occurring almost every year in the country [26]. The Nigerian Hydrological Agency highlighted the major causes of flooding in Nigeria as: soil moisture, extreme weather conditions, operation of dams, topography [27]. The intensity of flood problems in Nigerian urban centers is closely related to the rapid rate of urban expansion especially where the simultaneous provision of adequate run-off disposal systems is lacking [28].

Some of the models used for flood prediction by the Nigerian Hydrological Services Agency in Nigeria include: Geospatial Stream Flow Model (GEOSFM) and Soil Water Assessment Tool (SWAT). These models utilize hydrological and hydrogeological data, rainfall data, topographical data, soil and water balance index as well as Digital Elevation Model (DEM) [29].

3. SOME NOTES ON THE MAIN TECHNOLOGIES OF THE PROTOTYPE

3.1 HyperText Markup Language (HTML)

According to <https://en.wikipedia.org/wiki/HTML>, HTML is the standard markup language for documents designed to be displayed in a web browser. It defines the meaning and structure of web content. It is often assisted by technologies such as Cascading Style Sheets (CSS) and scripting languages such as JavaScript. A CSS file has a .css file extension, while a JavaScript file normally has a .js file extension. HTML provides a means to create structured documents by denoting structural semantics for text such as headings, paragraphs, lists, links, quotes, and other items. HTML elements are delineated by tags, written using angle brackets. Tags such as and <input> directly introduce content into the page. Other tags such as <p> and </p> surround and provide information about document text and may include sub-element tags. Browsers do not display the HTML tags but use them to interpret the content of the page. HTML can embed programs written in a scripting language such as PHP and JavaScript.

3.2 PHP Preprocessor

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3.3 Structured Query Language (SQL)

According to <https://en.wikipedia.org/wiki/MySQL>, SQL is a language that programmers use to create, modify and extract data from the relational database, as well as control user access to the database. SQL is free and open-source under the terms of the GNU General Public License. A relational database organizes data into one or more data tables in which data may be related to each other; these relations help structure the data. In addition to relational databases and SQL, an RDBMS like MySQL works with an operating system to implement a relational database in a computer's storage system, manages users, allows for network access and facilitates testing database integrity and creation of backups.

3.4 Apache Hypertext Transfer Protocol (HTTP) Server

According to https://en.wikipedia.org/wiki/Apache_HTTP_Server, Apache HTTP Server is an open-source cross-platform web server, released under the terms of Apache License 2.0. It supports server-side programming languages such as Perl, Python, Tcl and PHP. It also supports DBMS-based authentication databases, several graphical user interfaces (GUIs), password authentication and digital certificate authentication, embedded PHP scripting, public html per-user web-pages, Internet Protocol version 6 (IPv6)-compatible, HTTP/2 support and several other features.

3.5 Cascading Style Sheets (CSS)

According to <https://en.wikipedia.org/wiki/CSS>, CSS is a style sheet language used for specifying the presentation and styling of a document written in a markup language such as HTML. CSS is a cornerstone technology of the World Wide Web, alongside HTML and JavaScript. CSS is designed to enable the separation of webpage content and presentation, including layout, colors, and fonts. The CSS specifications are maintained by the World Wide Web Consortium (W3C).

3.6 JavaScript (JS)

According to <https://en.wikipedia.org/wiki/JavaScript>, JS is a programming language and core technology of the web platform, alongside HTML and CSS. Many websites on the World Wide Web use JS on the client side for webpage behaviour. JS has APIs for working with text, dates, regular expressions, standard data structures, and the Document Object Model (DOM).

4. DEVELOPMENT OF THE PROTOTYPE

After logging in to the web hosting account which is running the required software such as Apache Web Server version 2.4.56, PHP version 8.2.4, and MySQL Server version 10.4.28. The "Files" and "Database" sections under the "Tools" panel of the CPANEL software were used in developing the prototype. A screenshot of the dashboard of the CPANEL software on the QServers hosting platform is shown in Figure 3. The .php, .js, .html, .css etc. files that were used when developing the prototype were created via the "File Manager" module of the CPANEL software. A screenshot of the "File Manager" module showing the contents of the FEWS API folder/directory is shown in Figure 4. The PHPMyAdmin module in the CPANEL software of the web host domain of <https://okpara.net/phpmyadmin> was used to create the "FEWS" database for the prototype. The PHPMyAdmin dashboard is shown in Figure 5.

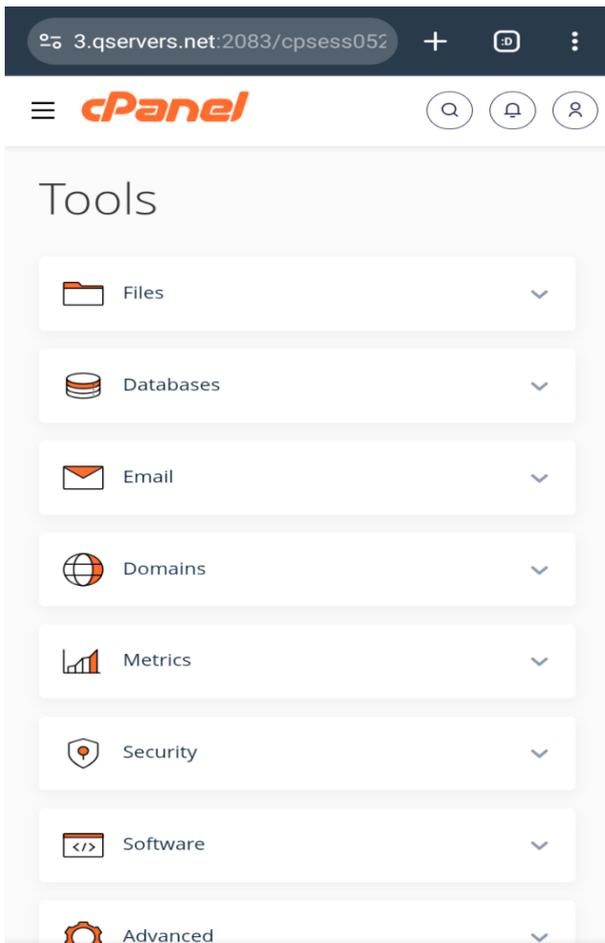


Figure 3: Screenshot of the CPANEL dashboard

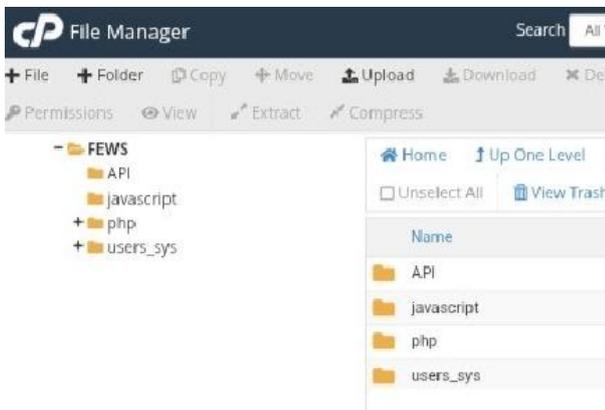


Figure 4: Screenshot of the File Manager module

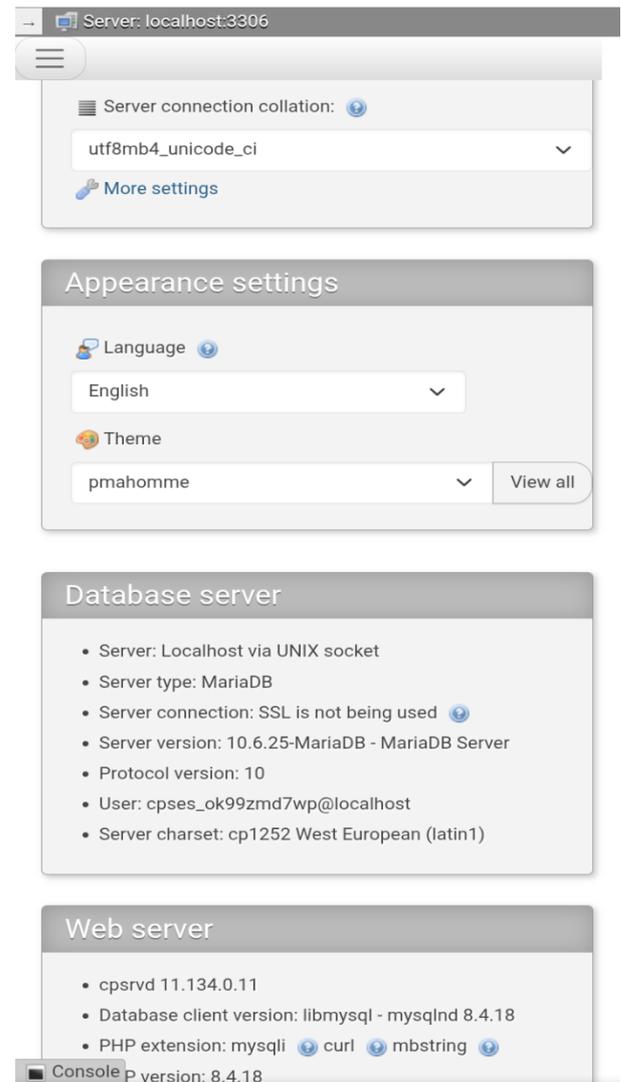


Figure 5: Screenshot of the PHPMyAdmin dashboard

5. DISCUSSION

From the analysis of the records of flood occurrences in all the 36 states of Nigeria from 2000 to 2022 extracted from the Emergency events Database of the Centre for Research on the Epidemiology of Disasters (EM-DAT, CRED / UCLouvain) Brussels, Belgium; the flooding in Lagos State in 2000 was as a result of flash flood from brief torrential rains. In 2001, the flash floods recorded in Jigawa and Kano States were associated with broken dam. In 2004, the flash flood recorded in Adamawa State was as a result of heavy rains; in the same year, Gombe State experienced flash flood from torrential rains. In 2006, Zamfara State had flash floods from both heavy and torrential rains, in addition to a broken dam. The Federal Capital Territory (FCT), had flash flood as a result of heavy rains in 2022. Some of the technical challenges in the establishment of an integrated and coordinated Flood Early Warning Systems in Nigeria include: the availability of hydrological and meteorological data; diverse topography and geology; sediment loading problems in river systems and its effects on long term operation of the FEWS; changes to channel geometry variability; adaptation of the FEWS for the diverse types of flooding experienced in Nigeria. In order to get locations that have experienced flooding in Nigeria, the total flood occurrences in the 36 states of Nigeria from the year 2000 to 2022 is presented in Table 1.

Table 1. Locations, river basin, origin of natural hydrological/meteorological disaster occurrences in Nigeria from 2000 to 2022 extracted from EM-DAT (<https://public.emdat.be>)

Disaster Subtype	Location	Year
Flood (General)	Sokoto North, Sokoto South districts (Sokoto state)	2000
Storm (General)	Benin City town (Ikpoba-Okha district, Edo state)	2000
Flood (General)	Cross River state	2000
Flood (General)	Zamfara state	2000
Flood (General)	Gusau district (Zamfara state)	2000
Flash flood	Lagos state	2000
Flood (General)	Kebbi state	2000
MASS MOVEMENT-Landslide (wet)	Amakor, Nanka villages (Orumba North district, Anambra state)	2000
MASS MOVEMENT-Landslide (wet)	Atakumosa West, Atakumosa East districts (Osun state)	2000
Flood (General)	oke-Ogun, Idimissa/olle-Oje, Ogbonmo, Oke-Idogbon, Ijebu-Owo, Post-Office, Oke-Ajama, Ilore, Iyere, Ishokun Oke, Ishokun Odo areas (Owo district, Ondo state)	2001
Riverine flood	Talata-Marafa district (Zamfara state)	2001
Flash flood	Jigawa, Kano states	2001
Flood (General)	Bariga, Bode Joseh areas (Shomolu district, Lagos state), Lagos Mainland district (Lagos state)	2002
EXTREME TEMPERATURE-Heat wave	Maiduguri district (Borno state)	2002

Riverine flood	Kaduna, Kano, Niger, Jigawa states	2003
Riverine flood	Lagos state	2004
Riverine flood	Jigawa state	2004
Riverine flood	Ughelli North, Ughelli South districts (Delta state)	2004
Flash flood	Adamawa state	2004
Flash flood	Gombe state	2004
Riverine flood	Lagos state	2005
Riverine flood	Jigawa, Bauchi, Taraba, Yobe states	2005
Riverine flood	Edo state	2006
Flash flood	Zamfara state	2006
Flash flood	Gusau district (Zamfara state)	2006
Riverine flood	Plateau, Adamawa, Borno, Anambra, Bauchi, Yobe, Ogun, Nassarawa, Lagos, Sokoto, Kebbi states	2007
Flood (General)	Ogun state	2007
Flood (General)	Ikorodu, Kosofe districts (Lagos state), Abeokuta North, Abeokuta South districts (Ogun state)	2007
Riverine flood	Zamfara, Kaduna, Niger, Benue, Adamawa, Nassarawa, Sokoto, Jigawa, Abuja states	2009
Riverine flood	Lagos state	2009
Riverine flood	Jigawa, Sokoto, Kebbi, Niger, Katsina states	2010
Riverine flood	Katsina, Lagos states	2011

Riverine flood	Kano state	2011
STORM-Thunderstorms	Balanga district (Gombe state), Damaturu district (Yobe state)	2011
Riverine flood	Ibadan North, Ibadan South-West, Oluyole, Ido, Ibadan North-West, Egbeda, Ona Ara, Ibadan North East, Lagelu, Akinyele districts (Oyo state)	2011
Riverine flood	Imo, Lagos states	2011
Riverine flood	Nassarawa, Niger, Plateau, Adamawa, Bauchi, Gombe, Taraba, Yobe, Jigawa, Kaduna, Kano, Katsina, Kebbi, Anambra, Ebonyi, Cross River, Lagos, Benue	2012
STORM-Thunderstorms	Lagos state	2012
Riverine flood	Abia, Bauchi, Ebonyi, Edo, Gombe, Jigawa, Kano, Katsina, Kebbi, Zamfara states	2013
Riverine flood	Ibadan North, Ibadan North-East, Ibadan North-West, Ibadan South-East, Ibadan South-West districts (Oyo state)	2014
Riverine flood	Kano, Katsina, Sokoto, Kebbi, Zamfara, Kaduna, Jigawa, Adamawa, Yobe, Gombe, Bauchi, Anambra, Benue, Delta, Niger, Ondo, Taraba states	2015
STORM-Thunderstorms	Akwa Ibom, Bauchi, Benue, Borno, Cross River, Delta, Kaduna, Kwara, Nasarawa, Yobe, Zamfara states	2016

Riverine flood	Gwaram, Dutse, Jahun, Ringim, Hadejia, Babura, Gumel, Malamadori, Birninkudu districts (Jigawa state)	2016
Flood (General)	Ekiti, Osun, Akwa Ibom, Kebbi, Niger (Suleja, Tafa), Kwara, Ebonyi, Enugu, Abia, Oyo (Ibadan), Lagos (Victoria Island, Lekki, Oniru), Plateau, Sokoto, Edo, Bayelsa	2017
Flood (General)	Benue (Makurdi), Kogi (Lokoja, Sarkin Noma suburbs, Ibaji, Igalamela-Odolu, Ajaokuta, Bassa, Koton-Karfe) states	2017
Flood (General)	Jibia district; Yobe, Edo, Ogun, Katsina, Ondo, Bauchi, Niger, Abuja states	2018
Flood (General)	Kogi, Delta, Anambra, Niger	2018
Flood (General)	Cross River, Kogi, Niger, Taraba States	2019
Flood (General)	Borno, Jigawa, Kano, Yobe states	2019
Flood (General)	Akwa Ibom (southern part of the country) and Kwara (west-central Nigeria)	2020
Flood (General)	Suleja City, Gwagwalada area, Abuja	2020
Flood (General)	Jigawa, Kebbi, Kwara, Sokoto, Zamfara	2020
Flood (General)	Jigawa, Bauchi, Adamawa and Borno states; Jalingo, Taraba, and the city of Lagos	2021
Flash flood	Trademoore, Light Gold, Wisdom Estates and Lugbe (Abuja)	2021

STORM-Severe weather	Mutum Biyu Town area (Gassol Local Government, Taraba State)	2022
Flood (General)	Anambra, Delta, Cross River, Rivers, Benue, Borno, Enugu, Imo, Kebbi, Kogi, Lagos, Nasarawa, Niger, Rivers, Taraba, and Yobe states	2022
Flood (General)	Emirates of Dukku and Nafada in Gombe State	2023

Figure 7 to Figure 12 shows the various frequencies of flood occurrences in the six geopolitical zones of Nigeria using data extracted from the emergency events database of the Centre for Research on the Epidemiology of Disasters (CRED), in Brussels, Belgium. In the North West region, flooding occurred mostly in Jigawa State. In the North East region, flooding occurred mostly in Bauchi and Yobe States. In the North Central region, flooding occurred mostly in Niger State. In the South West region, flooding occurred mostly in Lagos State. In the South East region, flooding occurred mostly in Anambra State. Finally, in the South South flooding occurred most in Cross River, Delta, and Edo States.

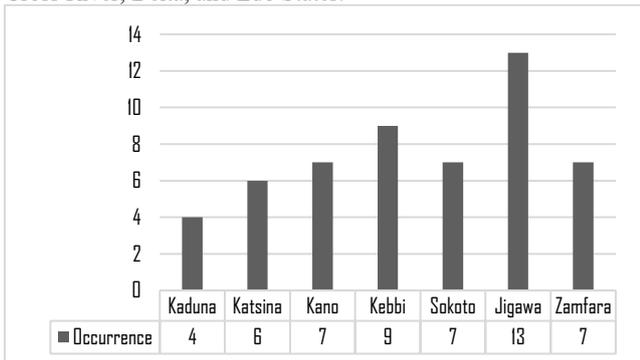


Figure 7: Flood occurrences in North West from the year 2000 to 2022

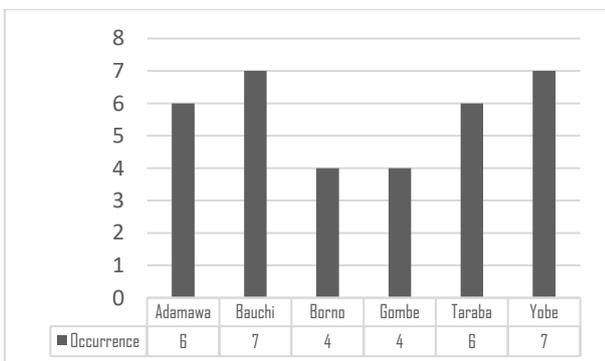


Figure 8: Flood occurrences in North East from the year 2000 to 2022

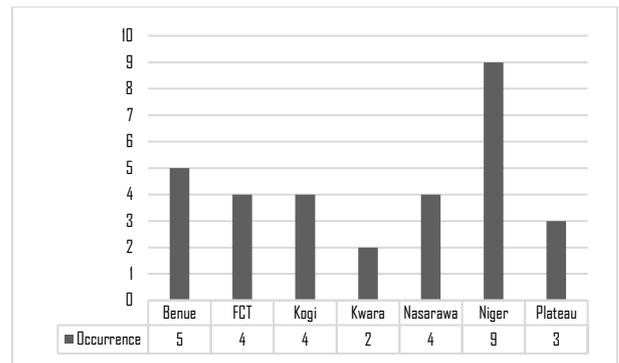


Figure 9: Flood occurrences in North Central from the year 2000 to 2022

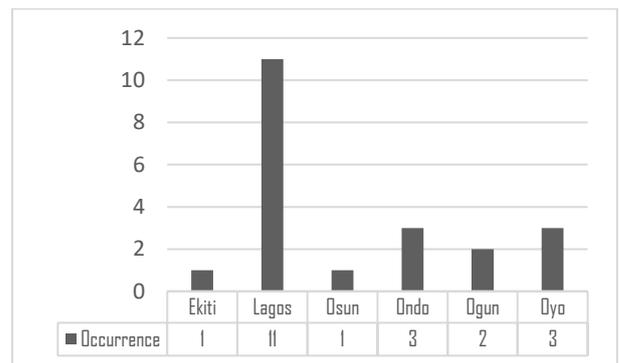


Figure 10: Flood occurrences in South West from the year 2000 to 2022

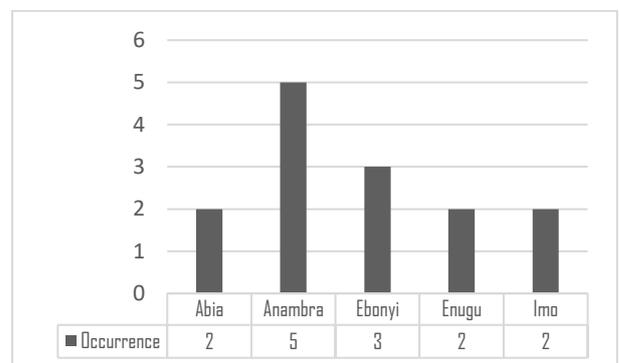


Figure 11: Flood occurrences in South East from the year 2000 to 2022

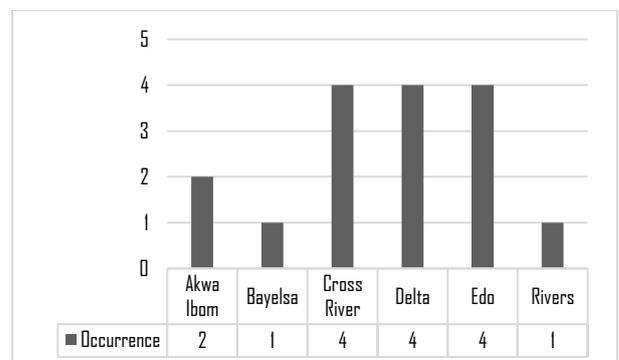


Figure 12: Flood occurrences in South South from the year 2000 to 2022

Figure 13 shows the flood occurrences in along the Nigerian coastline states. Figure 14 showed that the North West

geopolitical zone had the highest number of flood occurrences in Nigeria, while the South East had the least.

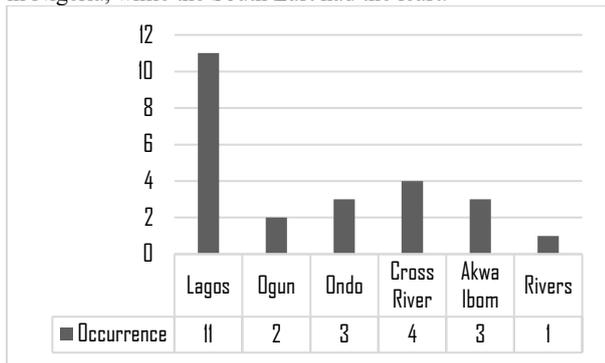


Figure 13: Flood occurrences in Nigerian coastline states from 2000 to 2022

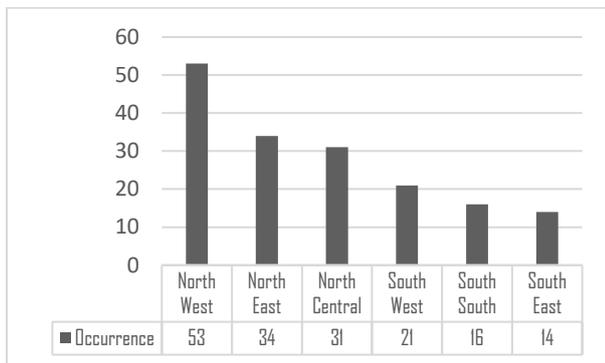


Figure 14: Flood occurrences in Nigeria by geopolitical zones from 2000 to 2022

6. HOW THE PROTOTYPE WORKS

When there is a possible flood alert detected from a configured external flood forecasting centre/server such as from a dedicated NIMET Early Warning (EW) forecasting workstation, the API endpoint at <https://okpara.net/FEWS> gets triggered automatically. A flood alert SMS is then sent from the FEWS website to all the phone numbers registered on the FEWS website with locations same as the location sent via a POST API request to the FEWS prototype by the EW forecasting workstation. During the testing of the prototype, a simplified version of the JSON code for the FEWS issuance, and triggering was used, that is:

```
{ "location": " Akure North", "message": " Dam release or Broken Dam is causing rise in water levels. Evacuate to higher ground immediately. Listen to the radio for further instructions.", "severity": "HIGH", "key": "..."} }
```

From the code, the “location” parameter is where the flood is expected to occur, in this case, the location is a Local Government Area (LGA). The “message” parameter contains both the type and cause of the flooding, as well as instructions on what to do, and where to go to get more information concerning the flood. The “severity” parameter indicates how severe or intense the flood will be if it occurs. Additionally, the “key” parameter is used to retrieve an alphanumeric API security key. The FEWS-SMS gateway was tested at <https://web.postman.co>, which is a website for testing APIs. An API POST request was initiated using the following API endpoint code:

```
https://okpara.net/FEWS/API/index.php?location=Akure North&message=Dam release or Broken Dam is causing rise in water levels. Evacuate to higher ground immediately. Listen to the radio for further instructions. & severity=HIGH
```

The conceptual framework is shown in Figure 16, while Figure 17 shows the activity flowchart. A user/collaborator is required to access the FEWS website online using a web browser. Then he/she registers his/her phone number and location/LGA from the homepage. During the registration process, the user/collaborator inputs or provides his/her phone number, photo, email address and password. These registered accounts can be managed at the backend on the FEWS website. But the subscription payment of the SMS notifications from the FEWS website is done from an account created at the website, www.termii.com.

The alert system was effective especially for any phone number in Nigeria that do not have an active Do Not Disturb (DND) status. The DND status of phone numbers in Nigeria can be checked by sending the word, “STATUS” via USSD code to the number 2442. Furthermore, the SMS alerts were successfully disseminated between the hours of 8am and 8pm on MTN, GLO and AIRTEL telecommunication networks in Nigeria.

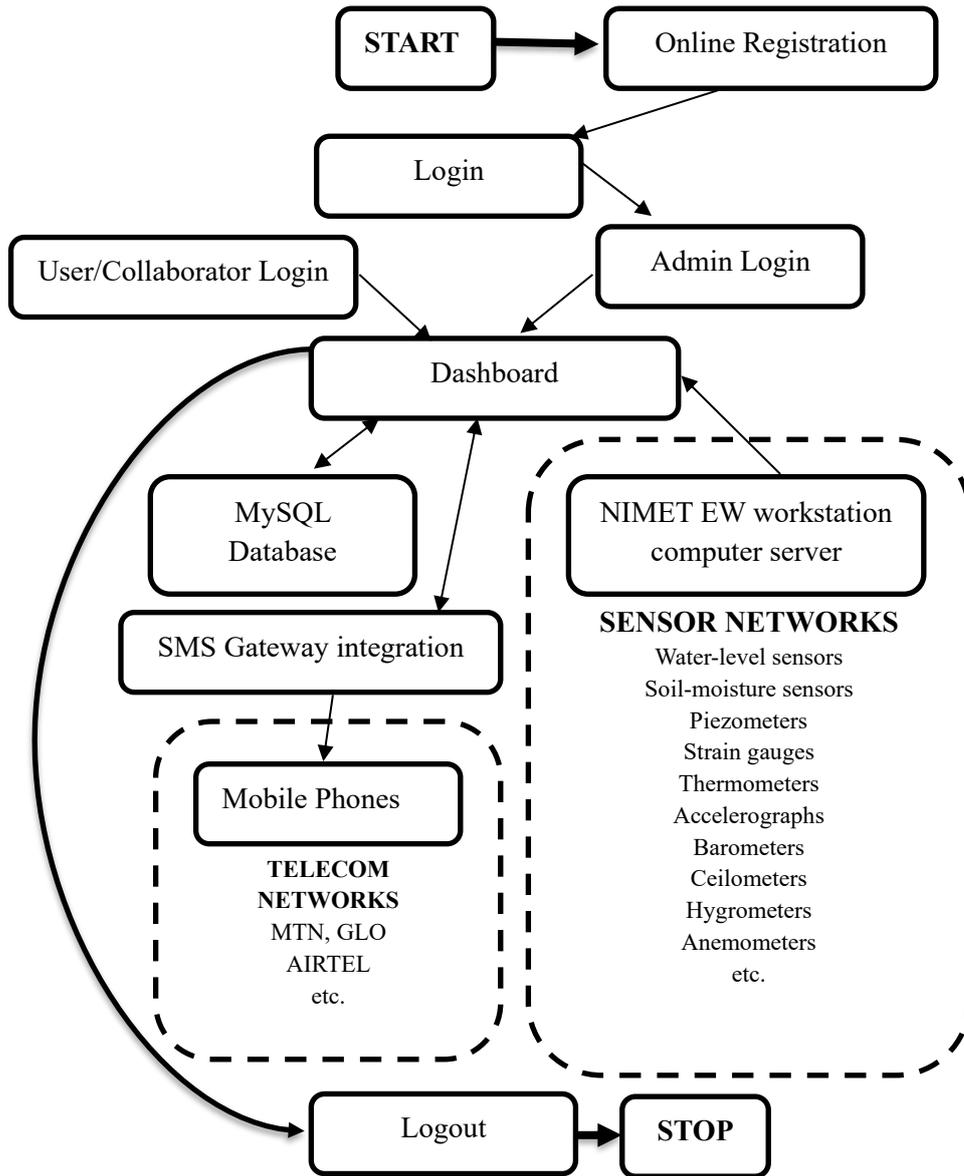


Figure 16: The conceptual framework

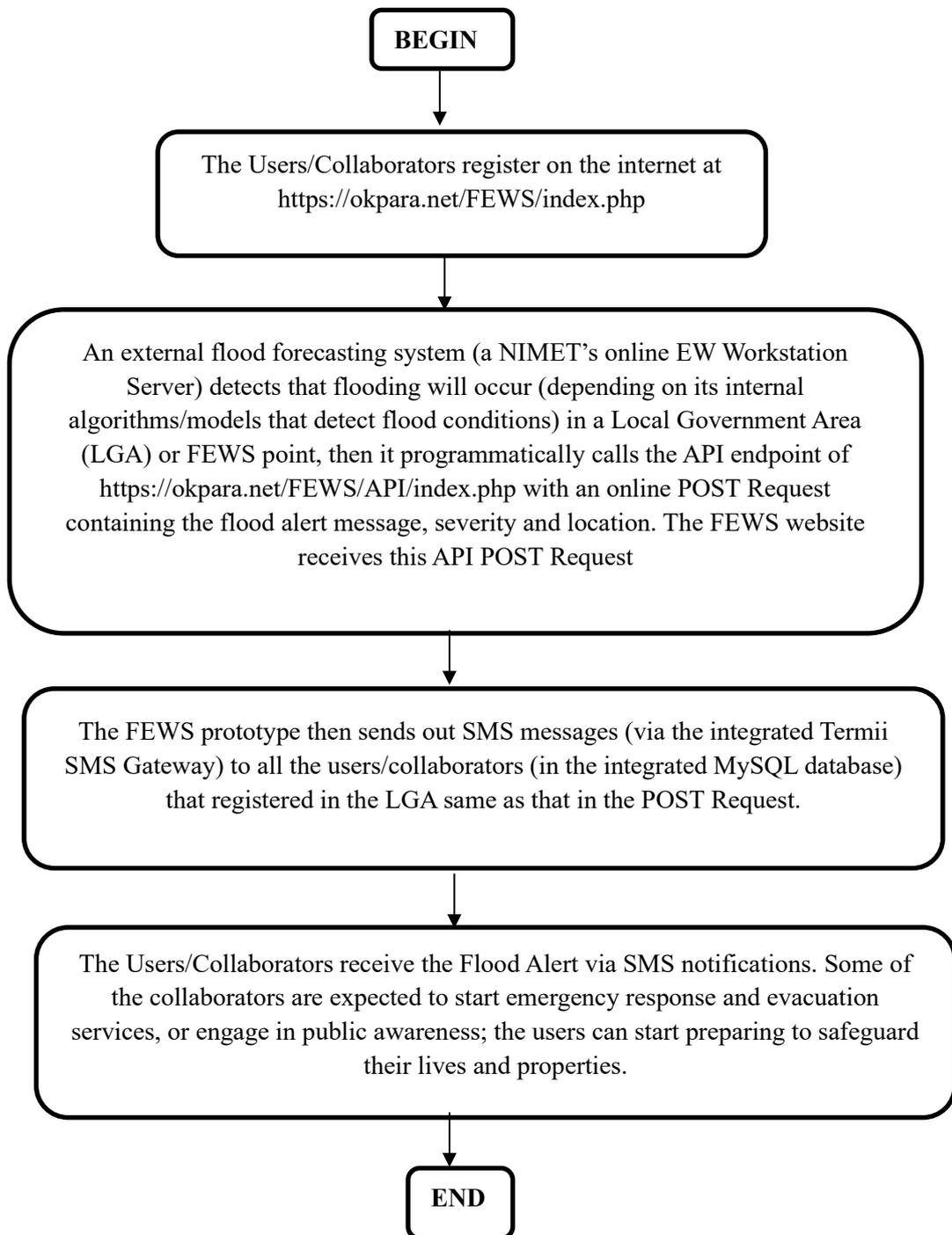


Figure 17: The activity flowchart

7. CONCLUSION

Jigawa State, in the North West region, has the highest occurrence of floods in the country from 2000 to 2022. From the survey, the North West is most susceptible to flooding when compared to other geopolitical zones in Nigeria. In locations or

States where flooding occurs, the populace is affected, and there is a negative impact on the livelihood.

Warnings and alerts provided during heavy rainfall, flooding and other hazards can help to avert disaster. For warnings and

alerts to be effective, they need to be understandable by most, or ideally all, people in the community.

The use of a web-based technological approach to enhance flood early warnings can leverage the efficient interconnectivity of information-centered systems (which focus on the storage, organization, and retrieval of data), and knowledge-based systems (which utilize Artificial Intelligence to interpret data, giving it meaning and applying logical rules to solve complex problems).

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