International Journal of Computer Trends and Technology
ISSN: 2231 – 2803 / https://doi.org/10.14445/22312803/IJCTT-V68I11P103
Volume 68 Issue 11, 15-23, November 2020

Original Article

Pluvial Flood Detection And Prediction Methods

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Received Date: 29 September 2020
Revised Date: 11 November 2020
Accepted Date: 14 November 2020

Abstract - *Pluvial flood is one category of a water-related natural hazard that has caused significant damages. However, the accurate detection and prediction of prone areas are considered difficult due to floods' complex and dynamic nature. In many parts of the world, flood prediction is among the few feasible measures to manage floods. This study applied an integrated review to assess the methodological strategies used in detecting and predicting pluvial flood. The identified literature was analyzed on an appraisal tool. According to the research question, a classification scheme followed this, including the model being used, characteristics, advantages, and limitations. Future directions in research and development were identified in tackling the challenges of managing pluvial flood.*

Keywords - *Pluvial Flood, Detection, Prediction, CERQual Tool, Classification Scheme*

I. INTRODUCTION

Human society's future has been challenged by increasing inhabitants, unsustainable suburbanization, and spatial development [1] infrastructure aging [2]. Climate change has also given rise to different risk levels from water-related natural disasters due to the challenges mentioned above. As reported by the World Bank in 2008, half of the world's population lived in urban areas, but in 2030, this number will increase to 60% and 70% in 2050 [3,4]. Different kinds of floods can affect society, and some may be more applicable to some areas/locations than others. The flood can be classified mainly into four types, namely: coastal, fluvial, pluvial, and flash floods. Historically, the most reported flood event is fluvial, followed by pluvial, which has increased in cities and has the highest proportion since 2010 compared to other flood types in the same period [4][5].

One category of water-related natural hazards is pluvial flood with alternative terms, which include "street," "sheet," or "overland flooding" [6], which is where high-intensity rainfall exceeds the capacity of urban drainage system [7, 8]. This type of flood is exclusive to urban areas [9]. Some cities are particularly prone to pluvial flooding. It is sometimes referred to as "urban flooding" because flooding in urban areas can occur from other fluvial and coastal flooding mechanisms. Although pluvial flood can occur in urban and rural areas [10], pluvial flooding is predominantly an urban phenomenon. It is in the urban areas where its effect and damages are more pronounced. In 2018, a series of pluvial flood caused significant property damage [11][12].

However, the accurate prediction of prone areas is considered difficult due to floods' complex and dynamic nature. There are mainly three aspects to successfully address during a pluvial flood risk assessment, namely (i) Need for a framework, (ii) getting the optimal set of conditioning variables, and (iii) estimating their influence, which can be achieved through the appropriate models and techniques [13]. Despite the importance, the pluvial flood has received limited attention in both research and practice compared to other types of the flood [14].

Although it is impossible to prevent this natural hazard (flood), the use of appropriate methods and analyses can anticipate the hazards and how to mitigate them [15]. There are two types of flood control measures, namely (i) structural measures by way of constructing flood retention walls, dykes, reservoirs, detention basins, and (ii) non-structural measures, which include flood prediction, flood proofing, and flood hazard zoning [16][17].

Pluvial flood is influenced not only by meteorological factors but also by hydrological factors and the hydrological process. Combining these factors can give rise to various types of flooding events [18][19]. The detection and prediction of a flood depend greatly on the available conditioning variables (meteorological database). It provides a basis for warning and informing decision-makers and those in the path of floods to minimize the damages normally measured in economic terms. Climate change indirectly aggravates pluvial flooding by changing the pattern of flooding in flood susceptibility areas, thereby frustrating efforts of flood prediction [20]. The poor and unavailability of flood prediction control systems and techniques are seen as the major cause of what aggravates the flood disaster in a country [18]. The paper will summarize the methods and various proposed pluvial flood detection techniques and prediction to assist in addressing this issue. The objective of this review is to provide a current, concise and comprehensive review of pluvial flooding detection and prediction method by adopting the model classification scheme

II. THE REVIEW

A. Aim

This review aimed to identify and assess the strategies used in pluvial flood detection and prediction methods. The two broad research questions were addressed.

(1) What are the methodological strategies researchers used in predicting and detecting pluvial flood?

(2) What conditioning variables were considered in detecting and predicting pluvial flood?

B. Design

The integrated review framework was systematically and rigorously reviewed and synthesized the literature on pluvial flood prediction. It incorporates a method of analyzing research from diverse empirical and theoretical sources and delineates a systematic process that enhances the integrative review process [21]. This framework identifies the problem and its related concepts to facilitate data extraction from the primary source. It then outlines well-defined literature search strategies, including search terms with inclusion and exclusion criteria, to assess primary sources' relevance (searched literature). The next line of action was data evaluation, where the identified literature was organized by saving electronically, and where necessary, hard copies were stored on file. The literature was read, and memoing was conducted through a combination of electronic notes, by hand using a pen and highlighter. The information gathered was captured electronically and arranged according to key phrases, ideas, and concepts. Each literature's descriptor was highlighted and then arranged in a format to describe each literature's key ideas and concept according to the classification of pluvial flood detection and prediction methodologies and the conditioning variables considered in detecting and predicting pluvial flood.

C. Literature Search

The search process to identify the body of literature relevant to pluvial flooding detection and the prediction was undertaken. A combination of the term such as "pluvial flooding," "pluvial flood prediction," "pluvial flood forecast," "pluvial flood model" applied to the search'. Electronic searching, hand searching, and citation tracking were carried out within Elsevier, Taylor & Francis, John Wiley & Sons, Springer, MDPI, and Copernicus. Overall, 241 pieces of literature were identified (Table 1). After removing the duplicate kinds of literature and filtering out for inclusion and exclusion criteria, one hundred and forty-two (142) relevant kinds of literature were identified. These studies are fundamental to the discussion presented in this study.

S/N	Issues relating to Pluvial Flood	Literature Search
1	Vulnerability Assessment	39
2	Pluvial Flood Prediction	33
3	Review on Flood	21
4	Other types of flood	47

Table 1: The reviews of a literature search of issues relating to pluvial flooding.

From these results, pluvial flood prediction has not received ample attention, and this gives a concern.

D. Data Evaluation

All literature was critically appraised before being included in any analysis. The literature was evaluated using an appraisal tool, confidence in the Evidence from Reviews of Qualitative Research (Grade-CERQual) [23][24]. One hundred and nine (109) kinds of the literature failed to adequately meet the selection criteria and were therefore discarded. Seventeen (17) were included in the analysis based on the appraisal tool.

E. Literature Classification

During this stage, literature was extracted and represented numerically and textually. To facilitate the review, literature was classified according to the research questions and answered by adopting the model classification scheme.

III. RESULT

A Literature Search – The Search Strategy

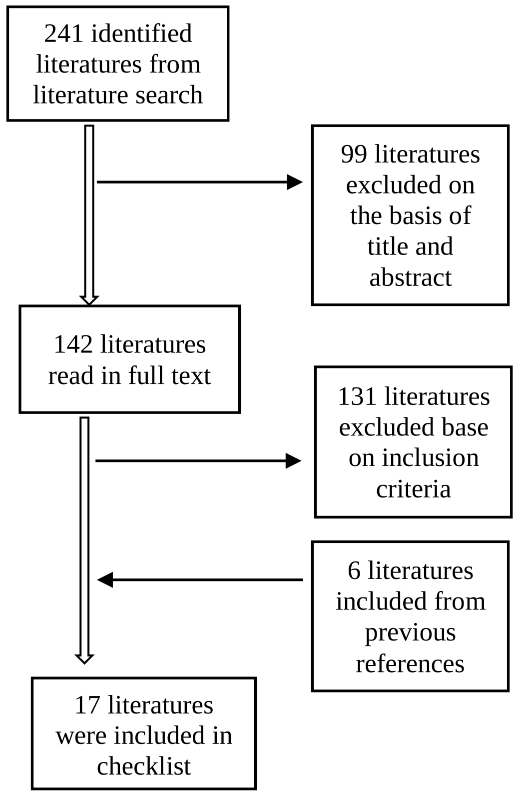

Fig. 1 Result of Literature Search

The comprehensive synthesis finding of the integrated review includes the overall quality of the selected literature. The literature searching strategy identified 241 pieces of literature. After applying the exclusion criteria based on title and abstract, 142 kinds of literature were read in full text; these 131 kinds of literature were excluded based on the inclusion criteria. Six (6) available pieces of literature were included from the references list. The remaining 17 pieces of literature were identified as being relevant in the checklist.

B. Data Evaluation

The synthesis findings of the literature in the checklist were developed using the CERQual assessment tool, which summarizes review findings and assesses the for accessing how much confidence to place in findings from the review literature, namely methodological limitations, coherence, adequacy of data, and relevance [22][23]. This was used to describe the overall assessment of confidence as derived in Table 2.

C. Data Analysis: Classification Scheme Model

The classification scheme model was adopted in giving responses to the research questions and drawing conclusions. Although there has been no homogeneity in the classification of pluvial flood prediction techniques, the classification has been based on the physical-based model, conceptual model, and data-driven model for this review and simplicity. The classification shows insight into the methodological strategies used to predict and detect pluvial flood and what conditioning variables were considered for the methods. Table 3 provides a list of some known prediction techniques applicable to pluvial flood based on this classification scheme. These are described alongside their advantages and limitation.

confidence in each finding. This tool is an approach used to assess how much confidence to place in findings from reviewed literature and the extent to which a review finding is represented reasonably based on the phenomenon of interest that is to synthesize quantitative and qualitative evidence on the detection prediction of a pluvial flood. The approach considered four components

IV. DISCUSSION

Results of this critical analysis suggest important consideration for giving ample attention to the sensitive issues on pluvial flooding. Pluvial flooding can broadly be seen as a result of heavy rainfall and water overflow, which can be caused by various factors [42]

There is no universal method to classify pluvial flood prediction models (methods/techniques). Models have been classified in several ways, depending on the criteria of interest. Over the years, the research conducted in pluvial flooding specific to techniques heavily concentrated on a physical model followed by a conceptual and data-driven model. Pluvial flooding often involves the use of computational techniques, and these techniques are applied mainly to solve (i) physical-based flow governing equation (ii) Data-driven model and empirical stochastic model [40][41]. [38] also shared a parallel idea that, in general, the available vulnerability assessment methodologies can be grouped into physical based, data-driven, and expert –knowledge-based model, also known as a conceptual model (see Figure 2).

Table 2. CERQual Summary of Findings

Summary of Reviewing Findings according to the classification scheme	Studies contributing to the review findings	CERQual Assessment of Confidence in the evidence	Explanation of CERQual Assessment
Physical Based Model	[29][34][40]	Low	Major concerns as regards methodological limitations and adequacy of data. No concern as regards coherence and relevance.
Conceptual Model	[25] [28] [31] [32] [33] [35] [39]	Moderate	Five literatures (5) with minor concerns as regards methodological limitations. Moderate concerns as regards adequacy of data, coherence and relevance.
Data Driven Model	[24] [26] [27] [30] [36] [37] [38]	Moderate	Moderate concerns as regards methodological limitations, coherence and relevance. Minor concerns as regards adequacy of real data.

Table 3. Summary of methods available for pluvial flood detection and prediction.

S/N	Reference	Model	Characteristics	Advantages/Disadvantages
1	[24]	Pluvial flood risk assessment tool (PFRA)	The model utilizes spatial data (soil type & its infiltration capacity, land use and land cover, height of predicted	It allows for conducting a quantified and repeatable risk assessment of pluvial flood for different time horizons. There are no local coefficients to

			precipitation, and topography) to estimate the surface runoff volume. It enables the identification of the spatial and temporal distribution of pluvial flood risk in newly developed areas.	quantify pluvial flood-related damages that can be used in the calculation. The simulation was based on the assumption of uniform rainfall spatial distribution due to precipitation resolution data. It requires high computing power.
2	[25]	Simplified Model for Urban Flood Risk Mitigation	A simple flood model was developed and utilized using an efficient scheme equation to simulate flood scenarios and apply Crichton's triangle of risk to implement the urban flood mitigation. Maps were integrated into a GIS environment to simulate flood scenarios to produce a flood risk map.	It has provided insights into the basic requirements for flood modeling It is a stand-alone model
3	[26]	Semi-Supervised Machine Learning Model	Employed an Enhanced Semi-supervised in urban flood susceptibility assessment. It uses an adaptation of the multiple kernel learning by group lasso (MKLGL) algorithm to solve the multiple label-kernel learning problems. It was observed that the WELLSVM is highly suited for flood susceptibility assessment, especially in the case of urban areas.	It can efficiently deal with weakly labeled data in large datasets. The performance of the model is highly dependent on the accuracy of the labeled flood inventories. Urban sprawl may affect the consistency of labeled flood inventories and thus influenced the model results. Distribution and unlabelled data size in the model implementation affect the model accuracy. Uncertain labeled inventories and massive unlabelled information can improve the accuracy of results.
4	[27]	Hybrid Model	A novel hybrid model that implements fuzzy weight of evidence and various data mining methods, specifically logistic regression, random forest, and support vector machine, produces a flood susceptibility map. The evidence support vector machine (Fuzzy WofE-SVM) that integrates fuzzy logic, expert knowledge, and data mining methods provides an alternative tool for flood susceptibility modeling.	It provides a better theoretical framework for handling the complexity of modeling multi-class data flexibly and consistently. It is simple and has a straight forward interpretation of weights corresponding to the flood conditioning variables. It focuses only on the geomorphological factors. The model performance is largely affected by the ability to handle complex data and non-linear pattern distribution more accurately and directly measure the variable's importance.
5	[28]	Portugal Digital Elevation Model	The digital elevation model utilizes four DEM techniques for modeling pluvial flooding. Using pond filtering algorithms and rolling ball techniques for generating the surface flow (pond and pathways).	The solution is cost-prohibitive. Different resolution and accuracy were generated The generation of a quality surface network is highly dependent on the resolution and accuracy of the dataset used. Therefore, realistic dataset representation is essential for improved surface flow network analysis and generation.
6	[29]	Notes-Based Sensor Network	Primarily designed to predict inundation zone and disseminate video information	The obstacle of interference with numerous other wireless applications in an urban location affects the model

			in real-time through different media by using three things–in-one computer, a sensor, and radio called Smart Sensor Dust (Motes), which links a meteorological remote sensing information	(technology). The model is internet dependent. It ceases to work when there is no connectivity. There is a need for a low power environmental sensor. Communication back and forth between the motes / smart sensor dust should be timely, efficient, and robust.
7	[30]	Real-Time Urban Flood Monitoring system	Designed an ahead-of-time flood level prediction using the random forest method as an ensemble learning algorithm (random forest) as the prediction model alongside electronic instrumentation sensor application and web services. (ground-based pressure sensor and automatic rain gauge)	The model underestimates the rise of flood level, but overestimating flood levels is the preferred behavior prediction model. The introduction of an algorithm optimization will enhance the model.
8	[31]	Pluvial Flood Early Warning System	A simplified pluvial flood was earning warning system using a 30 minutes' precipitation accumulation (both observed and forecasted) employing cross-correlation techniques for urban flood warning through a web-based platform dynamically showing geo-referenced information of real-time radar observation and nowcasting.	To obtain a reliable estimate of the accumulated precipitation, radar data may be the quickest but suffers from different error sources. The design does not need hardware and software since it is a cloud-based platform that can only be connected through any device to the internet.
9	[32]	Urban Flood Hazard Chart	Used a widely used hydrological and hydraulic model for the construction of urban flood hazard chart. Also used watershed data to calibrate and validate the stormwater management model. The model is usually used for catchment diagnostic, urban planning, and simulate several hydrological processes.	The model performance assessment was compromised and caused by an error in the water level register. The model failed to represent the more intensive rain event The model cannot represent the channel even with the introduction of adaptation in the model. The model cannot consider the occurrence of debris or the possibility of a situation.
10	[33]	Risk-Based Early Warning System	Developed a concept by linking rainfall-forecasting information and a coupled model system consisting of a hydro-numeral model and a GIS system to predict pluvial flooding processes and then impact using open geodata.	The model proved to be very fast and consistent. The absence of flow measurement could not allow the validation of the numerical flow velocities. Neglect of the effects of the sewage system leads to underestimation and overestimation of the flood risk.
11	[34]	3-Step Modelling Approach	The model is based on a simplified hydraulic approach with the integration of hydrodynamic calculation. The combination of a hydrological and a 2-D hydraulic modeling system to identify hazardous areas affected by pluvial flooding	The model failed to provide reliable information about a complex and dynamic flow situation. The quality of modeling results is high, and it gained credibility and public acceptance.

12	[35]	Geoinformation Flood Simulation Program-1	The model design consists of a cellular automata framework with a semi-implicit finite difference scheme (SIFDS), a dynamic interaction between two model components to enhance model performance in simulating a typical urban flooding event.	Lack of data relating to flood depth and cost of acquiring datasets was a major constraint to model validation. The model gives a reasonable impressive speed in flood simulation. The simulation is dependent on the availability of the DEM spatial resolution.
13	[36]	Urban Pluvial Flood Forecasting	Developed an enhanced predictive capability of urban pluvial in two categories, first to forecast urban flooding based on rain gauge network using support vector machine (SVM). Secondly, customization of urban drainage model with the creation of hybrid models that combine 1D and 2D models of the surface.	The hybrid model provides fast hydraulic simulation measurement of overland flow with measurement within the sewer system would allow improved calibration of the whole model because the overland network is not as well defined as the sewer network. Graphical tools will enhance and developed hybrid models.
14	[37]	Integrated Pluvial and Flash Pluvial Model	The model was developed by integrating two probabilistic inundation model (FF and PFF) and a sample random forest particle swarm optimization model and implementing a 2D-High resolution sub-grid (2D-HRS) approach for flood hazard and risk assessment	The model can be used for flood mitigation planning. The model can be improved by using laser scanning data and giving consideration to sewer capacity.
15	[38]	GIS-Bayesian Belief Network Model	This is a coupled GIS and Bayesian Belief Network model that can capture the casual nexus between factors, capable of quantifying uncertainty, and can utilize both data and knowledge-based sources for pluvial flood vulnerability assessment.	Advancement in data collection technology will improve data quality. The model can be adapted in any urban area based on its characteristics and data availability. It can quantify uncertainty in the decision-making process.
16	[39]	FloodCitiSense Early Warning Service	The project proposes an interactive and cooperative framework to improve the monitoring and management of pluvial flooding with citizen science and SME smart sensing, i.e., social sensing application and low-cost rainfall sensor network based on the principle of transition experiment.	Long term user's motivation as flooding events only happens rarely. They rely more on the data retrieved from sensors due to the low contribution for stakeholders (citizen participation). Improves the ties between research and public management. It supports better preventive communication to the public.
17	[40]	Fast 2D-Urban Pluvial Flood Model	Proposes a two dimensional model with a cellular automatic approach to stimulate the Spatio-temporal evolution of pluvial flooding	The proposed CA approach is suitable for parallelization, which would increase the model computation power.

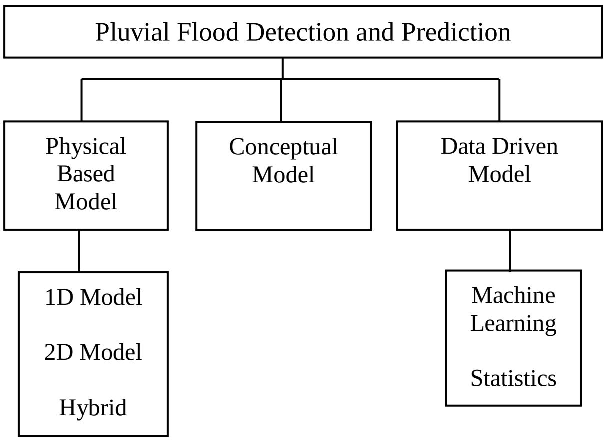

Fig. 2 Classification of pluvial flood prediction techniques

Nevertheless, with the variation in techniques, it is hard to be confident that this is the best pluvial flooding prediction method. The literature suggests that there are more data-driven models in scope. Models are normally characterized or classified to describe and derive their ability, strategies, and limitation.

Studies reviewed demonstrated high usage of hydrological factors as conditioning variables considered in predicting and detecting pluvial flood [19] justify the high prevalence found in their studies as it was highlighted that hydrological factors have a great impact on the intensity of the pluvial flood, i.e., conditioning variables under hydrological factors are the most important as it relates to pluvial flood.

[42] further explains in their project for future applications that combining extreme rainfall forecast with the mapping of susceptible areas depends on many factors. It was further suggested that the evolving complex approaches would be of greater relevance for more detailed studies on pluvial susceptibility. In choosing suitable models for pluvial flood prediction, it is always crucial to respond to how well the model will predict the event. Findings by [8] in Nigeria stated that pre-warning of flood events generally lacked flood areas that have been largely overloaded in flood management. Conversely, poor awareness of flood hazards is a major issue in its management [43].

[37] highlighted that despite the increase in awareness, there is still a general lack of coordination and integration across several important flood risk management systems and processes. [44][45] showed that a flood prediction system would be very useful in tackling the flood effect because it will help the urban dwellers prepare against the damages from a flood, which would further help redirect the flooding effect.

[46] also argues that robust and scientific approaches to flood risk reduction, such as flood prediction and vulnerability, are lacking in developing countries and make a pivotal recommendation in addressing these fundamental issues.

[24][47][48] Their pluvial flood risk assessment tool highlighted that a knowledge-based approach should improve the land design and urban surface geometry, and building design, which play a crucial role in pluvial flooding. It was also highlighted that high resolution and real-time pluvial forecasting remains a challenge despite advances in computing software and hardware.

Regarding pluvial floods, for prediction to be effective, the techniques must be timely, clear, and understandable to the entire community at risk. [49] Their findings bring to notice the need for a proactive approach that embraces an integrative risk management approach to flood risk management. [53] concluded in his study that Geographical Information System (GIS) techniques hold many processes as it is capable of combining various techniques and condition variables for predicting flood risk. Also, the use of data-driven models to predict pluvial flooding has shown promise in the absence of a hydraulic model [51].

[52] has highlighted the need for a better tool for flood susceptibility assessment as requested by the local decision workers because existing approaches are often partial and contextual.

V. CONCLUSION

Through this review of pluvial flood prediction and detection methods, the characteristics, advantages, disadvantages, and conditioning variables for pluvial flood were reviewed. Pluvial floods differ from other types of floods by predictability and temporal aspects such as duration and excess water pathways. The mindset that flood damage caused by pluvial flooding can occur even at a low level of precipitation. The widely recognized model was chosen specifically to give the reader helpful examples of classification methods in pluvial flood prediction. Many other methods/techniques could have been used for this example, and the inclusion of a model in this list should not be considered in any way as an endorsement.

More research efforts are needed to identify the challenges in managing pluvial floods, such as inadequate measures, the need to identify areas susceptible to pluvial floods, and a solution that adds value to human existence.

REFERENCES

[1] Eleutério, J. (2012). "Flood risk analysis: impact of uncertainty in hazard modeling and vulnerability assessments on damage estimations". Université de Strasbourg.

[2] Noymanee, J., Nikitin, N. O., & Kalyuzhnaya, A. V. (2017). "Urban Pluvial Flood Forecasting using Open Data with Machine Learning Techniques in Pattani Basin". Procedia Computer Science, 119(2017), 288–297. https://doi.org/10.1016/j.procs.2017.11.187

[3] Jha, Abhas K.; Bloch, Robin; Lamond, Jessica. (, 2012). "Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century". World Bank. https://openknowledge.worldbank.org/handle/10986/2241.

[4] Acosta-Coll, M., Ballester-Merelo, F., Martinez-Peiró, M., & De la Hoz-Franco, E. (2018). "Real-Time Early Warning System Design for Pluvial Flash Floods - A Review". Sensors (Switzerland), 18(7). https://doi.org/10.3390/s18072255

[5] "European Commission and Water Group Floods (WGF). Pluvial Flooding: An EU Overview". European Commission and Water Group Floods (WGF): Berlin, Germany, 2016.

[6] Rosenzweig, B. R., McPhillips, L., Chang, H., Cheng, C., Welty,

C., Matsler, M., … Davidson, C. I. (2018). "Pluvial flood risk and opportunities for resilience". WIREs Water, 5(6), 1–18. https://doi.org/10.1002/wat2.1302
[7] Houston, D., Werritty, A., Bassett, D., Geddes, A., Hoolachan, A., & McMillan, M. (2011). Pluvial (rain-related) flooding in urban areas: the invisible hazard. (November), 96. Retrieved from http://www.jrf.org.uk/sites/files/jrf/urban-flood-risk-full.pdf
[8] Adelekan, I. O. (2011). "Vulnerability assessment of an urban flood in Nigeria: Abeokuta flood 2007". Natural Hazards, 56(1), 215–231. https://doi.org/10.1007/s11069-010-9564-z
[9] Rözer, V. (2019). "Pluvial flood loss to private households (University of Potsdam)". Retrieved from https://publishup.uni-potsdam.de/frontdoor/index/index/docId/42991
[10] Susana, O.R. (2013). "Urban Pluvial Flood Modelling: Current Theory and Practice". London, UK.
[11] Environment Agency (2009). "Thames Catchment Flood Management Plan - Chapter 3: Current flood risks and management." Environment Agency, Bristol, UK. Document available online: http://www.jubileeriver.co.uk/CFMP%202008%2008%20Chapter%203.pdf Accessed 08.05.2020.
[12] Priest, S. J., Parker, D. J., Hurford, A. P., Walker, J. & Evans, K. (2011). "Assessing options for the development of surface water flood warning in England and Wales". Journal of Environmental Management, 92 (12), 3038-3048
[13] Bui, D. T., Tsangaratos, P., Ngo, P. T. T., Pham, T. D., & Pham, B. T. (2019). "Flash flood susceptibility modeling using an optimized fuzzy rule-based feature selection technique and tree-based ensemble methods". Science of the Total Environment, 668, 1038–1054. https://doi.org/10.1016/j.scitotenv.2019.02.422
[14] Cirella, G., & Iyalomhe, F. (2018). "Flooding Conceptual Review: Sustainability-Focalized Best Practices in Nigeria". Applied Sciences, 8(9), 1558. https://doi.org/10.3390/app8091558
[15] Razavi Termeh, S. V., Kornejady, A., Pourghasemi, H. R., & Keesstra, S. (2018). "Flood susceptibility mapping using novel ensembles of adaptive neuro-fuzzy inference system and metaheuristic algorithms". Science of the Total Environment, 615, 438–451. https://doi.org/10.1016/j.scitotenv.2017.09.262
[16] Shivaprasad Sharma, S. V., Roy, P. S., Chakravarthi, V., & Srinivasa Rao, G. (2018). "Flood risk assessment using multi-criteria analysis: A case study from Kopili river basin, Assam, India". Geomatics, Natural Hazards, and Risk, 9(1), 79–93. https://doi.org/10.1080/19475705.2017.1408705
[17] Escuder-Bueno, I., Castillo-Rodriguez, J. T., Zechner, S., Jöbstl, C., Perales-Momparler, S., & Petaccia, G. (2012). "A quantitative flood risk analysis methodology for urban areas with the integration of social research data." Natural Hazards and Earth System Science, 12(9), 2843–2863. https://doi.org/10.5194/nhess-12-2843-2012
[18] Nkoana, R. (2011). "Artificial Neural Network Modelling of Flood Prediction and Early Warning". University of the Free State Bloemfontein.
[19] Oladapo, K.A, Idowu, S.A, Adekunle Y.A, & Ayankoya F.Y (2020). "Categorization of Conditioning Variables for Pluvial Flood Risk Assessment" International Journal of Computer Applications Technology and Research Volume *– No.*, ______ 2020
[20] Nwoko, A. U. (2013). Flooding in Nigerian Cities: Problems and Prospects. A Case Study of Aba Urban, Abia State, Nigeria. Abia State University.
[21] Whittemore, R., & Knafl, K. (2005). "The Integrative Review: Updated Methodology". Journal of Advanced Nursing, 52(5), 546–553. https://doi.org/10.1111/j.1365-2648.2005.03621.x
[22] Chen, A. S., Djordjević, S., Leandro, J., & Savić, D. A. (2007). "The urban inundation model with bidirectional flow interaction between 2D overland surface and 1D sewer networks". Novatech, 2007, 465–472. https://doi.org/2042/25250
[23] Lewin, S., Booth, A., Glenton, C., Munthe-Kaas, H., Rashidian, A., Wainwright, M., … Noyes, J. (2018). "Applying GRADE-CERQual to qualitative evidence synthesis findings: introduction to the series". Implementation Science, 13((Suppl 1):2), 1–10. https://doi.org/10.1186/s13012-017-0688-3
[24] Szewrański, S., Chruścinski, J., Kazak, J., Swíader, M., Tokarczyk-Dorociak, K., & Zmuda, R. (2018). "Pluvial Flood Risk Assessment Tool (PFRA) for rainwater management and adaptation to climate change in newly urbanized areas". Water (Switzerland), 10(4), 1–20. https://doi.org/10.3390/w10040386
[25] Nkwunonwo, U. C., Whitworth, M., Baily, B., & Inkpen, R. (2014). "The Development of a Simplified Model for Urban Flood Risk Mitigation in Developing Countries." Vulnerability, Uncertainty, and Risk, American Society of Civil Engineers, (August 2016), 1116–1127. https://doi.org/10.1061/9780784413609.113
[26] Zhao, G., Pang, B., Xu, Z., Peng, D., & Xu, L. (2019). "Assessment of urban flood susceptibility using semi-supervised machine learning model". Science of the Total Environment, 659, 940–949. https://doi.org/10.1016/j.scitotenv.2018.12.217
[27] Hong, H., Tsangaratos, P., Ilia, I., Liu, J., Zhu, A. X., & Chen, W. (2018). "Application of fuzzy weight of evidence and data mining techniques in constructing the flood susceptibility map of Poyang County, China". Science of the Total Environment, 625(January), 575–588. https://doi.org/10.1016/j.scitotenv.2017.12.256
[28] Leitão, J. P., Boonya-aroonnet1, S., Prodanovi, D., & Maksimovi, Č. (2008). "Influence of DEM resolution on surface flow network for pluvial urban flooding and simulations of the integrated system". 11th International Conference on Urban Drainage, 1–11. Edinburgh, Scotland.
[29] Chang, N. Bin, & Guo, D. H. (2006). "Urban flash flood monitoring, mapping, and forecasting via a tailored sensor network system". Proceedings of the 2006 IEEE International Conference on Networking, Sensing and Control, ICNSC'06, 757–761.
[30] Garcia, F. C. C., Retamar, A. E., & Javier, J. C. (2016). "A real-time urban flood monitoring system for Metro Manila". Annual International Conference, Proceedings/TENCON, 3–7. https://doi.org/10.1109/TENCON.2015.7372990
[31] Llort, X., Sánchez-Diezma, R., Rodríguez, Á., Sancho, D., Berenguer, M., & Sempere-Torres, D. (2014). "FloodAlert: a simplified radar-based EWS for urban flood warning." Proceedings of the 11th International Conference on Hydroinformatics, 1–8. New York City, USA: HIC.
[32] Siqueira, R. C., Moura1#, P. M., & das Graças Silva, T. F. (2019). "Methodology for the construction of an urban flood hazard chart". Revista Brasileira de Recursos Hidricos, 24, 1–16. https://doi.org/10.1590/2318-0331.241920180125
[33] Hofmann, J., & Schüttrumpf, H. (2019). "Risk-based early warning system for pluvial flash floods: Approaches and foundations". Geosciences (Switzerland), 9(3). https://doi.org/10.3390/geosciences9030127
[34] Fritsch, K., Assmann, A., & Tyrna, B. (2016). "Long-term experiences with pluvial flood risk management". 3rd European Conference on Flood Risk Management, 7. https://doi.org/10.1051/e3sconf/20160704017
[35] Nkwunonwo, U. C., Whitworth, M., & Baily, B. (2019). "Urban flood modeling combining cellular automata framework with semi-implicit finite difference numerical formulation". Journal of African Earth Sciences, 150(October 2018), 272–281. https://doi.org/10.1016/j.jafrearsci.2018.10.016
[36] Simões, N. E. da C. (2012). Urban Pluvial Flood Forecasting by. Imperial College London.
[37] Hossein, M. R. (2018). "Flood risk assessment using multi-sensor remote sensing, geographic information system", 2d hydraulic, and machine learning-based models. University of Technology Sydney (UTS), New South Wales, Australia.
[38] Thorndahl, S., Nielsen, J. E., & Jensen, D. G. (2016). "Urban pluvial flood prediction: A case study evaluating radar rainfall nowcasts and numerical weather prediction models as model inputs". Water Science and Technology, 74(11), 2599–2610. https://doi.org/10.2166/wst.2016.474
[39] Verbeiren, B., Seyoum, S. D., Lubbad, I., Xin, T., Veldhuis, M.-C. Ten, Onof, C., … Willems, P. (2018). "FloodCitiSense: Early Warning Service For Urban Pluvial Floods For And By Citizens and City Authorities". 11th International Conference on Urban Drainage Modelling, 2(September), 96–101. https://doi.org/10.1007/978-3-319-99867-1
[40] Ghimire, B., Chen, A. S., Guidolin, M., Keedwell, E. C., Djordjević, S., & Savić, D. A. (2013). "Formulation of a fast 2D urban pluvial flood model using a cellular automata approach". Journal of Hydroinformatics, 15(3), 676–686. https://doi.org/10.2166/hydro.2012.245
[41] Chen, A. S., Djordjevic', S., Leandro, J. & Savic', D. A. (2010).

"An analysis of the combined consequences of pluvial and fluvial flooding". Water Science and Technology 62, 1491–1498.

[42] Falconer, R. H., Cobby, D., Smyth, P., Astle, G., Dent, J., & Golding, B. (2009). "Pluvial flooding: New approaches in flood warning, mapping, and risk management". Journal of Flood Risk Management, 2(3), 198–208. https://doi.org/10.1111/j.1753-318X.2009.01034.x

[43] Nkwunonwo, U. C. (2016). "A Review of Flooding and Flood Risk Reduction in Nigeria". Global Journal of Human-Social Science, 16(2). Retrieved from https://socialscienceresearch.org/index.php/GJHSS/article/view/1717

[44] Michael, E., & Patience, O. (2018). "Flood Prediction In Nigeria Using Artificial Neural Network." American Journal of Engineering Research (AJER), 7(9), 15–21. Retrieved from www.ajer.org

[45] Oladokun, V. O., & Proverbs, D. (2016). "Flood risk management in Nigeria: A review of the challenges and opportunities." International Journal of Safety and Security Engineering, 6(3), 485–497. https://doi.org/10.2495/SAFE-V6-N3-485-497

[46] Choubin, B., Moradi, E., Golshan, M., Adamowski, J., Sajedi-Hosseini, F., & Mosavi, A. (2019). "An ensemble prediction of flood susceptibility using multivariate discriminant analysis, classification and regression trees, and support vector machines." Science of the Total Environment, 651, 2087–2096. https://doi.org/10.1016/j.scitotenv.2018.10.064

[47] Nkwunonwo, U. C., Chiemelu, E. N., & Nkwunonwo, U. A. (2016). "Exploring the Inadequacy of Pertinent Capacities for Urban Flood Risk Management in the Developing Countries". Journal of Social Sciences. https://doi.org/10.3844/jssp.2016

[48] Ayuba, W. T. (2014). "Flood Vulnerability Classification of Lafia Township, Nasarawa State, Nigeria". International Conference on Earth, Environment and Life Sciences (EELS-2014), Dec. 23 - 24, 134–138. https://doi.org/http://dx.doi.org/10.15242/IICBE.C1214016

[49] Orimoogunje, O. O. I., Fashae, O. A., Oke, T. O., & Akinwumiju, A. S. (2016). "Flood Vulnerability in a Part of Southwestern Nigeria". Academia Journal of Environmental Science, 4(3), 55–61. https://doi.org/10.15413/ajes.2015.0101

[50] Kavitha.R, Kavitha.R, Jayalakshmi .C and Senthil Kumar.K, "Dam Water Level Monitoring and Alerting System using IOT" SSRG International Journal of Electronics and Communication Engineering 5.6 (2019): 19-22.

[51] Seyoum, S., Willems, P., & Verbeiren, B. (2019). "Data-Driven Models for Pluvial Flood Forecasting in Brussels". NOVATECH, 1–4. Stormwater and Urban Planning.

[52] Barroca, B., Bernardara, P., Mouchel, J. M., & Hubert, G. (2006). "Indicators for the identification of urban flooding vulnerability". Natural Hazards and Earth System Sciences, 6(4), 553–561. https://doi.org/10.5194/nhess-6-553-2006

[53] Ologunorisa, T. E., & Abawua, M. J. (2005). "Flood Risk Assessment: A Review". J. Appl. Sci. Environ. Mgt., 9(1), 57–63. Retrieved from https://tspace.library.utoronto.ca/handle/1807/6419