Development of an Advanced Knowledge Domain for Coordinated Flood Inundation Management in Developing Nations

ChukwuNonso H. Nwokoye[1], Obiajulu Ositanwosu[2], Ikechukwu Umeh[3],

[1]National Open University of Nigeria Unit, Nigeria Correctional Service, Awka, Nigeria.
[2,3]Computer Science Department, Nnamdi Azikiwe University, Awka, Nigeria.

chinonsonwokoye@gmail.com,ositanwosuobiajulu@yahoo.com,ikumeh@gmail.com

Abstract

Natural hazards such as floods has become in recent times a recurring phenomenon all over the world. In Africa, its effects has resulted to immense losses. Flood instances in Anambra state, Nigeria, has ravaged several communities causing deaths, displacements and damages to infrastructure. Therefore, this study is aimed at developingthe Anambra State Environmental Protection Agency Flood Management System (ANSEPA FMS), with an integrated spatial database and to implement this tool using an object-oriented platform of Visual Studio. This is to cater for several challenges which include the paucity of comprehensive data and the lack of instances of computer/communication technologies in the management and control of flood. Also, there exists the issue of isolation; here ANSEPA (under the State Ministry of Environment (SME)) hardly shares information to other flood/disaster-related agencies.On the methodology, firstly, we used data collection methods like observation, study of procedural manuals and interview of operators at functional (strategic) points of the institution in order to obtain necessary data and information. Subsequently, we performed system analyses and design, implementation and testing.The spatial database and corresponding forms was built based on the recent holistic flood management knowledge domain proposed by Kaewboonmaa, *et al.*, which employed experts'opinions in its conception. Aside the benefit of assuming a central position for data sharing amongst related agencies, ANSEPA FMS can positively impact study area familiarity, thereby, instigating vulnerability assessment and triggering the necessary post-flood readiness required for prompt response to flood inundation.

Keywords: *Knowledge domain, Information System, Flood Management, Nigeria, Africa*

1. Introduction

Floods make up one-third of natural disasters with approximately 37.1% [1], and this is due to urbanization and immense rise in human population, which allows for the continual transformation of open places to housing units and workplaces. More so, climate change is also a major reason for instances of flood. Considering the health consequences, threats, deaths, tragedies and related losses of floods, officials of nations and affected regions are becoming increasingly concerned. This is because the cost of damages caused by this hydrological extreme increases annually. In Africa, statistics has it that 19.59% of 1,699 disasters in 2017 was flood-related and specifically, approximately 28 people died in every event. In 2017, flood caused distress for 73,906.93 persons, and 7,402.12 others experienced untold hardship as a result [1]. All these shows that, "natural disasters occurring in African countries undermine the economic survival of poor communities" [2]. Countries such as Mozambique, Malawi, Zimbabwe, Botswana, Namibia, have experienced deaths and displacements in the past. Similarly, in Togo, Ghana, Mauritania, residents were in dire need of assistance as flood ravaged communities. X-raying East and Central Africa; people have been rendered homeless while crops and livestock were grossly damaged as a result of torrential rain and flood in Uganda, Sudan, Ethiopia, livestock, Rwanda and Kenya. In Nigeria, flooding has affected its 36 states including the Federal Capital Territory, Abuja. In the north-east region, it demolished roads and made difficult the landing of airplanes [3]. In the words of Okpala [3], "the causes of flood are improper city planning with regard to layout of building and other structures, poor drainage system, over population, government irresponsibility and climate change. On the other hand,to proffer management solutions, researchersposit that, "advances in computer and communication technologies have influenced the movement of the old fashioned hard copy flood maps, graphs and tables to more sophisticated form; providing much needed real time flood information in more detail, such as computerization of the flood prediction operations and usage of GIS as a platform for interaction with the users"[4].Evolutions in computer and communication technologies have governed the move from the obsolete maps, tables and graphs to more complicated systems that present timely and elaborate flood data and information. But essentially, there is the need to address a fundamental requirement for the introduction of other complex computer and communication technologies i.e. building a system that allows comprehensive and updated knowledge acquisition.Review of information systems studies on disasters showed that African nations are yet to vigorously apply instances of computer/communication technologies in the management and control of flood. Although, they perform post-flood management activities such as providing and catering for displaced persons, the dead etc., they are yet to introduce information systems (IS) for any of the phases of flood inundation.During investigation, we noticed several issues with flood management and control in Anambra state, Nigeria. As Okpala [3] puts it, "Anambra state is always affected by flood because it is situated at the lowest point of the River Niger, submerging in water local government areas such as Anambra West, Anyamelum, Anambra East and Ogbaru". Firstly, we observed from the few data available at the Anambra State Environmental Protection Agency (ANSEPA) (under the State Ministry of Environment) that the flood-prone areas in the state include Onitsha, Obosi, Nkpor, Iyowa Odaekpe, Ogidi (Afor Igwe), Awka (Iyiagu, Arthue Eze lane, Ziks Avenue) etc. However, we discovered that the agency do not use any kind of IS for collecting, organizing, analyzing and presenting flood-related data and information. The little information they possess are written on papers/notes and the information was found to be grossly inadequate and insufficient for effective and efficient management and control of flood in the state.

Interview of the personnel of the agency showed that there are other agencies under the State Ministry of Environment that are involved in different phases of flood inundation. They include Nigerian Erosion and Watershade Management Project (NEWMAP), State Emergency Management Agency (SEMA) and the Nigerian Inland Waterways Agency (NIMA). However, we discovered that these agencies work in isolation and like ANSEPA, they all possess few data and information for the effective management of flood (and every other disaster type) in the state. This isolated approach of flood control tends to make knowledge sharing difficult for these agencies. The management of ANSEPA alluded to the inclusion of other experts that will help Anambra state in handling flood issues, for example, by monitoring, controlling the water condition as well as the removal of waste blocking gutters and drainages. Actually, the knowledge owned by these experts and agencies are inadequate. Furthermore, the few existent flood-related information are yet to be captured, categorized and incorporated into an IS for purposes of proactive decision making. Interestingly, this situation matches the challenges faced by Chi River Basin (CRB), Thailand which necessitated research efforts expended by Kaewboonmaa, *et al.* [4], only that the African (Nigeria) case is even worse i.e. there are no data. These authors used document analysis, qualitative methods as well as the interview of professionals in Geographic Information Systems (GIS), Environmental engineering and Water resources engineering, so as to develop a comprehensive knowledge domain for flood management.

In view of these issues, our study, therefore, aims at developing an IS platform, which is a pragmatic extension of the proposal in Kaewboonmaa, *et al*. [4]. Thiswould enable data capturing and other capabilities that facilitates proper management of flood in the state. Specifically, this system would be implemented using an object-oriented platform such as the Visual Studio. In addition, our study goes further to presents a method in which ANSEPA, with the developed tool assumes a central position that makes it possible for other related agencies to share information i.e. a statewide data sharing and integrated approach to flood management as described in Figure 1. From the diagram, “OTHERS” implies other well spirited individuals, churches, state-based arm of the Nigerian Armed Forces (i.e. Army and Navy formations), the Nigeria Police Force, non-governmental institutions (NGO) that partner with Anambra state during post-disaster times.

2. Related Works

In this review, we hope to learn insights that will impact positively the design and implementation of Flood Management System (FMS). Note that decisions support systems (DSS) and geographic information systems (GIS) enjoyed the most usage in the automation of flood management and administration. While conducting a literature search, which resulted in the review below, we couldn’t find a study bearing the aversion of flood in Africa in mind, and this singular reason underlies the essentiality of work herein.

Parker and Fordham [6] presented results from the EUROflood research project which assessed the degree of advancement in flood prediction, notifications and response structures within the European Union in relation to foods in Netherlands, the United Kingdom, Germany, France and Portugal. In order to serve the needs of decision-makers and stakeholders in the Red River Basin, Simonovic [7] developed and implemented a Red River Basin Decision Support System(REDES), wherein the purpose is to move past improving readiness, strategizing, reactions and recovery to flood forecast, inspection, response at emergency times as well as residents involvement in control, management and administration of flood. The study by Todini [8] shed light on the development of a wholesome tool for flood strategizing and management, so as to exploit the merits of the ubiquitous high level computing platforms. With this system, it was possible to identify risk areas, estimate potential damages and predict hydrological extremes by relying on a real-time understanding of the current meteorological scenario as well as the extant forecasts at diverse spatio-temporal scales.

Sanders and Tabuchi [9] evaluated the advantages of creating a DSS for flood-related risk assessment alongside its applications, with emphasis on the insurance industry. Furthermore, the study elaborates on the “Intederometric Synthetic Aperture Radar (IFSAR)map products data in the building of a huge flood risk assessment system for the River Thames in the United Kingdom”.Shim, *et al*. [10] built a prototype spatial DSS for wholesome, timely river basin flood management for a system that possessed numerous reservoirs and purposes. In the words of the authors, “this DSS incorporates, a database system, a real-time meteorological and hydrological data monitoring system, a model-base subsystem for system simulation and optimization, and a graphical dialog interface allowing effective use by system operators". After studying diverse system development approaches for the object-oriented idea, Mwakapuja [11] built a GIS that caters for local level flood management; this is due to recurring nature of environmental hazards. The gruesome deaths and huge destruction of physical infrastructure and social/economic activities in the Red River basin caused by flood disasters inspired Booij [12] to develop a DSS for identifying and selecting a better mixture of flood management and ecosystem development initiatives. As part of a joint IST project between the EU and the People's Republic of China, Prastacos, *et al*. [13] designed and implemented a DSS called ANFAS, which is an online platform, possessing a distributed internal structure that allows the management level executives to estimate future flood effects by varying system parameters of river floods.

Ahmad and Simonovic [14] developed a smart DSS which incorporated knowledge possessed by humans so as to provide virtual assistance for decision makers who daily strategize to solve both engineering and non-engineering associated to flood control at different phases. To alleviate the limitation of only making availablehard copy inundation maps in a specific GIS application format, Muncaster, *et al*. [15] developed a web-based GIS interface to enable online access and interpretation of maps. In the light of the statistics that named Gold Coast as Australia's most susceptible location for flood inundation,Mirfenderesk [4] built a flood emergency DSS amongst a decade-long flood and drainage plan to address the issue of an increase in residual flood risk. Complexities in the urban environment and the lack of high-resolution topographic and hydrologic data compromise the development and implementation of models of non-riverine flooding in urban areas spurred Chen, *et al*. [16] to perform a case study analysis of an urban university campus to develop and test a GIS-based urban flood inundation model (GUFIM). The essentiality of an exhaustive knowledge of flood risk in different spatial locations and the development of a flood mitigation scheme for a watershed motivated Karmakar, *et al*. [17] to perform a flood risk-vulnerability analysis using a GIS, with emphasis on the four categories of vulnerability to flood (i.e. physical, the economic, infrastructural and social).

Honghai and Altinakar [18] developed a DSS for integrated flood management within the framework of ArcGIS based on realistic two dimensional flood simulations. This system has the ability to interact with and use classified Remote Sensing (RS) image layers and other GIS feature layers like zoning layer, survey database and census block boundaries for flood damage calculations and loss of life estimations. Ibañez, *et al*. [19] designed and implemented a DSS that is based on an open-shell platform for integrating various data sources and different simulation models. In order to display the benefits of applying information technology in monitoring and enhancing flood response management, Hysenaj [20] developed a GIS that allows the presentation of a complete statistic synopsis of flood occurrences in the region. Laine,*et al*. [21] described the development of a new flood management DSS which significantly enhances the ability of flood practitioners to; "identify adaptation and mitigation solutions to flood inundation, facilitate objective community flood risk management consultation and justify floodplain management decisions in a transparent and structured manner to all stakeholders".Demir and Krajewski [22] developed the community-centric Iowa Flood Information System (IFIS) – "a web-based platform application to provide access to flood inundation maps, real-time flood conditions, flood forecasts both short-term and seasonal, flood-related data, information and interactive visualizations for communities in Iowa". Due to numerous reoccurrences of flood in the Portuguese river Lima basin, Vieira, *et* *al*. [23] built a DSS called FEWS-LIMA, which incorporates a hydrological database and model for flood forecasting and was implemented by employing the Delft-FEWS software.

To curb the imminent occurrences of long term risk (due to climate change and population growth) and to facilitate the development of long-term flood mitigation plans, Maier, *et al*. [24] developed a framework for a DSS framework consisting of an integrated model consisting of dynamic, spatially distributed land-use and flood inundation models. Due to the floods that struck Johor state in 2006 and 2007 and the East Coastal in 2014, flood management using IT has been greatly triggered in Malaysia. Bukari, *et al*. [25] showed how a GIS can be used to identify potential areas of flooding. Mirfenderesk, *et al*. [26] challenged the following paradigm; "that undertaking complex flood simulation models has been considered as infeasible in the short time available during a flood emergency and this has warranted the use of surrogate or simplified flood modelling systems in the DSS of flood emergency management". The desire for this paradigm shift is underpinned by the recent advent of Graphic Processing Unit (GPU) flood modelling systems and sophisticated web-based GIS systems that can better present the results of these models. Muste and Firoozfar [27] identified several reasons that calls for the formation of a strategic global partnership for framing and subsequently assisting in the development of a generalized flood DSS (FLOODSS) that can overcome the current associated drawbacks. Xu, *et al*. [28] identified several issues with the existent Enterprise Information Systems (EISs) designed for urbanized flood control. Therefore, they proposed a cloud-based asset management platform to cater for some of the highlighted challenges which include; "ineffective management of physical assets which has greatly impeded their deployment, the sharing of assets and services between agencies, and ensuring real-time and flexible decision supports.

Our literature search availed few studies related to flood management and control that did not necessarily involve the use of an IS such as FIS, DSS, GIS and EIS. These were discussed here. Ghozalia, *et al*. [29] attempts to make a case for climate change as having significant direct and indirect impact on flood risks by exploring flood management procedures in in Ayutthaya, Thailand and Samarinda, Indonesia using both primary and secondary data, while qualitative methods were used for analysis. Findings of the study depicts that the flood risk on both cities has same characteristics and indicates that the role of government of Ayutthaya also stronger than Samarinda. Since Huaihe River Basin is a transitional river which has been frequently hit by big floods and has suffered from flood disasters; it motivated Wang, *et al*. [30] to summarize flood management and disasters of the River basin, and then summarizes achievements in flood control and management. The fact that climate change is expected to cause rise in both the magnitude and frequency of extreme precipitation instances, which culminatesto hugely intense and frequent river flooding inspired Shrestha and Lohpaisankrit [31] to assess the flood hazard potential under climate change scenarios in Yang River Basin of Thailand.

In summary, the reviewed works involved DSSs [4, 9, 10, 12-14, 18, 19, 21, 23, 24, 26-27], GISs [11, 15-17, 20, 25] and an EIS [28]. Unlike these studies, our work herein proves more holistic and comprehensive i.e. it includes not only scientific data which are necessary for flood forecast, response and recovery, it also allows for a more detailed approach to making decisions related to water management using geo-informatics (ground water, bank line, river basin network etc.) and historical data such as climate, population, irrigation demands, irrigation efficiency as well as soil/water conservation and moisture.

3. Methodology

Major methodologies for developing an IS include the Structured System Analysis and Design Methodology (SSADM), Systems-Development Life Cycle (SDLC), Rapid application development (RAD) and Agile approaches. A thorough look at these methodologies [32]shows they all include requirement gathering, system analysis, design, and implementation. Therefore, we would concentrate and present herein the requisite activities performed for these phases of IS development.

Requirement Gathering Phase: The developed application has some needs that must be fulfilled for it to function efficiently. FMS is an electronic platform needed by staff of ANSEPA and other related agencies of the SME for the proper management of flood and other disasters in the State. The system mirrors an efficient and secure manner of handling flood-related issues. Since most of our conceptions are for a non-existent system, ANSEPA would have to think of employing information technology (IT) personnel or retrain its staff in system security and administration; and with these skills they can secure there IT infrastructure and manage the electronic system respectively. These trained staffalongside other ANSEPA staff ensure that all necessary data and information are collected, documented and used for appropriate decision making in all the phases of flood management. Aside documentation, the developed system must achieve the needs of authorization and authentication according to the regulations of the agency. At this phase, we were able to elicit several challenges facing the agency. As a result of in-depth analysis and investigation of the present system, its policies, practices and procedures, many weaknesses were identified. In order to have an efficient service delivery, the following weaknesses are worthy of note. First, books are used to store data, which implies manual data entry and recovery procedures as well as slower update and retrieval of information. Consequently, operations are prone to errors. Additionally, there is the challenge of unavailability of information for faster decision making and less effective method of sorting and searching for required information. The managerial approach is adjudged tough and consumes a lot of time and labor. All these are issues still add to the isolated nature of the overall flood administration. However, the proposed design of an IS would eliminate the above weaknesses as well as enhance the smooth running of Anambra State Environmental Protection Agency (ANSEPA).

System Analyses: for the developed system we channeled analytical thoughts towards prospective graphics and functions of the ANSEPA FMS. On the graphics, we noted color schemes, logos and as well as other images to be employed. Subsequently, the colors used included white, ash, pink, yellow alongside the map of Anambra state, Nigeria (on the home page) while the renowned unified modeling language (UML) was used to express the necessary functions of the system. The gallery also holds photographs of several damages caused by the flood over time. On the navigation of the system, Figure 2 shows the main menu of the knowledge system i.e. a graphical description of the road throughout the FMS. UML diagram were employed in order to shed light on the requirements of ANSEPA in flood management, which include addressing both pre-flood and post-flood activities, implementing government land use policies and increasing the learning experience of the their staff on predictions for proactive management. Figure 3is a UML case diagramthat incorporates roles and functions in the proposed ANSEPA FMS. In the light of the organizational structure of ANSEPA, the case diagrams depicts activities that may be performed by officials i.e. Secretary (lower level management), Engineer 1, Engineer 2, Field Inspector(middle level management), and Chairman/Director and General Manager (top level management)as well as other stakeholders that help in flood recovery. On the database specifications, we used

MySQL for the creation of tables that will eventually hold scientific data, historical data, geoinformatics data, pre-flood social and economic data, post flood scientific data, flood response and the flood recovery data. Figure 4 shows a topmost section of theANSEPA FMSflowchart.

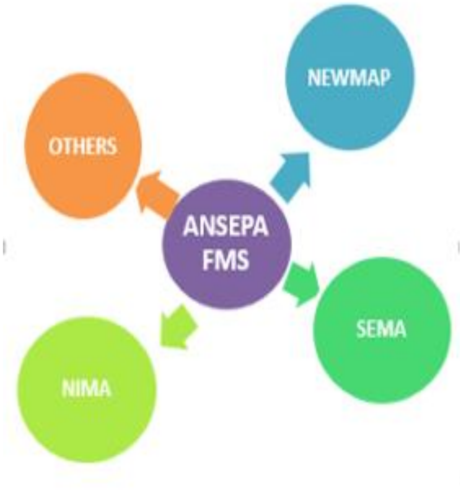


Figure 1. Data sharing approach

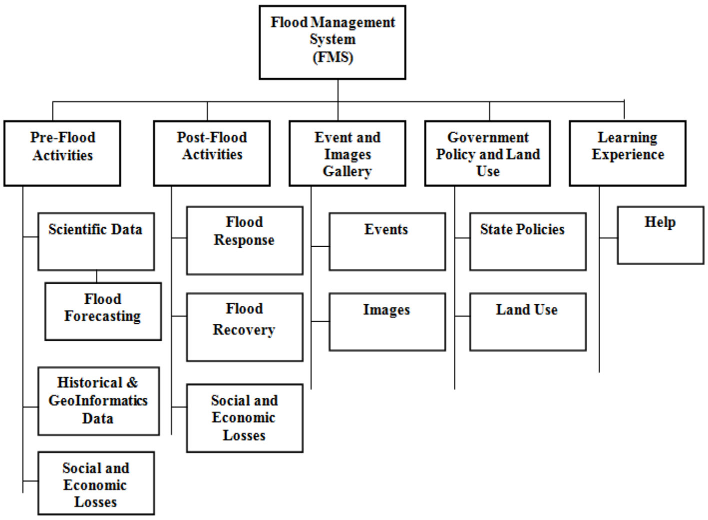
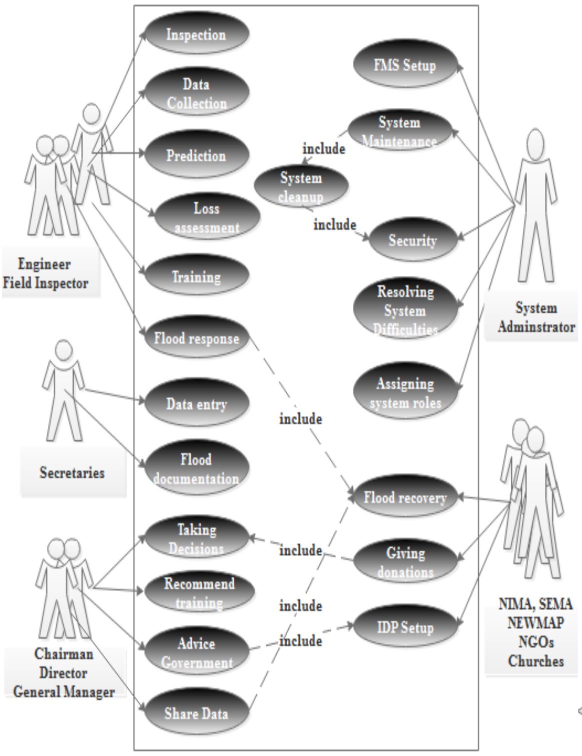


Figure 2. Main Menu of FMS



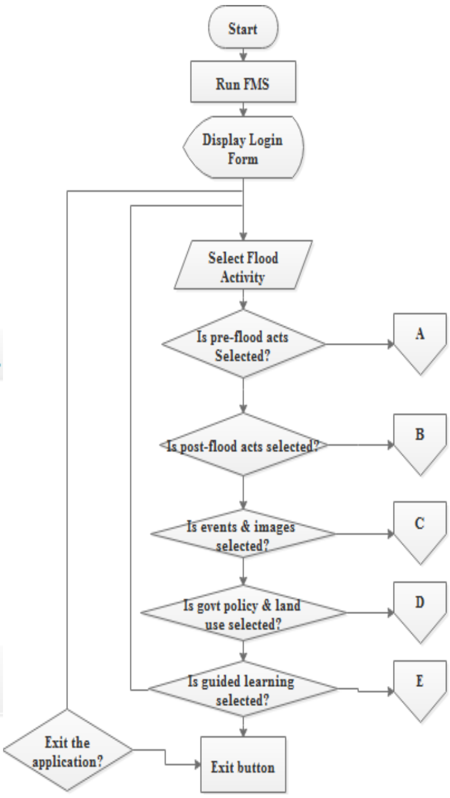


Figure 3. Use case diagram for FMSFigure 4. Flowchart of the Proposed FMS

Design: With the requirements gathered from the analysis performed above, the graphical user interface (GUI) layout of the FMS is created. More so, we ensured that these interfaces possessed the vital elements, and this is was achieved by involving the actual users of the system, which are the ANSEPA officials themselves. The aim of an active user involvement in our design is to increase the usability of the final application. Note that the minimum hardware requirements needed to run the developed application are processor – Intel 80586 and above, hard disk capacity of 4 Gigabyte and above, with an enhanced window keyboard, DVD/CD ROM, a printer and a computer that has both webcam and Bluetooth. On the software requirements, there is need for the installation of the operating system (Windows or Linux) as well as the Visual Studio with the .Net framework.

Implementation and Testing : As was stated above, the database tables was created using MySQL while actual coding was done with Visual Studio. This integrated dvelopment environemnt (IDE) was used due some of its beenefits which include assited/accurate coding, quick debugging, rigourous testing and team colloboration. At first, we implemented smaller modules, and thereafter, these modules were brought together to meet several designated specifications. We commenced the testing phase, as soon as the implementation of all the necessary moduiles were complete. This is to identify errors of any kind that may hinder the smooth running of the application. Some of the forms are presented below.The results of the study are GUIs, which are described as figures 5 – 11. Figure 5shows the login page for the flood activities (or different modules) involved in the ANSEPA FMS. They include Pre-flood, Post-flood Activities, Government Policy and Land Use, Guided Learning Experience and the Events/Images Gallery. The user chooses a particular flood activity and inserts the right username and password in order to gain access into the system. Figure 6 consists of renowned and emerging flood areas in the State. It also allows the inclusion of more flood prone areas to the two categories mentioned. On that same screen are buttons for acquiring several flood-related knowledge such as scientific data, geo-informatics data and the social/economic losses incurred. Figure 7 allows input for scientific data such as flood area, date, frequency, severity level, images, observation, water level, ground water level, rainfall, water quality, flood hazard and dam break hazard. Figure 8 depicts the historical and geoinformatics data i.e. we allowed the collection of two different types of data using one input/output form. Data that consistitute historical information inlcude climate, cropping pattern, deficiencies, ground water, irrigation demand, land used, potential evans-transportation, population, reservoir, soil moisture, irrigation efficiencies, stream flow and water used. While the data that consistute the geoinformatics information include; bank line, contour, dam location, digital elevation, flow part, hydro edge, hydro junction, LU manning, river basin network, contour and profile, spot GPS, height and river etc.Figure 9 and 10 allows the documentation of social/economic losses for both the pre and post flood phases.

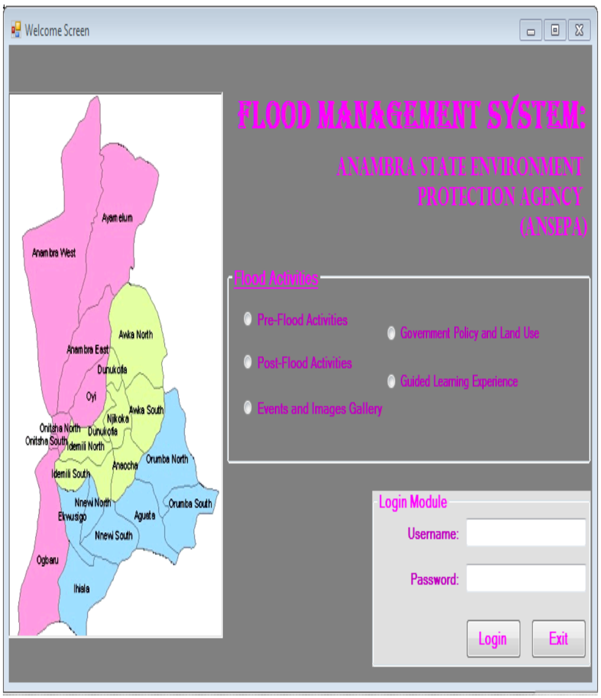


Figure 5. Welcome Screen for the Proposed FMS

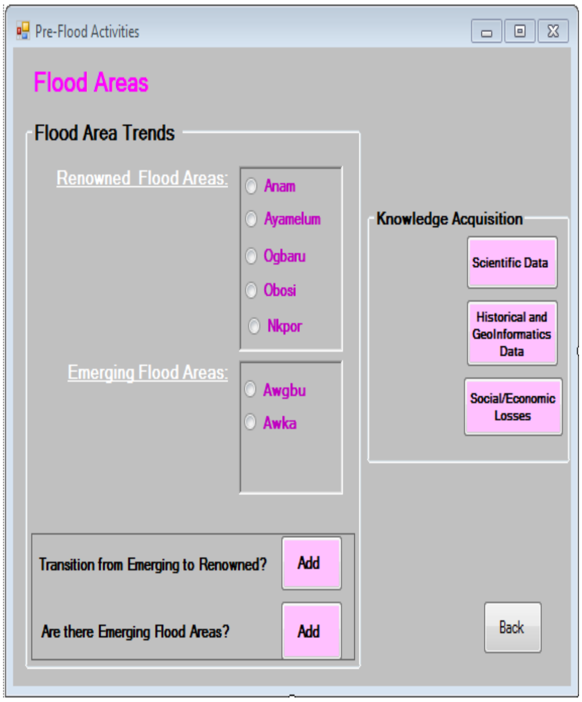


Figure 6. Top Form for Pre-flood Activities

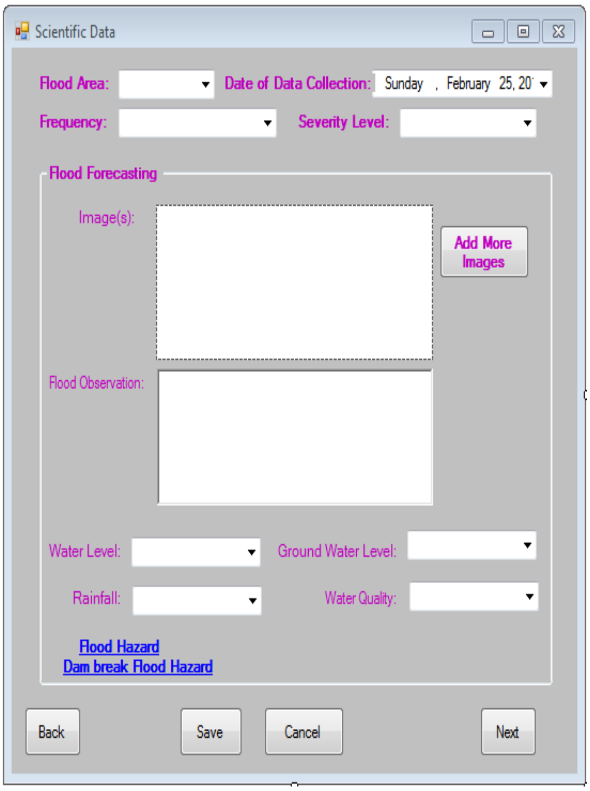


Figure 7. Scientific data screen

Figure 8. Historical/GeoInformatics form

Figure 9. Pre-flood Social/Economic Losses Form

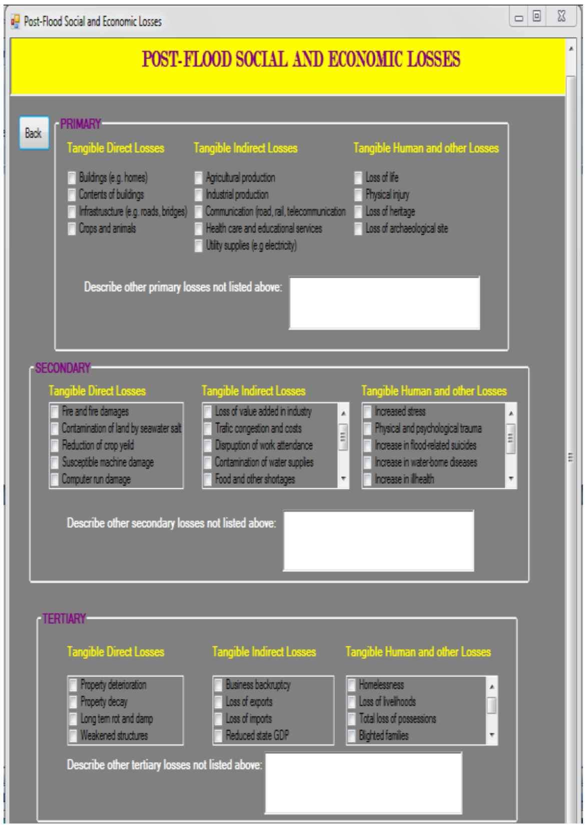


Figure 10: Post-flood Social and Economic Losses

Note that the losses in Figure 9 and Figure 10 include tangible direct, tangible indirect and tangible human and other damages for primary, secondary and tertiary categories of losses due to disaster. These forms allow the user check the applicable losses. Primary losses can be in form of damages to buildings (and other infrastructure), crops, animals, death, heritage and archeological sites. Secondary losses can be fire damages, crop yield reduction, water contamination, work disruption as well as increased stress, physical and psychological trauma, and ill-health. While tertiary losses include property deformation/decay, loss of imports/exports, reduced GDP, homelessness, loss of livelihoods and total loss of possessions. Figure 11depicts the post-flood form which allows the electronic documentation of both flood response and its recovery. Specifically, it allows inputs for rainfall, channels, evacuation team, risk forecast, weather forecast, tide predictions, peak river height, predicted river height, river levels and temperature. Whereas for flood recovery it collects information on evacuation center name and locations, donations, water level, committee name and committee decisions. Finally, Figure 12 shows the events and gallery form, wherein photographs and training events meant to enlighten the members of ANSEPA staff are displayed.

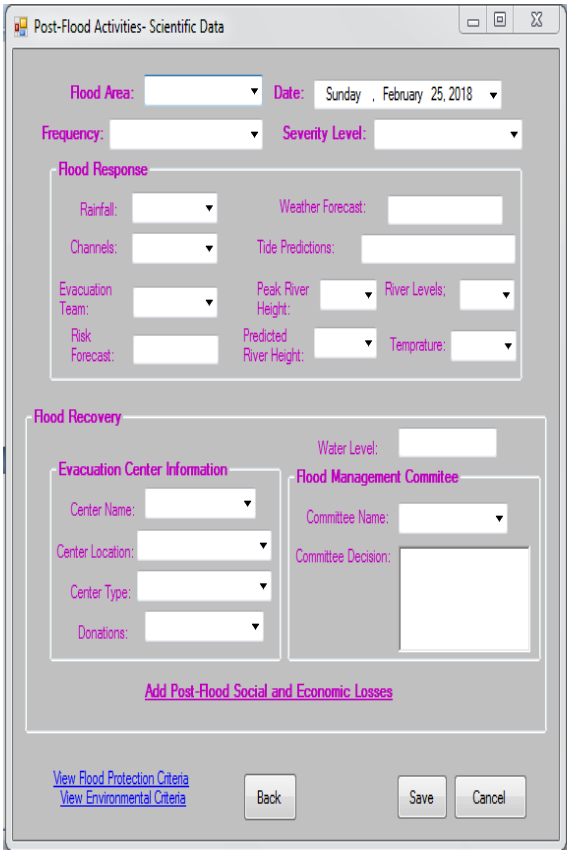


Figure 11. Post-flood Form

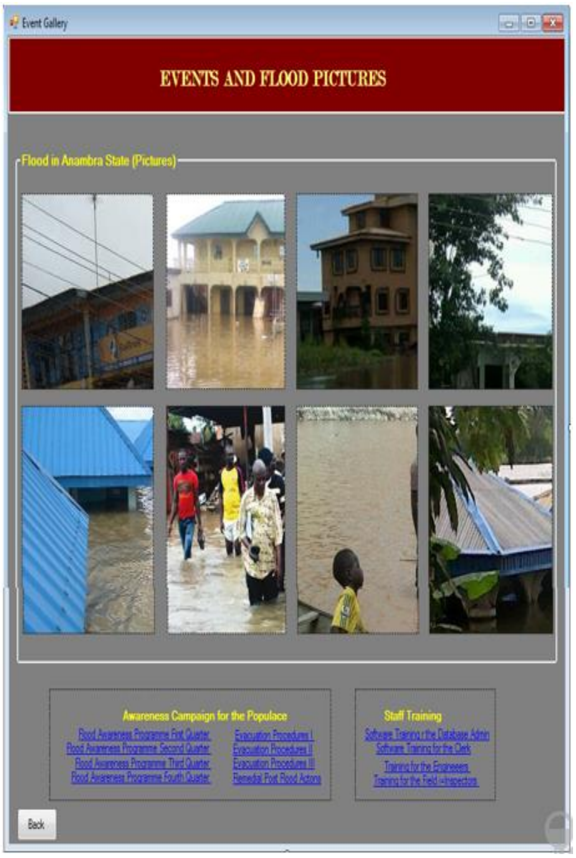


Figure 12. Events and gallery form

4. Conclusion and Future Work

The study proposed the design and implementation of the ANSEPA FMS, which allows for better coordinated flood administration. FMSwould play a major role in collecting, organizing, analyzing and presenting data for all flood phases allowing proactive management. More so,the system would enable documentation and sharing of knowledge meant for responsible flood-related organizations and researchers who are the experts in monitoring and controlling the parameters that influence flood. With this system, the knowledge owned by professionals can be easily captured, categorized and integrated better for decision making. Note that since we built the system for the state level, FMS can be used to formulate investment projects and specific investment mitigation plans. With extensions suggested in this study, the FMS can also beused at the national level for study area familiarity to planners who need references for the whole disaster scenario and at the regional level for analyzing resources and identifying viable projects. In the light of the comprehensive data collected, the system can be used to initiate flood and area vulnerability evaluation as well as the activation of the readiness required for post-flood phases where authorities seek to respond, recover and reconstruct all form of damages/losses. Since our study advocates the inclusion of 'flood inspectors', alongside the developed flood management system, our work herein would provide a monitoring capability that may add to the mitigation strategies formulated by Anambra state. In the future, when ANSEPA staff and all stakeholders must have appreciated the impact of the developed FMS, we would explore the possibilities of mobile version of the tool, wherein the masses are allowed to contribute to flood management and control.

References

[1]. EM-DAT: The OFDA/CRED International Disaster Database, Universiti catholique de Louvain, Brussels, Belgium, 2020.
[2]. M. Lukamba, “Natural disasters in African countries: what can we learn about them?” TD The Journal for Transdisciplinary Research in Southern Africa, vol. 6(2), 2010, pp. 478 – 495.
[3]. V. U. Okpala, “The environmental effects of flood disaster in Anambra state. Advances in Applied Science Research, vol. 4(1), 2013, pp. 499-505.
[4]. H. Mirfenderesk, “Flood emergency management decision support system on gold coast, Australia,” The Australian Journal of Emergency Management, vol. 24(2), 2009, pp. 48-58.
[5]. N. Kaewboonmaa, K. Tuamsukb and W. Kanarkard, “Knowledge acquisition for the design of flood management information system: Chi River Basin, Thailand, Procedia - Social and Behavioral Sciences, vol. 73, 2013, pp. 109 – 114.
[6]. D. J. Parker, “Designing flood forecasting, warning and response systems from a societal perspective,” International Conference on Alpine Meteorology and Meso-Alpine Programme,Switzerland, 2003, pp. 1-21.
[7]. S. P. Simonovic, “Decision support system for flood management in the red river basin,” Report prepared for the International Joint Commission Red River Basin Task Force, 1998, pp. 1-44.
[8]. E. Todini, “An operational decision support system for flood risk mapping, forecasting and management. Urban Water, vol. 1(2), 1999, pp. 131-143.
[9]. R. Sanders and S. Tabuchi, “Decision support system for flood risk analysis for the River Thames, United Kingdom,” Photogrammetric Engineering & Remote Sensing, vol. 66, no. 10, 2000, pp. 1185-1193.
[10]. K. Shim, D. G. Fontane and J. W. Labadie, “Spatial decision support system for integrated River Basin flood control,” Journal of Water Resources Planning and Management, vol. 128(3), 2002, pp. 13-35.
[11]. F. S. Mwakapuja, “System development for flood hazard management – A local level scenario,” MSc. Thesis submitted to International Institute for Geo-information Science and Earth Observation, The Netherland, 2003, pp. 1 – 94.
[12]. M. J. Booij, “Decision support system for flood control and ecosystem upgrading in the Red River basin. Water Resources Systems—Hydrological Risk, Management and Development (Proceedings of symposium HS02b held during IUGG2003 at Sapporo), 2003, pp. 115-122.
[13]. P. Prastacos, W. Castaings, N. Courtois, L. Hluchy, P. Houdry and V. Tran, “ANFAS: A decision support system for flood risk assessment,” Technical Report on the European implementation of the ANFAS project, 2003.
[14]. S. Ahmad and S. P. Simonovic, “An intelligent decision support system for management of floods,” Water Resources Management, vol. 20(3),2006, pp 391–410.
[15]. S. Muncaster, T. Womersley, G. MacLaren, G. Crapper and G. Tierney, G. (2006). Use of web-based flood mapping during emergency response operations. 46th Annual Floodplain Mitigation Authorities of NSW, 2006, pp 1-9.
[16]. J. Chen, A. A. Hill and L. D. Urbano, “A GIS-based model for urban flood inundation,” Journal of Hydrology, vol. 373(1-2), 2009, pp. 184-192.

[17]. S. Karmakar, S. P. Simonovic, A. Peck and J. Black,“An information system for risk-vulnerability assessment to flood,” Journal of Geographic Information System, vol. 2, 2010, pp. 129-146.
[18]. Q. Honghai and M. S. Altinakar, “A GIS-based decision support system for integrated flood management under uncertainty with two dimensional numerical simulations,” Environmental Modelling & Software, vol. 26(6), 2011, pp. 817-821.
[19]. A. C. Ibañez, D. Schwanenberg, L. Garrote-Marcos, M. F. Mahamud and J. A. González, “An example of flood forecasting and decision-support system for water management in Spain,” Proceedings of the 8th International ISCRAM Conference – Lisbon, Portugal, 2011, pp. 1-5.
[20]. M. Hysenaj, “Application of geographic information systems towards flood management in Shkodër, Albania,” Journal of Knowledge Management, Economics and Information Technology, vol. 2, 2012, pp. 1-17.
[21]. R. Laine, C. Cook and B. Lemass, “Decision support: Informing flood management. 52nd Floodplain Management Association, 2012, pp. 1-10.
[22]. I. Demir and W. Krajewski, “Flood risk management in iowa through an integrated flood information system. Geophysical Research, vol. 15, 2013, pp. 1-11.
[23]. L. Vieira, J. Pinho and D. Schwanenberg, “Towards a decision support system for flood management in a River Basin” 11th International Conference on Hydroinformatics, New York City, USA, 2014, pp. 1-8.
[24]. H. R. Maier, H. Van-Delden, J. P. Newman, G. A. Riddell, A. C. Zecchin, G. C. Dandy and C. P. Newland, “Decision support system for mitigating long-term flood risk. American Geophysical Union, 2015, pp. 1-8.
[25]. S. M. Bukari, M. A. Ahmad, T. L. Wai, M. Kaamin and N. Alimin, “Spatial analysis in determination of flood prone areas using geographic information system and analytical hierarchy process at Sungai Sembrong’s catchment,” Soft Soil Engineering International Conference, 2015, pp. 1-6.
[26]. H. Mirfenderesk, D. Carroll, E. Chong, A. Jafari, N. Hossain, R. Doorn and S. Vis, “New generation flood forecasting and decision support system for emergency management,” Australian Journal of Emergency Management, vol. 31(2), 2016, pp. 31-37.
[27]. M. V. Muste and A. R. Firoozfar, “Toward generalized decision support systems for flood risk management. FLOODrisk 2016 - 3rd European Conference on Flood Risk Management, 2016, pp. 1-12.
[28]. G. Xu, G. Q. Huang, J. Fang and J. Chen, “Cloud-based smart asset management for urban flood control,” Enterprise Information Systems, vol. 11(5), 2017, pp. 719-737.
[29]. A. Ghozalia, A. Ariyaningsih, R. B. Sukmara, B. U. Aulia, “A comparative study of climate change mitigation and adaptation on flood management between Ayutthaya City (Thailand) and Samarinda City (Indonesia),” International Conference, Intelligent Planning Towards Smart Cities, Indonesia, 2015.
[30]. K. Wang, D. Chu and Z. Yang, “Flood control and management for the transitional Huaihe River in China,” Procedia Engineering, vol. 154, 2016, pp. 703 – 709.
[31]. S. Shrestha and W. Lohpaisankrit, “Flood hazard assessment under climate change scenarios in the Yang River Basin, Thailand. International Journal of Sustainable Built Environment, 2017, pp. 1-14.
[32]. D. Bourgeois and D. T. Bourgeois. Information Systems Development in Information Systems for Business and Beyond: A look at the technology, people, and processes of information systems. Pressbooks, Montreal, Quebec, H2T 1X3, 2020