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Real-Time Impact Based Flood Forecasting for Tropical Rivers: A Review of Current Status, Critical Development, and Future Trends

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ABSTRACT: People living in tropical areas around rivers and sea cover face critical challenges mirrored by the severe flooding events due to the massive precipitation rate in winter and monsoon intervals between November and February. Building on this fact, several scholars and engineers conducted analysis work and evaluation of these zones by taking real-time measures of different flooding parameters (including precipitation intensity, rainfall type: snow, hail, or rain, soil humidity, water level, and evapotranspiration). Evaluating these variables is greatly beneficial and effective in assessing the flash flooding events opportunity and providing valuable guidelines for authorities and citizens on what they should act and do in case these severe events occur. This paper conducts a systematic literature review through which state-of-the-art techniques associated with Real-time-based impact floods forecasting (RTIBFF) are addressed and identified. The paper's results related to systematic literature analysis revealed that implementing RTIBFF offered significant advantages to citizens living around rivers with a high number of flooding events around the year. In addition, the research findings indicated that several scholars utilized the machine learning (ML) principles and artificial intelligence (AI) to improve the RTIBFF quality and performance in predicting dangerous flooding events and forecasting future trends of flash floods depending on taking real-time measures. Relying on these research outputs, this paper provides a remarkable relevance and valid contribution related to the RTIBFF that can improve the research and development (R&D) on the RTIBFF approach and enrich the literature with innovative techniques in forecasting flooding events.

KEYWORDS: Real-Time Impact Based Flood Forecasting, flooding, damage, water level, precipitation, tropical rivers.

ABBREVIATIONS:

| | |
|--------|---|
| RTIBFF | Real-Time-Based Impact Floods Forecasting |
| ML | Machine Learning |
| IoT | Internet of Things |
| AI | Artificial Intelligence |
| R&D | Research and Development |

I. INTRODUCTION

RTIBFF is a state-of-the-art approach used to predict severe flooding events and extreme hydrological circumstances that cause dramatic losses in lives and properties. The RTIBFF depends on ML algorithms. ML algorithms can be described as a set of rules that depends on AI and concentrate on utilizing mathematical calculations and data to imitate and simulate the human way of thinking. This aspect can improve its accuracy and data analysis precession (Fradkov, A. L., 2020). Thus, employing ML and AI in the RTIBFF is greatly beneficial and effective as it helps predict dangerous flooding situations depending on the database and parameters defined as datasets. These variables and factors, that the RTIBFF relies on, include river's level, air temperature, humidity rate, rainfall intensity, precipitation type (either hail, rain, or snow), and annual and monthly precipitation intensity (Krajewski et al., 2017). Scientists and engineers implemented a set of sensors that can be installed along the rivers and critical areas at which flooding events may occur. These sensors are considered vital as they can provide real-time databases of weather status

over time. Thus, any severe weather events, including floodings and increasing rivers, can be easily predicted. Furthermore, the RTIBFF can develop maps and profiles of higher-water level regions and zones at which floods have a higher opportunity to occur, enabling active communication and helping communities plan actively and smartly to act and respond quickly when floods occur. While the RTIBDFF approach considers assessing flooding factors and measuring weather variables on a real-time basis, such as precipitation type and rainfall density, it is also crucial to take into account the evapotranspiration process (Han et al., 2022). Evapotranspiration evaluation is significant to estimate the amount of water that evaporates from land and soil. This aspect is essential to check the soil's capacity to absorb moisture in case a higher rainfall rate and rapid precipitation occur (Trivedi et al., 2020). When the soil is highly saturated with water, the large rainfall will increase the opportunity of flash flooding events. On the other hand, when the soil is arid and contain less humidity, then flash flooding opportunity will need more time, as part of the rain can be absorbed in the soil (Ye et al., 2021).

II. LITERATURE REVIEW

i. Framework on the concept of impact based forecasting

Craninx et al. (2021) published a manuscript discussing the benefits, significances, and critical contributions of the RTIBFF. Craninx et al. relied on analyzing the Flood4castRTF performance and effectiveness in predicting floods in urban cities. They conducted a comparative study to compare the performance of Flood4castRTF model with other flooding events forecasting models. Their comparative analysis revealed that their novel model, Flood4castRTF, outpaced the performance of other floods forecasting models. Also, Flood4castRTF has the capability to provide accurate flooding forecasting without the need for a wide range of data to be defined compared to other forecasting methods. Besides, Flood4castRTF model is greatly cost-effective and can depend on GIS real-time data to offer better precise predictions than conventional models that rely on physical data collection.

Jabbari et al. (2018) conducted an analysis examining the key contribution of the RTIBFF that exploits the hydrological model to predict the flooding occurrence opportunities for the Imjin River that flows through North and South Korea depending on real-time databases. Jabbari et al. carried out a group of tests to estimate the precision of some models utilized to offer accurate results and information regarding the flooding circumstances and extreme hydrological events that may result in severe damages to citizens. Their investigation and numerical analysis confirmed that their hydrological model offered an appropriate method to predict the flooding events at the Imjin River. However, the divergence in spatial and temporal resolutions contributed to a reduction in precision. In addition, Jabbari et al. reported that their model had a lower root-mean-square value and lower errors than conventional models used to predict severe flooding events.

Sidek et al. (2021) conducted research to analyze a case study of flooding events in Malaysia's Kelantan River. Sidek et al. depended on investigating the contributinal role of warning systems and impact-based flooding forecasting to alert citizens quickly and respond flexibly before the floods make serious and harmful damages and losses for Malaysian citizens. Furthermore, Sidek et al. collected numerous databases of Kelantan River, including historical data of flooding events related to Kelantan River, rainfall rates, rainfall intensity, rainfall depth, and water level. Sidek et al. aimed to develop an automated warning system according to color codes for triggering risks mitigation responses at the national level for communities prone to frequent flooding events around the Kelantan River basin. Sidek's et al. major findings revealed that their color-code warning system is remarkably helpful and beneficial in alerting people and institutions to act quickly before floods cause dangerous impacts. In addition, the color code system can be easily and quickly understood by several citizens. However, Sidek et al. reported the need for more investigations to validate their results based on real-time circumstances. Further, Sidek et al. reported that an impact-based flooding forecasting system has great potential for Malaysian citizens and institutions. Nevertheless, it needs considerable long-term and short-term changes to implementing color-code warning system.

ii. Application of impact based forecasting in other countries

Kurian et al. (2020) carried out research exploring the significant values and advantages of the RTIBFF. Kurian et al. exploited artificial neural networks to predict flooding events using a hybrid flooding detecting model (M4t+4). Their analysis results affirmed that artificial neural networks are a promising technique to improve the accuracy and effectiveness of the RTIBFF in predicting floods events. Furthermore, their proposed model for detecting severe model events (M4t+4) provides reasonable accuracy and good effectiveness corresponding to high leading intervals. Noor et al. (2016) investigated flood forecasting methods to predict the flooding events at the Terengganu River, Malaysia, which is prone to periodic floods and higher water levels due to large rainfall and attributed topography. Moreover, the Terengganu River has higher rainfall and monsoon between November and February, which increases the flooding opportunity. Noor et al. relied on a statistical database gathered to determine the water levels of the Terengganu River through past years. They used two approaches to achieve their study goal: (1) non-

inclusion residual and (2) inclusion of residual. Their analytical results revealed that the non-inclusion residual approach is better than the inclusion of residual approach to predict the water level's rise and flooding chance at the Terengganu River. In addition, their proposed method provided higher level of accuracy and better performance in predicting severe flooding events compared to conventional methods. Faruq et al. (2020) conducted an investigation to explore the significant role of deep learning applied to the RTIBFF to predict flooding and help warning systems alert citizens when floods occur. Faruq et al. depended on innovative long short-term memory networks. These networks implement deep-learning to forecast high water levels at the Klang River basin, Malaysia. They also used a radial basis neural network function to compare the accuracy of flooding forecasting with long short-term memory networks.

Faruq et al. major findings confirmed that the accuracy of long short-term memory networks is remarkably similar to the accuracy of the radial basis neural network function. Also, the integration of deep learning into the RTIBFF approach provided remarkable level of performance in predicting severe flooding events. Sai et al. (2018) investigated the use of impact-based flood forecasting and warning to alert citizens and societies living around Rajapur and Ghorjan in the Sirajganj area before floods occur. Sai et al. relied on collecting a historical database of Jamuna River (prone to frequent flooding events) related to the precipitation rate and water level. Sai et al. developed a framework and implemented short- and long-term solutions to help citizens and the community respond quickly with the least damages and losses. Their results indicated that one of the effective solutions that can help mitigate flooding events' severity is the color codes. Thus, they can be easily understood by all citizens. Regardless, the authors reported the need for validating their results according to real-time conditions. Additionally, their proposed framework that implemented short- and long-term solutions can help people and the authorities respond quickly with the least damages and losses. Rözer et al. (2021) conducted research to examine the critical role of impact-based forecasting systems in providing a reasonable way to alert citizens effectively and practically before flooding events cause severe damage to buildings and goods. Rözer et al. reported that conventional warning and flooding alerting systems are limited to poor information and cannot provide a quick and easy approach to alert people.

Rözer et al. investigated pluvial flooding occurrence in urban regions caused by fast storms and higher precipitation events leading to rapid buildings and streets inundation. Rözer et al. examined a model chain of rainfall forecasting to offer predictions related to the expected precipitation in urban areas. Furthermore, artificial neural network-based inundation modeling is conducted to minimize the computation time needed to predict the rainfall rate. Also, they used a flood forecasting method for a pluvial flooding event that occurred recently in the German urban zone. Their analysis results indicated that their model is considerably effective and practical in predicting severe flooding events and provides five minutes for quick and significant responses before extreme floods occur. Additionally, their proposed model chain of rainfall forecasting was beneficial in offering predictions related to the expected precipitation in urban areas. Nevo et al. (2021) executed research to analyze the functional role of machine learning in forecasting flooding events with higher accuracy. Nevo et al. employed Google machine learning models to predict the water levels in rivers located in Bangladesh and India. They reported that the monsoon season is associated with heavy precipitation that encourages severe flooding events, which cause several damages and harmful impacts. They relied on a real-time flooding warning system to help respond quickly before dangerous losses result. The machine learning model comprises stage forecasting, alert distribution, data validation, and inundation models. Further, they utilized long and short-term memory networks and linear models to provide a database of water levels. Their analytical results revealed that ML used in floods forecasting offered more than 100 million flooding events warning systems to citizens near severe flooding areas and rivers. Furthermore, the authors Nevo et al. found that utilizing past flooding and water levels data has significantly improved the machine learning models to predict floods and alert the related agencies and citizens.

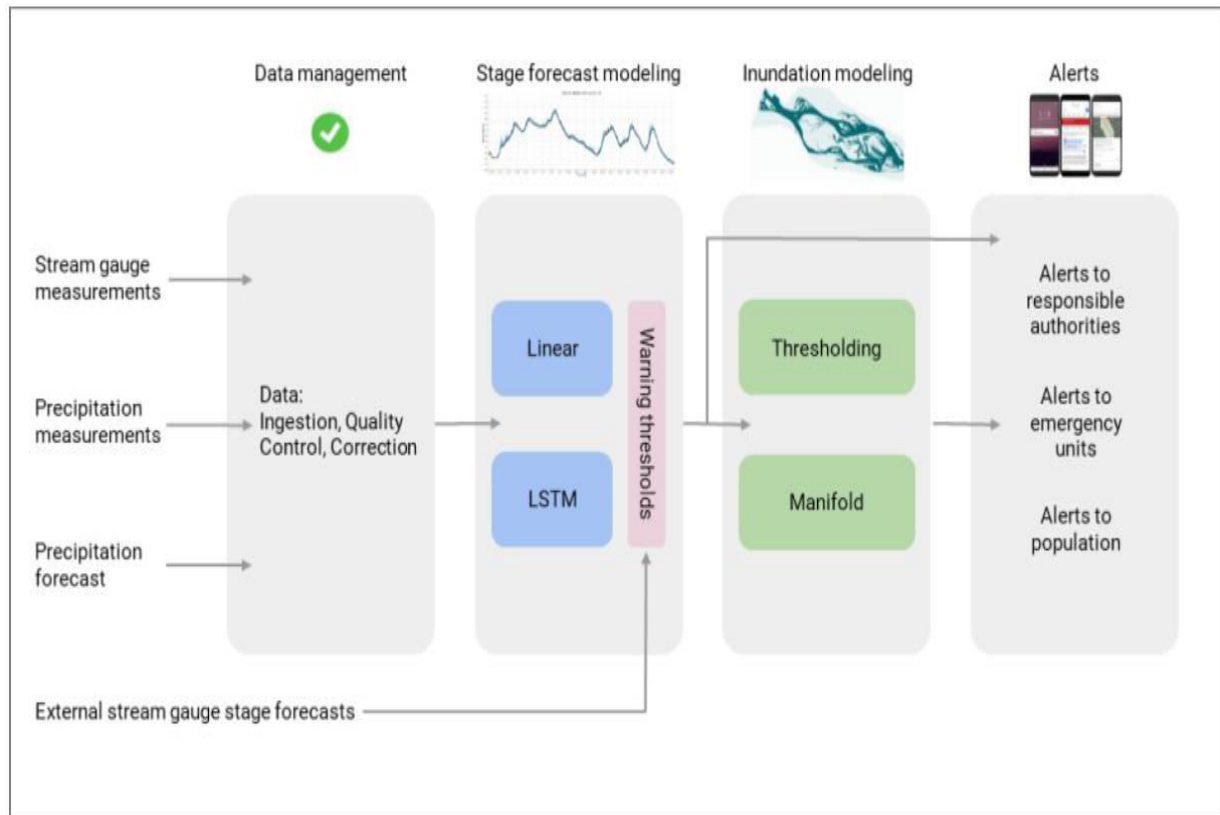


FIGURE 1 PRESENTS THE NEVO ET AL.'S PROPOSED SYSTEM TO MAKE FORECASTING AND PREDICTION OF SEVERE FLOODING EVENTS.

Mekruksavanich et al. (2021) conducted research to explore the major contribution of the internet of things (IoT) and AI in predicting water levels and making flood forecasting practical. They utilized several internet and wireless communication devices to collect real-time databases related to the flooding parameters. These floods variables include water levels and rainfall rate. Their findings affirmed the functional role of wireless communication systems and artificial intelligence in predicting severe flooding events with better accuracy than conventional methods, saving much time to respond to critical flooding events. Further, the use of AI and IoT in flood forecasting prediction schemes provided higher level of performance which help offer fast alerting system for citizens. Kim et al. (2021) performed a study to examine the active contribution of artificial neural networks in predicting water levels and making effective floods forecasting. Kim et al. employed some functions in the artificial neural networks to improve their prediction speed, including exponential linear units, ReLU, and leaky ReLU. In addition, they used a real-time dataset from one to six hours associated with the runoff and rainfall rates.

Their analysis confirmed that using exponential linear units in artificial neural networks gave the highest speed in predicting water levels and forecasting flooding. In addition, the performance and accuracy associated with severe flooding events were significant when the artificial neural networks were implemented. Kumar, V., & Yadav, S. M. (2021) published a manuscript investigating artificial neural networks' critical contribution and major role in predicting flooding events via the RTIBFF. Kumar, V., & Yadav, S. M. depended on data collection assessing the rainfall rate and evaluating the Tapi River basin water level. In addition, Kumar, V., & Yadav, S. M. implemented simulations and numerical analysis that rely on smart algorithms which use artificial neural networks principles. Their findings revealed that their proposed model that uses artificial neural network algorithms effectively predicted severe flooding events via the RTIBFF approach. Furthermore, the results confirmed that the accuracy of their model is satisfactory and high. Besides, the smart algorithms which use artificial neural networks principles were reliable and had higher performance in determining the future flooding events.

iii. Trend in the impact based forecasting

Miau, S., & Hung, W. H. (2020) conducted an analysis to investigate the critical role of deep learning in managing extreme flooding events and activating practical warning systems to respond to pluvial floods quickly. Miao & Hung reported that flash floods are dangerous weather events and rare. However, they can cause destructive and harmful impacts on several aspects within short periods. The deep learning model used in their research is employed to predict the water level related to a river in Taiwan. Additionally, they utilized gated recurrent units and convolutional neural networks to expect the water level accurately. Their analysis results indicated that their prediction model of deep learning with gated recurrent units and convolutional neural networks outpaced other advanced methods to predict water level. Moreover, their study could predict the water levels of several twenty-seven rivers. Moreover, deep learning algorithms had a critical role in managing extreme flooding events and activating functional warning systems to respond to flash floods quickly.

iv. Analysis method in Impact based forecasting

Khaire and Subramaniam (2019) conducted an analysis to predict severe flooding events and make efficient weather forecasting associated with floods to enable quick response to dangerous flooding circumstances. Khaire and Subramaniam implemented the internet of things (IoT) principles to assess and evaluate real-time measurements and provide updates and critical notifications for the authorities in the community to help people respond and act in case flash flooding events occur. Figure 2 presents the IoT principles employed in the flooding management system to predict water level.

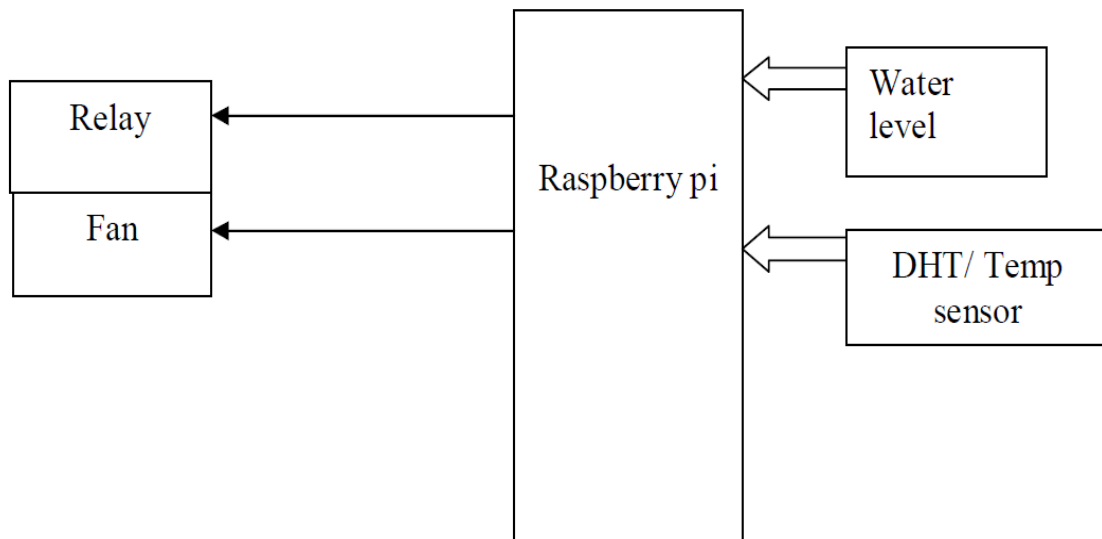


FIGURE 2. THE IOT PRINCIPLES EMPLOYED IN THE FLOODING MANAGEMENT SYSTEM TO PREDICT WATER LEVEL.

Their analysis indicated that using IoT principles is greatly important and practical. It helps measure the water level over time and gives authorities and people indication and alarm to the severe flash flooding events. Silvestro et al. (2019) carried out an investigation to study the impact-based flash-flood forecasting system and its key role in managing and predicting extreme flooding events to provide earlier warning systems. Silvestro et al. depended on real-time data collection of soil moisture rate, rainfall, and water level. They used a two-dimensional hydraulic modeling and losses evaluation approach to estimate the economic effects on citizens when flash floods happen. They applied their research on Genoa located in the northwestern zones of Italy. Their analytical results revealed the tremendous significance of impact-based flash-flood forecasting systems in giving corresponding authorities and responsible governments quick decision-making processes to save properties and economic aspects of citizens around the river and critical flooding zones. Figure 3 presents the framework of Silvestro et al.'s work to predict severe flooding events.

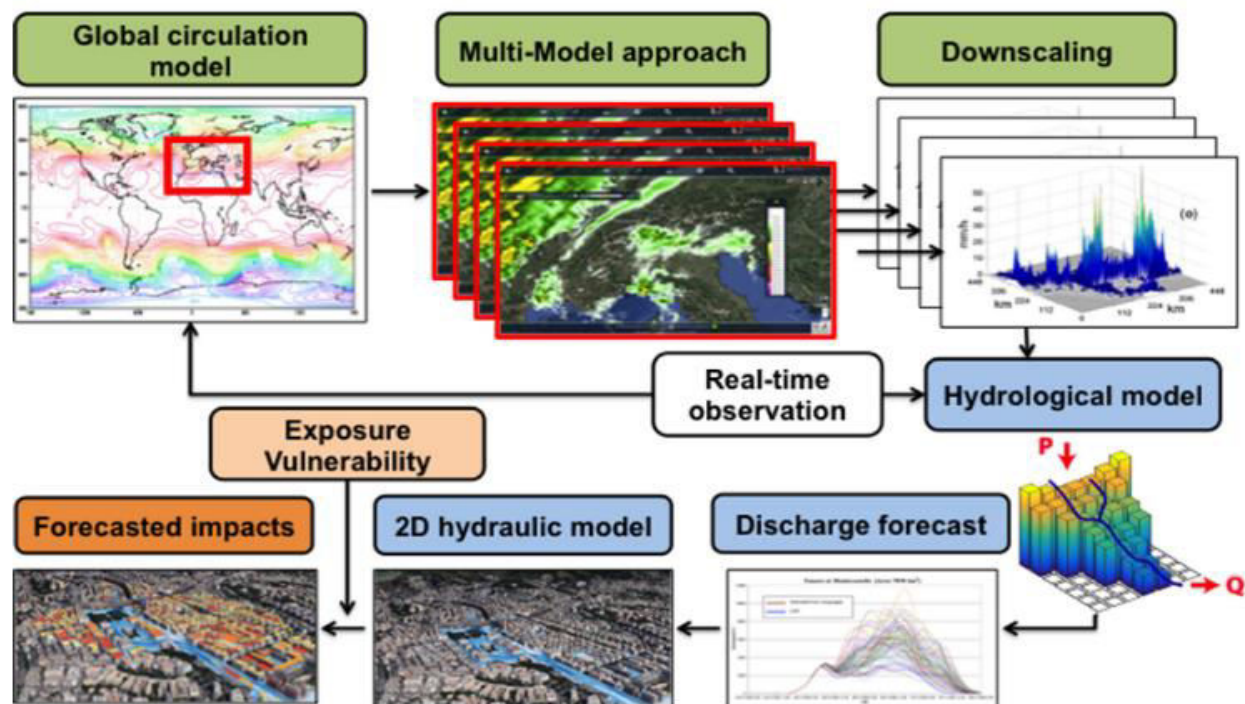


FIGURE 3. THE FRAMEWORK OF SILVESTRO ET AL.'S WORK TO PREDICT SEVERE FLOODING EVENTS.

v. Performance of Impact based forecasting

Zanchetta, A. D., & Coulibaly, P. (2020) performed research exploring recent advances and developments in the methods and smart approaches implemented for flash floods forecasting. Zanchetta, A. D., & Coulibaly, P. relied on a comprehensive literature review by which several peer-reviewed articles and recent publications were reviewed. Their literature review analysis confirmed that the latest years witnessed the implementation of smart methods and techniques that helped increase the RTIBFF performance and accuracy in predicting floods and detecting extreme hydrological events that can cause dramatic losses in the economy and lives. Moreover, the literature analysis findings revealed that an urban environment with expensive infrastructure requires cost-effective methods that can predict severe flooding events and save a lot of budgets and reduce flooding losses. These methods use AI principles and IoT. Chau, T. K., & Thanh, N. T. (2021) published a paper identifying the critical role of RTIBFF in forecasting severe flash flooding events in Vietnam. Chau, T. K., & Thanh, N. T. developed Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) model and measured real-time data associated with flooding variables in Vietnam.

They took measurements of thirty-five locations on a field trip. In addition, they applied empirical equations to validate their model. Their analysis indicated that their model successfully predicted flash flooding events at the Nam Ly and Na Nhung basins inside the Ha Giang province located in Vietnam. However, to obtain higher accuracy, further real-time rainfall measuring instruments should be installed at the Na Nhung and Nam Ly basins to estimate temporal and spatial rainfall amounts. In addition, the precipitation threshold of the regions at which flash floods may occur should be carefully determined to provide better accuracy of the RTIBFF.

vi. Gap in impact based forecasting

Ivanov et al. (2021) carried out research exploring major limitations and key obstacles of the RTIBFF approach in predicting rapid flooding events in urban cities. They developed a novel flood forecasting approach to provide an effective emergency system and help authorities act quickly when flooding events occur. They made a complex analysis of flooding effects before severe storm circumstances began. Their analysis results revealed that the flooding forecasting process could be complex, inaccurate, and difficult to achieve in cases where a large volume of databases are used in the flooding forecasting system. Thus, the computation process and predicting procedure will take much time to complete and may not be completely precise.

Nevertheless, their state-of-the-art floods forecasting approach successfully predicted flooding events and had a functional capability to handle large databases and treat complex information related to a wide range of time. Chen et al. (2019) performed an analysis examining the innovative contribution of the RTIBFF method in predicting Typhon

flooding extreme events. They considered analyzing two major parameters that influence the RTIBFF performance, including the defuzzification process and the application of effective intervals related to the analysis.

They implemented a fuzzy time series approach to provide an active prediction of Typhon flooding discharges. The midpoint method and centroid approach were examined in the fuzzy time series approach to achieve their study goal. Their analysis confirmed that using the fuzzy time series approach is greatly efficient and practical to offer an active prediction of Typhon flooding discharges.

Also, their novel model that implements the fuzzy time series method had higher accuracy and good performance and can be reliable in detecting severe Typhon flooding events. Sanders et al. (2022) conducted a study analyzing the key role of RTIBFF in predicting flooding events. In addition, they determined some limitations and key obstacles of RTIBFF in predicting floods.

Sanders et al. depended on developing a novel flooding alerting system using eXtreme Gradient Boost approach and implementing machine learning principles to provide sufficient accuracy of flooding events prediction. Their analysis revealed that hydrological flooding forecasting methods face challenges mirrored by large uncertainties, numerous errors, and complexity due to the large amount of data engaged in the prediction process and large forecasting interval implemented in the RTIBFF. In addition, their results revealed that their model - eXtreme Gradient Boost was successful and beneficial in predicting extreme flooding events. Also, their proposed model provided a remarkable level of accuracy.

III. CONCLUSION

This paper conducts a systematic literature review through which state-of-the-art techniques associated with Real-time-based impact floods forecasting (RTIBFF) are addressed and identified. The paper's results related to systematic literature analysis revealed that implementing RTIBFF offered significant advantages to citizens living around rivers with a high number of flooding events around the year. In addition, the research findings indicated that several scholars utilized the machine learning (ML) principles and artificial intelligence (AI) to improve the RTIBFF quality and performance in predicting dangerous flooding events and forecasting future trends of flash floods depending on taking real-time measures. Relying on these research outputs, this paper provides a remarkable relevance and valid contribution related to the RTIBFF that can improve the research and development (R&D) on the RTIBFF approach and enrich the literature with innovative techniques in forecasting flooding events. Table 1 presents a summary of the literature review's articles addressed.

Table 1. Main findings of the research articles reviewed in this paper.

| # | Authors | Year | Paper Title | Major Contributions |
|---|---|------|--|--|
| 1 | Craninx, M., Hilgersom, K., Dams, J., Vaes, G., Danckaert, T., & Bronders, J. | 2021 | Flood4castRTF: A Real-Time Urban Flood Forecasting Model | Their comparative analysis revealed that their novel model, Flood4castRTF, outpaced the performance of other floods forecasting models. Also, Flood4castRTF has the capability to provide accurate flooding forecasting without the need for a wide range of data to be defined compared to other forecasting methods. Besides, the Flood4castRTF model is greatly cost-effective and can depend on GIS real-time data to offer better precise predictions than conventional models that rely on physical data collection. |

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| 2 | Jabbari, A., So, J. M., & Bae, D. H. | 2018 | Accuracy assessment of real-time flood forecasting of coupled hydrological and mesoscale meteorological models | Their investigation and numerical analysis confirmed that their hydrological model offered an appropriate method to predict the flooding events at the Imjin River. However, the divergence in spatial and temporal resolutions contributed to a reduction in precision. In addition, Jabbari et al. reported that their model had a lower root-mean-square value and lower errors than conventional models used to predict severe flooding events. |
| 3 | Sidek, L. M., Basri, H., Mohammed, M. H., Marufuzzaman, M., Ishak, N. A., Ishak, A. M., & Hassan, M. H. | 2021 | Towards Impact-Based Flood Forecasting and Warning in Malaysia: A Case Study at Kelantan River | Major findings revealed that their color-code warning system is remarkably helpful and beneficial in alerting people and institutions to act quickly before floods cause dangerous impacts. In addition, the color code system can be easily and quickly understood by several citizens. However, Sidek et al. reported the need for more investigations to validate their results based on real-time circumstances. Further, Sidek et al. reported that an impact-based flooding forecasting system has great potential for Malaysian citizens and institutions. Nevertheless, it needs considerable long-term and short-term changes to implementing color-code warning system. |
| 4 | Kurian, C., Sudheer, K. P., Vema, V. K., & Sahoo, D. | 2020 | Effective flood forecasting at higher lead times through hybrid modelling framework | Their analysis results affirmed that artificial neural networks are a promising technique to improve the accuracy and effectiveness of the RTIBFF in predicting floods events. Furthermore, their proposed model for detecting severe model events (M4t+4) provides reasonable accuracy and good effectiveness corresponding to high leading intervals. |
| 5 | Noor, M. S. F. M., Sidek, L. M., Basri, H., Husni, M. M. M., Jaafar, A. S., Kamaluddin, M. H., & Osman, S. | 2016 | Development of Flood Forecasting Using Statistical Method in Four River Basins in Terengganu, Malaysia | Their analytical results revealed that the non-inclusion residual approach is better than the inclusion of residual approach to predict the water level's rise and flooding chance at the Terengganu River. In addition, their proposed method provided higher level of accuracy and better performance in predicting severe flooding events compared to conventional methods. |

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| 6 | Faruq, A., Arsa, H. P., Hussein, S. F. M., Razali, C. M. C., Marto, A., & Abdullah, S. S. | 2020 | Deep Learning-Based Forecast and Warning of Floods in Klang River, Malaysia | The major findings confirmed that the accuracy of long short-term memory networks is remarkably similar to the accuracy of the radial basis neural network function. Also, the integration of deep learning into the RTIBFF approach provided remarkable level of performance in predicting severe flooding events. |
| 7 | Sai, F., Cumiskey, L., Weerts, A., Bhattacharya, B., & Haque Khan, R. | 2018 | Towards impact-based flood forecasting and warning in Bangladesh: a case study at the local level in Sirajganj district | Their results indicated that one of the effective solutions that can help mitigate flooding events' severity is the color codes. Thus, they can be easily understood by all citizens. Regardless, the authors reported the need for validating their results according to real-time conditions. Additionally, their proposed framework that implemented short- and long-term solutions can help people and the authorities respond quickly with the least damages and losses. |
| 8 | Rözer, V., Peche, A., Berkahn, S., Feng, Y., Fuchs, L., Graf, T., & Neuweiler, I. | 2021 | Impact-based forecasting for pluvial floods | Their analysis results indicated that their model is considerably effective and practical in predicting severe flooding events and provides five minutes for quick and significant responses before extreme floods occur. Additionally, their proposed model chain of rainfall forecasting was beneficial in offering predictions related to the expected precipitation in urban areas. |
| 9 | Nevo, S., Morin, E., Gerzi Rosenthal, A., Metzger, A., Barshai, C., Weitzner, D., & Matias, Y. | 2021 | Flood forecasting with machine learning models in an operational framework | Their analytical results revealed that ML used in floods forecasting offered more than 100 million flooding events warning systems to citizens near severe flooding areas and rivers. Furthermore, the authors Nevo et al. found that utilizing past flooding and water levels data has significantly improved the machine learning models to predict floods and alert the related agencies and citizens. |
| 10 | Mekruksavanich, S., Sooksomsatarn, K., & Jitpattanakul, A. | 2021 | Flooding Forecasting System Based on Water Monitoring with IoT Technology | Their findings affirmed the functional role of wireless communication systems and AI in predicting severe flooding events with better accuracy than conventional methods, saving much time to respond to critical flooding events. Further, the use of AI and IoT in flood forecasting prediction schemes provided higher level of performance which help offer fast alerting system for citizens. |

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| 11 | Kim, J., Jun, S. M., Hwang, S., Kim, H. K., Heo, J., & Kang, M. S. | 2021 | Impact of Activation Functions on Flood Forecasting Model Based on Artificial Neural Networks | Kim et al. (2021) performed a study to examine the active contribution of artificial neural networks in predicting water levels and making effective floods forecasting. Kim et al. employed some functions in the artificial neural networks to improve their prediction speed, including exponential linear units, ReLU, and leaky ReLU. In addition, they used a real-time dataset from one to six hours associated with the runoff and rainfall rates. Their analysis confirmed that using exponential linear units in artificial neural networks gave the highest speed in predicting water levels and forecasting flooding. In addition, the performance and accuracy associated with severe flooding events were significant when the artificial neural networks were implemented. |
| 12 | Kumar, V., & Yadav, S. M. | 2021 | Real-Time Flood Analysis Using Artificial Neural Network | Their findings revealed that their proposed model that uses artificial neural network algorithms effectively predicted severe flooding events via the RTIBFF approach. Furthermore, the results confirmed that the accuracy of their model is satisfactory and high. Besides, the smart algorithms which use artificial neural networks principles were reliable and had higher performance in determining the future flooding events. |
| 13 | Miau, S., & Hung, W. H. | 2020 | River flooding forecasting and anomaly detection based on deep learning | Their analysis results indicated that their prediction model of deep learning with gated recurrent units and convolutional neural networks outpaced other advanced methods to predict water level. Moreover, their study could predict the water levels of several twenty-seven rivers. Moreover, deep learning algorithms had a critical role in managing extreme flooding events and activating functional warning systems to respond to flash floods quickly. |

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| 14 | Silvestro, F., Rossi, L., Campo, L., Parodi, A., Fiori, E., Rudari, R., & Ferraris, L. | 2019 | Impact-based flash-flood forecasting system: Sensitivity to high resolution numerical weather prediction systems and soil moisture | Their analytical results revealed the tremendous significance of impact-based flash-flood forecasting systems in giving corresponding authorities and responsible governments quick decision-making processes to save properties and economic aspects of citizens around the river and critical flooding zones. |
| 15 | Láng-Ritter, J., Berenguer, M., Dottori, F., Kalas, M., & Sempere-Torres, D. | 2022 | Compound flood impact forecasting: Integrating fluvial and flash flood impact assessments into a unified system | Their analysis results revealed that their model developed from various methods was effective and useful in predicting flooding events indicating acceptable accuracy. Furthermore, their model is highly important to implement in such severe events. It can save hundreds of millions of losses due to flooding events that cause damage to lives and properties. |
| 16 | Zanchetta, A. D., & Coulibaly, P. | 2020 | Recent advances in real-time pluvial flash flood forecasting | Their literature review analysis confirmed that the latest years witnessed the implementation of smart methods and techniques that helped increase the RTIBFF performance and accuracy in predicting floods and detecting extreme hydrological events that can cause dramatic losses in the economy and lives. Moreover, the literature analysis findings revealed that an urban environment with expensive infrastructure requires cost-effective methods that can predict severe flooding events and save a lot of budgets and reduce flooding losses. These methods use AI principles and IoT. |
| 17 | Chau, T. K., & Thanh, N. T. | 2021 | Primarily Results of a Real-Time Flash Flood Warning System in Vietnam | Their analysis indicated that their model successfully predicted flash flooding events at the Nam Ly and Na Nhung basins inside the Ha Giang province located in Vietnam. However, to obtain higher accuracy, further real-time rainfall measuring instruments should be installed at the Na Nhung and Nam Ly basins to estimate temporal and spatial rainfall amounts. In addition, the precipitation threshold of the regions at which flash floods may occur should be carefully determined to provide better accuracy of the RTIBFF. |

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| 18 | Ivanov, V. Y., Xu, D., Dwelle, M. C., Sargsyan, K., Wright, D. B., Katopodes, N., ... & Bras, R. L. | 2021 | Breaking Down the Computational Barriers to Real-Time Urban Flood Forecasting | Their analysis results revealed that the flooding forecasting process could be complex, inaccurate, and difficult to achieve in cases where a large volume of databases are used in the flooding forecasting system. Thus, the computation process and predicting procedure will take much time to complete and may not be completely precise. Nevertheless, their state-of-the-art floods forecasting approach successfully predicted flooding events and had a functional capability to handle large databases and treat complex information related to a wide range of time. |
| 19 | Chen, C. S., Jhong, Y. D., Wu, W. Z., & Chen, S. T. | 2019 | Fuzzy time series for real-time flood forecasting | Their analysis confirmed that using the fuzzy time series approach is greatly efficient and practical to offer an active prediction of Typhon flooding discharges. Also, their novel model that implements the fuzzy time series method had higher accuracy and good performance and can be reliable in detecting severe Typhon flooding events. |
| 20 | Sanders, W., Li, D., Li, W., & Fang, Z. N. | 2022 | Data-Driven Flood Alert System (FAS) Using Extreme Gradient Boosting (XGBoost) to Forecast Flood Stages | Their analysis revealed that hydrological flooding forecasting methods face challenges mirrored by large uncertainties, numerous errors, and complexity due to the large amount of data engaged in the prediction process and large forecasting interval implemented in the RTIBFF. In addition, their results revealed that their model - eXtreme Gradient Boost was successful and beneficial in predicting extreme flooding events. Also, their proposed model provided a remarkable level of accuracy. |
| 21 | Khair and Subramaniam | 2019 | Flood Disaster Management System Using IoT | Their analysis indicated that using IoT principles is greatly important and practical. It helps measure the water level over time and gives authorities and people indication and alarm to the severe flash flooding events |

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