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A SYSTEMATIC REVIEW OF REAL-TIME URBAN FLOOD FORECASTING MODEL IN MALAYSIA AND INDONESIA - CURRENT MODELLING AND CHALLENGE

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ABSTRACT

Several metropolitan areas in tropical Southeast Asia, mainly in Malaysia and Indonesia have lately been witnessing unprecedentedly severe flash floods owing to unexpected climate change. The fast water flooding has caused extraordinarily serious harm to urban populations and social facilities. In addition, urban Southeast Asia generally has insufficient capacity in drainage systems, complex land use patterns, and a large susceptible population in confined urban regions. To lower the urban flood risk and strengthen the resilience of vulnerable urban populations, it has been of fundamental relevance to create real-time urban flood forecasting systems for flood disaster prevention agencies and the urban public. This review examined the state-of-the-art models of real-time forecasting systems for urban flash floods in Malaysia and Indonesia. The real-time system primarily comprises of the following subsystems, i.e., rainfall forecasting, drainage system modelling, and inundation area mapping. This review described the current urban flood forecasting modelling for rainfall forecasting, physical-process-based hydraulic models for flood inundation prediction, and data-driven artificial intelligence (AI) models for the real-time forecasting system. The analysis found that urban flood forecasting modelling based on data-driven AI models is the most applied in in many metropolitan locations in Malaysia and Indonesia. The analysis also evaluated the existing potential of data-driven AI models for real-time forecasting systems as well as the challenging towards it.
Keywords: Urban Flood, Real-time forecasting, Malaysia, Indonesia, and modeling

ABSTRAK

Beberapa wilayah metropolitan di Asia Tenggara yang beriklim tropis, khususnya di Malaysia dan Indonesia baru-baru ini mengalami banjir bandang yang belum pernah terjadi sebelumnya akibat perubahan iklim yang tidak terduga. Banjir air yang deras telah menyebabkan kerusakan yang sangat serius terhadap penduduk perkotaan dan fasilitas sosial. Selain itu, wilayah perkotaan di Asia Tenggara umumnya memiliki kapasitas sistem drainase yang tidak memadai, pola penggunaan lahan yang kompleks, dan jumlah penduduk rentan yang besar di wilayah perkotaan yang terbatas. Untuk menurunkan risiko banjir perkotaan dan memperkuat ketahanan penduduk perkotaan yang rentan, penciptaan sistem prakiraan banjir perkotaan real-time bagi lembaga pencegahan bencana banjir dan masyarakat perkotaan merupakan hal yang sangat penting. Tinjauan ini mengkaji model-model canggih dari sistem prakiraan real-time untuk banjir bandang perkotaan di Malaysia dan Indonesia. Sistem real-time terutama terdiri dari subsistem berikut, yaitu prakiraan curah hujan, pemodelan sistem drainase, dan pemetaan area genangan. Tinjauan ini menjelaskan pemodelan prakiraan banjir perkotaan saat ini untuk prakiraan curah hujan, model hidrolik berbasis proses fisik untuk prediksi genangan banjir, dan model kecerdasan buatan (AI) berbasis data untuk sistem prakiraan waktu nyata. Analisis tersebut menemukan bahwa pemodelan prakiraan banjir perkotaan berdasarkan model AI berbasis data adalah yang paling banyak diterapkan di banyak lokasi metropolitan di Malaysia dan Indonesia. Analisis ini juga mengevaluasi potensi model AI berbasis data untuk sistem perkiraan real-time serta tantangan yang dihadapinya.
Kata Kunci: Banjir Perkotaan, Real-time Forecasting, Malaysia, Indonesia, dan Pemodelan

1. INTRODUCTION

During the last 30 years, floods have been the most common natural catastrophe in Asia, and this tendency only seems to be increasing. A previous high-resolution global survey found that 1.47 billion people worldwide, including 956 million in East and South Asia, live in areas at high risk of flooding (Rents, J.E et al 2021). Asia is the most vulnerable continent in terms of population and economic losses from flooding (Ward PJ et al 2011). When it comes to urban floods, Malaysia and Indonesia rank third and third, respectively, in Asia. Particularly devastating in Malaysian and Indonesian cities is the recurrence of flash floods. Several people have been killed or are still missing after flash floods swept over portions of Malaysia and Indonesia. Insurers should better manage flood risk in Southeast Asia after devastating floods hit Malaysia and Indonesia between the middle of December 2021 and the middle of January 2022. Southern Peninsular Malaysia and northern Indonesia have been hit by heavy rainfall over a short time, leading to floods that have displaced people and caused property damage. It has recently gained greater attention from city inhabitants because of the widespread destruction it has wreaked on buildings, individuals, and everyday life. The problem has only become worse as the population has grown and metropolitan areas have expanded rapidly.

Rapid urbanisation, flood protection, and complex natural processes may increase flood danger. Jakarta and Kuala Lumpur are examples. Kuala Lumpur's population grew from a quarter million to 8.2 million between 1950 and 2015, with 30% of the rise coming after 2010. Southeast Asian cities are growing faster than their stormwater capacity. Climate change, urbanisation, and drainage infrastructure might cause catastrophic floods without flood risk management. Fast-growing communities struggle to forecast flood damage. The model must include the latest data and flood-generating systems of these huge metropolitan zones. Flood causes have been studied for decades due to their devastation. Since the 1970s, flood inundation models have driven flood research (Teng,J et al 2017). Urban flooding may be costly. Urbanization and climatic change will worsen. Urban flood models have been created due to its characteristics and socioeconomic significance. Flash floods are nature's worst. Flash floods kill around 5,000 people annually (computed as the number of fatalities divided by the number of affected persons). Flash floods caused half of the flood's property, infrastructure, and industrial deaths. Flash floods are hazardous because to their quick occurrence and confined watershed (e.g., heavy rainfall causing mountain runoff) (Modrick and Georgakakos, 2015). Due to its geography, topography, and temperature, flash floods are widespread. Flash floods were hard to predict, making prevention impossible.

. In order to predict urban floods, hydrologists apply physically based models that take into account meteorological data, watershed factors, and streams/conduits (Zounemat-Kermani M et al 2020). Yet, this data may be hard to obtain constantly for model validation or real-time applications, leading to erroneous predictions (Piadeh, F et al 2022). The short-term water level/depth of urban floods may be quickly and accurately predicted using data-driven models in hydrology and data sciences (Rezaie Adaryani, F.et al 2022). Due to their inflexibility, these models may provide inaccurate results in novel circumstances, such as extreme weather events exacerbated by climate change (Garca, L et al., 2015). It makes sense to link these models together for real-time flood warning systems in urban catchments. The urban drainage system is one factor that is accounted for in flood modelling. Predicting and modelling rainfall has helped with urban flood management. The accessibility of data is a bottleneck for hydro informatics technology. Rainfall prediction systems and flood modelling technologies may be hampered by several issues that make it difficult to provide accurate real-time flood forecasts.

Most Southeast Asian cities consider upgrading drainage network infrastructure harder than getting data or predictions. Early flood warning systems predict floods in rivers, reservoirs, lakes, stream flows, steep terrain, prairies, urban surface runoff, and coastal cities (Hadid et al., 2020; Meyers et al., 2021). Real-time forecasting must account for Table 1 flood characteristics. These traits describe performance measures, flood consequences, flood modelling, and geographical and temporal data. Modelling geographically and temporally distributed systems for real-time urban drainage system flood forecasting is difficult due to spatial and timing restrictions (Zhao et al., 2019a; Mullapudi et al., 2020). Cities in the Global North have well-established flood simulation and mitigation methods (Teng, J et al 2017). Urban flood models and simulation have improved, but we still know little about urban floods in metropolitan areas of the Global South, notably Southeast Asia (Sidek, L.M et al 2021). Hence, real-time flood predictions and accurate weather forecasts would help mitigate climate change-related flood disasters.

Table 1. *Main features of flood in urban and non-urban areas*

Characteristics	Urban areas	Non-urban areas
Flood description	- Lack of adequate drainage leading to a city's drainage systems overflowing	- Flooding or rising water levels in areas such as rivers, streams, the ocean, and reservoirs

Characteristics	**Urban areas**	**Non-urban areas**
Flood causalities	-Mainly fast surface runoff generated by rainfall	-High intensity of rainfall or accumulation of surface runoff
Flood duration	-Between a few minutes to a couple of days	-Part of days to a week
Spatial flood impacts	-Small areas i.e., streets to neighborhoods, can be extended to all urban areas, but highly distributed	-Large scale such as vulnerable zones, and river riparian zones
Spatial restrictions for flood management	-No flexibility in land surfaces or underground modification as previously occupied -Fast variation in land use	-High flexibility in non-urban areas
Main types of impacts	-Economic loss and business interruption -Human loss, Mental and social problems -Urban structure and infrastructure damages	-Soil erosion -Wasting crops and livestock -Natural habitat loss -Water pollution -Reservoir or water infrastructure damages

In conclusion, the reviews have mostly concentrated on urban flood forecasting, analysing real-time forecasting models in the context of Malaysia and Indonesia, and explaining data needs, existing models, and quantifying model performance. So far as we can tell, there hasn't been a critical and complete assessment written to shed light on this background information, which is necessary for the development of the discipline and the articulation of its present and future orientations. Hence, this paper's overarching goal is to review all advances of the real-time data-driven forecasting models of urban flooding, demonstrating a complete picture of the current approaches and highlighting future directions of real-time control of urban flooding in the context of Malaysia and Indonesia.

Even though a lot of literature has been presented regarding the results regarding flood risk in urban Asia, there are still several gaps that provide opportunities for further research and analysis. Addressing these gaps can contribute to a more comprehensive understanding of the factors contributing to urban flooding, the effectiveness of prediction models, and the development of resilient flood management strategies in Southeast Asia

2. LITERATURE REVIEW

2.1 Flood in Malaysia

In Malaysia, 18% of the nation is impacted by floods each year, making it the country's most devastating natural catastrophe in terms of population, area, frequency, social-economic damage, and length of flood. Every year, flash floods threaten the country of Malaysia because of the monsoon season and the tremendous rainfall that comes with it.

As rapid urbanisation occurs, the problem worsens. Major floods have been documented in the past (Table 1). An estimated 20% of Malaysians live in flood-prone areas. Repeated, extensive flooding causes considerable disruption to towns, businesses, and key infrastructure, and often necessitates the evacuation of tens of thousands of people (Brown, E et al 2017). Rapid urban expansion over the last decade has worsened the effect of severe floods by altering the flow regimes and flooding mechanisms of the rivers. Kuala Lumpur, the biggest city in Malaysia and the country's capital, is well-known across the world. The Bureau of Statistics in Malaysia estimates that there are 1.78 million people living in Kuala Lumpur as of the year 2019. In terms of population, GDP, and social progress, it is one of the most rapidly expanding urban areas in all South and Southeast Asia. Nonetheless, Kuala Lumpur is one of the tropical locations often plagued by extended rains and storms that finally lead to flood because of its location. There are several causes for flash flooding. Particularly, the study discovered four characteristics contributing to the incidence of flash floods in the instance of Kuala Lumpur, a large metropolis in a tropical country: rainfall and climate change, urbanization and human interference, network and catchment elements, and geomorphological aspects. The intensity of rainfall is significantly affected by climate change, as stated in (1). The climate is a key contributor to the intensity of rainfall, which may lead to flooding.

Table 2. *Major floods in Malaysia since 1926 to 2021*

Year	Area	Types of floods
1926	Whole country	Monsoon Flood
1971	Kuala Lumpur	Flash Flood
1996	Sabah	Flash Flood
2000	Shah Alam	Flash flood
2001	Kuantan	Monsoon flood
2003	Kuala Lumpur, Sarawak	Flash Flood
2004	Kelantan	Monsoon flood
2005	Kedah, Perlis	Monsoon flood
2006	Shah Alam, Johor	Flash flood
2007	Johor, Melaka, Pahang, Kuala Lumpur	Flash flood
2008	Pahang	Monsoon flood
2010	Kedah, Perlis	Monsoon Flood
2013	Cameron Highlands, Kuantan, Kemaman	Monsoon flood
2014	Kelantan, Terengganu, Pahang, Perak, Perlis	Monsoon flood, Flash Flood
2017	Penang	Flash flood
2021	Kuala Lumpur, Terengganu, Pahang	Flash flood

2.2 Flood in Indonesia

Indonesia is known as the market of natural hazards (L.Y. Chuang et a 2011). The risk of floods in Indonesia is severe. From 1973 to 2002, Indonesia was one of the top five nations with the highest number of flood-related natural disasters, as reported by the National Disaster Management Agency (NDMA). More people in Indonesia have been uprooted by floods than by any other natural calamity in the previous 20 years, and the country's economy has been severely impacted as a result. National Agency for Disaster Management (BNPB) data shows that between 2010 and 2019, floods were the most common natural catastrophe in Indonesia. There were 343 flood occurrences in Indonesia in 2019, with 1,045 people wounded and 94,493 homes inundated, according to data compiled by DIBI. The impoverished and the helpless are disproportionately impacted by flood risks. They often reside in high-risk environments, such as crowded urban districts located in low-lying flood plains, highly exposed coastal regions, and riverbanks subject to frequent flooding. In addition, they often lack access to financial services and fundamental assistance in the wake of flood occurrences. Urban areas without adequate drainage are more vulnerable.

Indonesia's capital, Jakarta, is a major metropolis. Urban flooding still causes major economic damage and deaths. Jakarta is "high-risk" for natural disasters (J.C. Bezdek et al 1998). 1996, 2002, 2007, 2013, and 2020 were major Jakarta floods. Floods from overflowing rivers and inadequate drainage and storm surges threaten the city (from rising sea levels and storm surges). City population, economy, and infrastructure have grown. In 2007, the first major floods killed 57 and displaced 420,000. (ReliefWeb 2013). In 2013, Merdeka's presidential palace, low-lying areas, and city flooded. (Vaswani 2013). Housing colonies around problematic river and coastal zones have grown due to noncompliance with construction laws and flood risk reduction requirements, such as constructing above flood levels and using flood-resistant materials. In January 2020, Jakarta's greatest flood, over 5 metres high, inundated two- to three-story homes. Rapid water accumulation causes a greater flood. Deltaic floodplains and 13 rivers flood Jakarta. 27 rivers border Jakarta, 7 m above sea level. Several serve multiple uses (L.-F. Chang et al 2015). Western Java's southern highlands supply these rivers. The rivers must incorporate Java Sea water from North Jakarta and Katulampa river water from Bogor, West Java (A. Kaur et al 2020). s ed Experts expect half of the state capital to sink 9 inches year, costing $521 million (B.I.

Nasution et al.2020). Sub-district maps show Cengkareng and East Jakarta were worst hit by floods (F. Ullah et al. 2021).

Table 3. *Flood event in Indonesia from 2007 to 2021*

Year	Area	Causalities	People affected	Economic loss
29 January-2 February 2007	Jakarta City	57 deaths	400,000 people	USD 900 million
17 January 2013	West Jakarta	48 deaths	250,000 people	USD 490 million
January 2014	Jakarta City	23 deaths	180,000 people	USD 340 million
January 2020	Jakarta City	60 deaths	20,000 people	USD 521 million
31 March 2021	Medan City	5 deaths	50,000 people	USD 287 million
January 2023	Semarang City	-	3,460 people	USD 195 million

2.3 Overview Flood Forecasting Studies

In many regions, forecasting floods is the only viable solution. Hydrology makes flood prediction difficult. Hydrology's most serious concern, it prevents financial and human harm (Jain SK et al 2018). Forecasting floods helps manage water and natural resources, evacuate flood-prone areas, establish insurance premiums, and plan infrastructure improvements. (Chen Lu, 2020). Flood forecasting and warning systems (FFWS) alert the public and relevant authorities of impending floods. Recent advances in meteorological and hydrological modelling, satellite data collecting, and uncertainty analysis and communication have increased prediction dependability. Soft computing-based operational flood forecasting models outperform their counterparts regardless of data availability. (i) collecting and transmitting hydrological and meteorological data; (ii) projecting future rainfall, water heights, and discharge for a few hours to a few days; and (iii) providing information to user agencies and communities. River heights, inundation area, and peak flow time with ample notice for authorities and affected populations are the most useful FFWS outputs. The lead time is the time between the prediction's release and its validity (WMO 2000).

Table 4. *Recent articles of analysing flood using flood forecasting model.*

Author	Year	Topic Review	Technique / Model	Remarks / Findings
Samantara y S	2023	Prediction of Flood Discharge	Support Vector	excellent accuracy for

Author	**Year**	**Topic Review**	**Technique / Model**	**Remarks / Findings**
		Using Hybrid PSO-SVM Algorithm	Machine and Particle Swarm Optimization (PSO-SVM)	flood hazard mapping
Shada B	2022	Hourly Flood Forecasting Using Hybrid Wavelet-SVM	Wavelet-Support Vector Machine (WSVM)	accurately estimate peak discharge magnitude and time to peak.
Parsian S	2021	Flood Hazard Mapping Using Fuzzy Logic, Analytical Hierarchy Process, and Multi-Source Geospatial Datasets	Fuzzy Analytical Hierarchy Process (FAHP)	excellent accuracy for flood hazard mapping
Wong WM	2021	Development of Short-term Flood Forecast Using ARIMA	ARIMA Model	appropriate short-term water level forecast
Ming X et al	2020	Real-Time Flood Forecasting Based on a High-Performance 2-D Hydrodynamic Model and Numerical Weather Predictions	2-D Hydrodynamic Model	The approach provides a good indicator of flood inundation areas
Nadia Zehra	2020	Prediction Analysis of Floods Using Machine Learning Algorithms (NARX & SVM)	Non-linear (NARX) and Support Vector Machine (SVM)	accurately estimate peak discharge magnitude and time to peak.
Talha S	2019	Prediction of Flash Flood Susceptibility Using Fuzzy Analytical Hierarchy Process (FAHP) Algorithms and GIS	Fuzzy Analytical Hierarchy Process (FAHP)	excellent accuracy for flood hazard mapping
Tuankrua V	2019	Flood Risk Mapping Using	Hydrologic Engineering Center	appropriate short-term

Author	Year	Topic Review	Technique / Model	Remarks / Findings
		HEC-RAS and GIS Technique	River Analysis System (HEC-RAS)	water level forecast
Falah F et al	2019	Artificial Neural Networks for Flood Susceptibility Mapping in Data-Scarce Urban Areas	Artificial Neural Networks (ANN)	The approach provides a good indicator of flood inundation areas
Wu, J et al	2019	Flash Flood Forecasting Using Support Vector Regression Model in a Small Mountainous Catchment	Support Vector Regression (SVR)	The SVR model has satisfactory predictive performances for one to three-hours ahead forecasting

2.4 Theoretical of Real time Flood Forecasting

Accurate and timely flood warnings are significantly assisted by real-time flood forecasts. In terms of non-structural flood management measures, real-time flood forecasting is among the most effective (Singh RD 2021). On the other hand, life and property may be saved with the use of real-time flood forecasting methods. At the outset of a predicted catastrophic catastrophe, knowing the locations of high-risk areas allows emergency personnel to prioritise evacuations and other efforts (Arrighi, C et al 2019). The three main components of real-time flood forecasting (data collection/preparation/model building/performance evaluation) have all seen advancements in the last several decades. One of these three key features of real-time flood forecasting has been predicted by research. There are a lot of research holes that need to be filled. The various theories, models, and technologies for predicting urban floods in real time are compared in Table 2. Data collection and preparation have been criticised in a few studies. McKee and Binns (2015) proposed combining data sets to better predict urban flood hydrology. The accuracy of data-merging techniques was evaluated by Ochoa-Rodriguez et al. (2018). The "performance assessed" urban flood forecasting utilising data has been conducted by Daal et al. (2017) and Thorndahl et al. (2017). Analysis of uncertainty in input data affects the need to evaluate model performance, according to Daal et al. (2017). Radar data was proven accurate by hydrological models. In 2015, Salvadore et al. analysed urban hydrological process models critically and predicted future trends in model development based on data resolutions. Real-time control approaches, models, and programmes have been evaluated by Gara et al (2015) and Nkwunonwo et al. (2020).

2.5 Types of Flood Forecasting Model

2.5.1 ARMA and ARIMA Model

At large timescales, such as monthly or seasonal, the dynamics of the RR process can be adequately represented by stationary stochastic models like the Autoregressive Moving Average (ARMA), and non-stationary models like the Auto-Regressive Integrated Moving Average (ARIMA), where the parameters have some physical interpretation. These models have been widely used because they successfully replicate hydrographs while having minimal mathematical and computing requirements. ARMA models are primarily utilised for error correction in the context of operational flood forecasting. One intriguing use of data-driven methods is to enhance the real-time predictions made by deterministic lumped RR models, in which a conceptual model simulates the catchment response and an ARMA model simulates the residuals. When ARIMA models are combined with data-driven models (i.e., ANNs) for precipitation forecasting and discharge updates, Brath and Toth (2002) observed significant improvements in discharge predictions.

2.5.2 Artificial Neural Networks (ANNs)

An early application of ANNs in the field of water resources research was the estimation of flood occurrences and the prediction of monthly water usage. Rainfall-runoff processes and flood forecasting may be effectively modelled using nonlinear time-series models, such as Artificial Neural Networks (ANNs), which are an example of a data-driven FF technique (ASCE Task Committee, 2000a, b). Since then, ANNs have been used in a variety of water resource contexts, most notably for time-series prediction in the areas of precipitation forecasting, runoff processes, and river salinity. Other applications of ANNs include the modelling of soil and water table variations, pesticide transport in soils, water table control, and water quality management (Parson, 1999). ANNs may describe complicated nonlinear interactions and are nonparametric models that adapt to new information (Antar et al. 2006, De Vos and Rientjes 2005). Networks of artificial neurons (ANNs) can learn from data, generalise data behaviour, and tolerate noise. The deployment of ANNs and other models in a small number of pilot applications where their efficacy can be compared to that of existing methods is warranted considering current concerns regarding their efficacy in flood forecasting.

2.5.3 Support Vector Machine

In the 1960s, Russian mathematicians Vapnik and Lerner came up with the concept that would become known as the Support Vector Machine. Vapnik advanced the discipline significantly, and he published the seminal book on the topic. The components of an SVM are the support vectors and the kernel. The training data is used to generate a collection of vectors known as the support vectors. The function is approximated using the kernel and the support vectors. The SVM model used by Hu et al. (2011) to predict monthly runoff in the Fenhe River's headwaters was shown to be more accurate than the ANN model's predictions. The study examined the viability of using a hybrid forecasting approach based on support vector regression and its applicability for rainfall-runoff forecasting. Rainfall-runoff connections were simulated using several different SVM models and compared to the ANN model after training. The findings demonstrate that, compared to the ANN models, the SVM model's nonlinear mapping skills are superior, making it more adept at capturing patterns in runoff data.

2.5.4 Fuzzy Logic

Data-driven models also include those based on fuzzy logic and set theory (Zadeh 1965). A vector of fuzzy explanatory variables and a vector of fuzzy consequences are used in IF-THEN fuzzy models (Shrestha et al. 1996). There have been several implementations of fuzzy logic, fuzzy rule-based systems, and hybrid fuzzy-based flood forecasting techniques (Dubrovin et al. 2002). According to Luchetta and Manetti (2003), a fuzzy logic-based approach to hydrologic forecasting outperformed ANNs. The daily water levels of Bangladesh's Buriganga River were estimated by Liong et al. (2000) using a fuzzy logic model based on data from upstream. Dubrovin et al (2002).'s Fuzzy-State Stochastic Dynamic Programming takes into consideration the uncertainty and unpredictability of hydrologic variables as well as the imprecision of variable discretization. In 2005, Yu and Chen proposed employing a fuzzy rules-based system for error prediction to provide hourly updates to real-time flood forecasts. Fuzzy and ANN ideas comes together in ANFIS. Bae et al. built an operational forecasting model based on ANFIS to predict monthly reservoir inflows (2007).

2.6 Development of Real Time Flood Forecasting Model in Malaysia and Indonesia

The use of meteorological and hydrological data collected in real time is essential to the process of refining flood forecasting and modelling in Malaysia and Indonesia. The purpose of the flood forecasting model is to provide the authorities with an efficient tool for evacuating the population in the case of a flood, with the end objective of reducing the number of human casualties and material losses as much as possible. A comparison of the different levels of development reached by the flood prediction models in Malaysia and Indonesia is shown in Table 5.

Table 5. *The Comparison Between Development of Flood Forecasting Model in Malaysia* and Indonesia

No	Detail	Malaysia	Indonesia
1	**Model**	Atmospheric Model Based Rainfall and Flood Forecasting (AMRFF)	Indonesia Flood Model (IFM)
	Year	2012-2014	2020
	Case study	Developed for three (3) river basins – Pahang River, Kelantan River, and Johor River (East Coast Region)	Covers whole Indonesia
	Objective	To forecast flood every six (6) hours for the three basins separately, three (3) days ahead to allow early warning to be issued	To simulate rainfall and river discharges across the river network in the country.
	Data Input	Numerical Weather Prediction (NWP) from Global Forecast System (GFS)	10,000-year stochastic catalogue simulating both riverine and rainfall flooding
	Models used	Hydrological Analysis: Watershed Environmental Hydrology (WEHY) Hydrodynamic Analysis: HEC-RAS	Hydrological and Hydraulic Modelling
2	**Model**	Integrated Flood Forecasting and River Monitoring (iFFRM)	The Rapid Flood Model
	Year	2008-2009	2023
	Case Study	Klang Valley – the most important suburb in Malaysia	Makassar
	Objective	To forecast water level and flood area in Klang Valley with lead time of 1 – 4 hours	To estimate the height and area of the flood basin
	Data Input	Numerical Weather Prediction & Real time telemetry data	Rainfall and topographic data

No	Detail	Malaysia	Indonesia
	Models used	Hydrological and Hydrodynamic Analysis: Info works RS. Flood monitoring & forecast: Flood Works	Hydrodynamic Model
3	**Model**	Integrated Flood Forecasting and Warning System	The Willis Re Indonesia Flood model
	Year	2004-2006	
	Case Study	Muda River Basin (North Coast Region) – interstate river basin	Covering major river catchments in Indonesia
	Objective	To forecast flood every six (6) hours for the Muda River Basin, three (3) days ahead to allow early warning to be issued	To assess a detailed flood risk countrywide, including the industrial estates in West Java which are prone to frequent flooding
	Data Input	Radar data from MMD, Real time telemetry data	37 year-record of global rainfall observations and local rain data.
	Models used	Hydrological and Hydrodynamic Analysis: MIKE 11 Flood monitoring & forecast: Flood Watch	High Resolution Hydrological and Hydraulic Models
4	**Model**	Integrated Flood Forecasting and Warning System Based on Real Time Radar Rainfall	Indonesian Coastal Inundation Forecasting System (Ina-CIFS)
	Year		2019
	Case study	Padas River Basin, second largest river basin in Sabah, East Malaysia	Jakarta and Semarang-City
	Objective	To forecast flood every six (6) hours for the Padas River basin, two (2) days ahead to allow early warning to be issued	To monitor coastal communities, adapt to the impact of coastal floods. Act as a Decision Support System (DSS)
	Data Input	Radar data from MMD, Real time telemetry data	Ocean force observation, Atmospheric force observation, Surface water observation
	Models used	Hydrological and Hydrodynamic Analysis: MIKE 11 Flood monitoring & forecast: Flood Watch	BMKG Ina Waves (based on Wave watch III: Global to Regional Coupling Wave-Hydrodynamic Models

No	Detail	Malaysia	Indonesia
			• Nested Wave watch III (WW3) – SWAN model. • Coupled Delft3D Flow – SWAN (Delft3D Wave) Integrated with River Flood Model - Delft FEWS & SOBEK Model

3. METHODOLOGY

Recent years have seen an increase of real time forecasting modelling in analysing the urban flood. This study utilises the methodology established by Arksey and O'Malley (2005) to specify the following: research objective, relevant studies, select topic studies, chart the data, and compile, summarise, and present findings.

3.1.1. Search Strategy

Scopus Database, a resource for urban flood risks, forecasting, and modelling, was used to search the IIUM's online library for relevant publications for review. These sites provide conference proceedings and e-books. The assessment evaluated global, regional, federal, and local statistics and information with a focus on Malaysia and Indonesia and a short evaluation of relevant research globally. This paper reviews all real-time flood predicting studies in Malaysia and Indonesia and briefly reviews global studies employing statistics, chaos theory, and machine learning. The authors' current model development work is another goal. Lastly, these models' prospects and problems will be discussed. This research used Scopus keywords to gather data. The chosen literature covered 1992–2022. Risk assessment, open data, and data analysis approaches were reviewed. Table 6 lists this study's keywords and publications. Citation and keyword networks were analysed.

Table 6. The keywords and the number of articles selected for this study.

Topic	Keywords/Search Strings Used
Urban flood	Urban Flood Malaysia, Urban Flood Indonesia, flood hazards, flood risk, flood vulnerability, hazards Malaysia, hazard Indonesia
Flood forecasting	Urban flood forecasting, flood forecasting system, development of flood forecasting
Real-time modelling	Real-time modelling system, warning system
Analytical tools used in Malaysia	flood analytical tools, open flood risk models, flood risk assessment in Malaysia, flood risk assessment model, flood modelling, flood hazard models, flood data analysis

Topic	Keywords/Search Strings Used
Analytical tools used in Indonesia	flood analytical tools, open flood risk models, flood risk assessment in Indonesia, flood risk assessment model, flood modelling, flood hazard models, flood data analysis

3.1.2. Relevant studies

A search of Scopus database for "REAL TIME URBAN FLOOD FORECASTING MODELLING" reveals over 667 papers between 1992 and 2022. The yearly document distribution is presented in Figure 4a. Most of the documents were released after 2013, according to the distribution, while the years 1992 to 2008 had the fewest total releases. The most common types of publications were articles (73.8%) and conference papers (19.9%), while the least common type was Book, Erratum and Short Survey which published (0.2%) respectively.

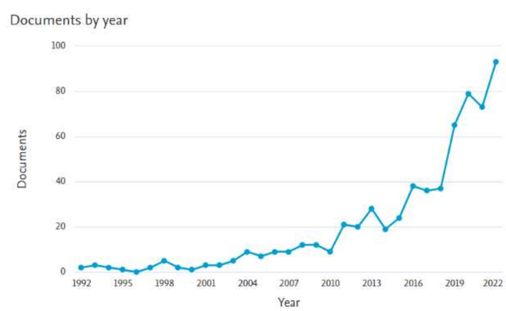

Figure 1a. *Yearly publications in Scopus*

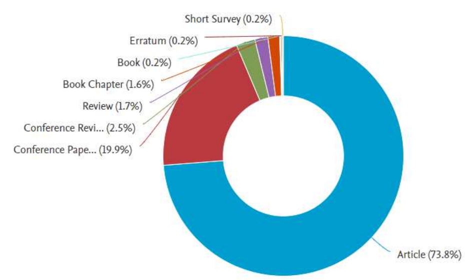

Figure 1b. *Types of publications in Scopus*

4. RESULT AND DISCUSSION

One of the most useful non-structural metrics in flood risk assessment is real-time flood forecasting. Several procedures in the constructed environment have made substantial use of it for mapping, prediction, and decision making, and all have shown remarkable performance and accuracy. Table 7 displays a case study of flood analysis using flood forecasting model in Malaysia based on SCOPUS database. In Malaysia, artificial neural networks (ANN) and hydrological equilibrium and hydrodynamic modelling systems (HEC-HMS) were the most popular models for urban flood forecasting. The network architectures and models used in ANNs, and HEC-HMS have shown to be adaptable in the context of flood hazard evaluation. Academics and researchers are actively using cutting-edge methods, like as ANN, to create and evaluate flood prediction in populated areas. It is possible to use either a feed-forward method for implementing ANN or a back-propagation strategy for training ANN. Hydrologic Modelling System (HEC-HMS) excels with large datasets, produces accurate forecasts posttraining, and allows for a long enough lead time for forecasting and fast computation of runoff/stage threshold conditions.

Table 7. *Case Study of Flood Analysis using Flood Forecasting Model in Malaysia (SCOPUS Database)*

Author	Year	Case Study	Model	Analysis Context	Types
Abdul Majid, M	2021	Kelantan	ANN, HEC-HMS	Rainfall prediction	Conference
Eddy Herman,S	2021	Dungun River	ANN, HEC-HMS	Flow simulation	Article
Wong WM	2020	Melaka River	ARIMA	Prediction hourly water level	Article
Goudarzi S et al	2020	Selangor	WSN-UAV	Monitoring rivers' water levels	Article
Faruq A et al	2020	Klang River	RBFNN, ANFIS, SVM, LSTM	Prediction river water level	Conference
Billa L	2019	Kuala Lumpur	NOAA-AVHRR	Precipitation forecasting	Article
Zainorzuli SM	2019	Kedah	NARX-ENN	Water level prediction	Article
Osman S	2018	Kelantan River	ANN	Prediction hydrograph in watershed	Conference
Wan Hazdy AM	2017	Muar River	ANN	Rainfall and streamflow prediction	Conference
Wan Hazdy AM	2017	Kelantan River Basin	ANN, PDM	Flood mapping in watershed	Conference
Jun C. L	2016	Kampun g Kasipilla y, Kuala Lumpur	Empirical Unit Hydrograph Model	Rainfall and water level prediction	Article
Perere ED	2015	Kelantan River Basin	FL	Prediction downstream discharge	Article

*ANN-Artificial Neural Network
*RBFNN-Radial Basis Function Neural Network
*LSTM-Long Short-Term Memory Network
*SVM-Support Vector Machine
*ANFIS-Adaptive Neuro-Fuzzy Inference System
*AVHRR-Atmospheric Administration Advanced Very High-Resolution Radiometer
*PDM- Probabilistic Distribution Moisture Model
*FL-Fuzzy Logic

Table 7 below displays a case study of flood analysis using flood forecasting model in Indonesia based on SCOPUS database. ARIMA models were the most used in Indonesia for urban flood forecasting. The largest studied region in Indonesia was modelled statistically using the autoregressive integrated moving average (ARIMA) technique. Due to its accuracy in predicting variables including monthly rainfall, streamflow, and water level, this sort of flood forecasting models is increasingly being employed within the framework of flood risk assessments. Model identification, parameter estimates, diagnostic verification, and prediction are the four steps that make up ARIMA modelling. It may be used to make short-term forecasts and has the capacity to recognise complicated patterns in brief datasets. ARIMA's effectiveness at forecasting interval series, whether linear or non-linear, is pleasing. For forecasting multi-valued time series, it is also a viable choice.

Table 8. *Case Study of Flood Analysis using Flood Forecasting Model in Indonesia (SCOPUS Database)*

Author	Year	Case Study	Model	Analysis Context	Types
Rohmat F. I	2022	Majalaya, Bandung	HEC-HMS, HEC-RAS.	Flood mapping in urban area	Article
Wang M	2022	Kalimantan	ANN	Flood simulation in urban area	Article
Ruhiat Y	2022	Banten Province	ARIMA, ANN	Rainfall prediction	Article
Hidayah E et al	2022	Welang River, East Java	HEC-RAS	Flood hazard mapping in watershed	Article
	2021	Jakarta City	ARIMA	Flood mapping in urban area	Conference
Gunawan G	2021	Air Bengkulu Watershed	SUH, HEC-HMS	Flood mapping in watershed	Conference
Supatmi, S	2021	Bandung West Java Province	ARIMA, HN-FIS	Flood prediction based on long-term time series	Article
Mawardi N	2021	Bekasi watershed	ARIMA	Flood mapping in watershed	Conference
Yusya RR	2020	Jakarta City	HEC-HMS	Flood Risk Mapping	Conference
Suparta W	2020	South Tangerang	ANFIS	Rainfall prediction	Article
Supatmi, S	2019	Bandung, West Java Province	HN-FIS, ARIMA	Forecasting Flood Event Vulnerability (Data time series prediction)	Article
Sumitra ID	2019	Indonesia Region	MSARIMA	Time series modelling and prediction	Conference

Tunas I. G	2018	Telen Watershed, East Kalimantan Province	SUH, ARIMA	Predict potency of flood peak based on rainfall inputs in the watershed system	Conference
Vadiya R et al	2016	Aceh Besar Regency	SUH	Flash flood hazard mapping in mountainous small watershed	Article
Nastiti KD	2015	Citarum Watershed, West Java	RRI, ARIMA	Flood mapping in watershed	Article
Roberts S	2014	Jakarta	ANUGA	Rainfall simulations	Conference
Purwandari , T et al	2011	Surakarta City	ARIMA	Flood hazard mapping (water depth, flow velocity analysis)	Article
Anwar S	2010	Cimanuk River, West Java	TH, ARIMA	Flood mapping in watershed	Article
Yulianto	2006	Ciliwung River	ANN	Real-time precipitation and stream flow	Article
Marfai M A	2003	Semarang City, Central Java	GIS-Hydrological Model	Assessing flood hazard (river and tidal flood)	Article

*ANN-Artificial Neural Network
*LSTM-Long Short-Term Memory Network
*TH- Transfer Hydrograph
*HN-FIS- Hybrid Neurofuzzy Inference System
*RRI- Rainfall-Runoff-inundation
*SUH- Synthetic Unit Hydrograph
* MSARIMA-Multiplicative Seasonal ARIMA
* ANFIS- Adaptive Neuro Fuzzy Inference System

Many practical flood forecasting models have been developed and implemented in Asian nations, but computationally efficient models that can appropriately include watershed features and their fluctuations and promptly update predictions are still needed. Pagano et al. (2014) list four key challenges in operational forecasting: best use of available data, modelling for accurate prediction, translating forecasts to effective warnings-disseminating timely information to affected community and concerned authority for right decision, and administering the operational forecast-conservative approach of forecasting institutions due to perceived liability, capacity building of personals and As global flood models are improving, hydrologic forecasting in ungauged basins remains difficult (Bates et al. 2015). Forecast uncertainty should be included in warnings. To take advantage of remote-sensing developments, hydrologic modelling methods for flood forecasting must be upgraded. Satellite-based River flow monitors may solve difficulties when such data are unavailable. Since flood forecasters need to know the lag time between data observation and availability, ground-based, real-time hydrologic observation is still lacking. Administrative data barriers across geopolitical borders and within the same boundary but among agencies can hinder flood forecasts. Lead time and forecast accuracy suffer. Urban flood forecasting is non-technical yet technical to design. Logistics and administration include planning, gathering supplies, evacuation plans, transit facilities, warnings, communication systems, electrical systems, shelter, food, clothes, medical supplies, personnel, counselling, and more. Several nontechnical factors strongly affect urban flood forecasts. Technical and non-technical elements must be blended. If non-technical difficulties are addressed, urban flood forecasting may function effectively.

5. CONCLUSION

This article presents a systematic evaluation of the literature on the use of urban flood forecasting models in Malaysia and Indonesia. The first segment provides an overview of real-time flood forecasting models, followed by case examples demonstrating the efficacy of data-driven artificial intelligence (AI)-based algorithms in flood prediction. The article concludes with a discussion of the challenges that currently exist in the use of AI models, as well as some prospective future routes for AI research in flood prediction. In several industries, machine learning has supplanted previous models and grown in popularity during the last few years. It is apparent that ML is receiving considerable interest from hydrologists for flood forecasting. Utilized properly, they may be a potent instrument for producing flood warnings and mitigating the resulting damages. His evaluation focuses on academic databases with established search strategies. Comparable research and a study of the scope were used to construct the data gathering criteria. Regardless of the quality of the examined research, this analysis encompassed those that used standardised reporting standards and were peer-reviewed and published online. In both Malaysia and Indonesia, the use of machine learning models in urban flood forecasting continues to be predominantly utilised for decision making, analysis, mapping, and prediction. A flood forecasting system's main objective is to minimise the loss of life, property, and business by giving accurate warnings with adequate lead time to users and emergency management. The lead time is governed by the effectiveness and accuracy of the hydrologic model and prediction. Several prior research have noted that a benefit of data-driven artificial intelligence (AI) models over traditional flood prediction approaches is that they do not need expert knowledge and can extract vital information from the input data alone.

6. REFERENCE

Abdul Majid, M. et al. (2021) "River-flood forecasting methods: the context of the Kelantan River in Malaysia," IOP conference series. Earth and environmental science, 880(1), p. 012021. doi: 10.1088/1755-1315/880/1/012021.

Afriyanie, D., Julian, M. M. and Nugraha, H. A. (2022) "Urban flood resilience through Spatial Plan in Bandung city, Indonesia," IOP conference series. Earth and environmental science, 986(1), p. 012052. doi: 10.1088/1755-1315/986/1/012052.

Anwar, S. (2010) "Flood Forecasting using a Transfer Hydrograph Approach," Majalah IPTEK Institut Teknologi Sepuluh Nopember 1945 Surabaya, 21(1). doi: 10.12962/j20882033.v21i1.27.

Azmeri, Hadihardaja, I. K. and Vadiya, R. (2016) "Identification of flash flood hazard zones in mountainous small watershed of Aceh Besar Regency, Aceh Province, Indonesia," Egyptian journal of remote sensing and space sciences, 19(1), pp. 143–160. doi: 10.1016/j.ejrs.2015.11.001.

Chitwatkulsiri, D. et al. (2022) "Development and application of a real-time flood forecasting system (RTFlood system) in a tropical urban area: A case study of Ramkhamhaeng polder, Bangkok, Thailand," Water, 14(10), p. 1641. doi: 10.3390/w14101641.

Craninx, M. et al. (2021) "Flood4castRTF: A real-time urban flood forecasting model," Sustainability, 13(10), p. 5651. doi: 10.3390/su13105651.

Malek, N. S. A., Zayid, S., Ahmad, Z., Ya'Acob, S., & Bakar, N. A. A. (2020). Data understanding for flash flood prediction in urban areas. Journal of Environmental Treatment Techniques, 8(2), 770-778.

Elsafi, S. H. (2014) "Artificial Neural Networks (ANNs) for flood forecasting at Dongola Station in the River Nile, Sudan," Alexandria Engineering Journal, 53(3), pp. 655–662. doi: 10.1016/j.aej.2014.06.010.

Falah, F. et al. (2019) "Artificial neural networks for flood susceptibility mapping in data-scarce urban areas," in Spatial Modeling in GIS and R for Earth and Environmental Sciences. Elsevier, pp. 323–336.

Faruq, A. et al. (2020) "Deep learning-based forecast and warning of floods in Klang River, Malaysia," Ingénierie des systèmes d information, 25(3), pp. 365–370. doi: 10.18280/isi.250311.

Flood Risk Mapping Using HEC-RAS and GIS Technique: Case of the Xe Bangfai Floodplain (no date). Khammoune Province, Lao PDR.

Forecasting, R.-T. U. F. (no date) Real-Time Urban Flood Forecasting: Application of Hybrid Modelling Using Both Physically based and Data-Driven models.

Goudarzi, S. et al. (2022) "Real-time and intelligent flood forecasting using UAV-assisted wireless sensor network," Computers, materials & continua, 70(1), pp. 715–738. doi: 10.32604/cmc.2022.019550.

Hapuarachchi, H. A. P., Wang, Q. J. and Pagano, T. C. (2011) "A review of advances in flash flood forecasting," Hydrological processes, 25(18), pp. 2771–2784. doi: 10.1002/hyp.8040.

Hidayah, E. et al. (2022) "Flood hazard mapping of the Welang river, Pasuruan, East Java, Indonesia," Journal of applied water engineering and research, pp. 1–12. doi: 10.1080/23249676.2022.2114025.

Jain, Sharad Kumar et al. (2018) "A Brief review of flood forecasting techniques and their applications," International journal of river basin management, 16(3), pp. 329–344. doi: 10.1080/15715124.2017.1411920.

Le et al. (2019) "Application of Long Short-Term Memory (LSTM) neural network for flood forecasting," Water, 11(7), p. 1387. doi: 10.3390/w11071387.

Li, C. et al. (2022) "Review on urban flood risk assessment," Sustainability, 15(1), p. 765. doi: 10.3390/su15010765.

Mark, O. and Gourbesville, P. (eds.) (no date) Real-time urban flood forecasting and modelling - a state of the art Justine Henonin.

Ming, X. et al. (2020) "Real-time flood forecasting based on a high-performance 2-D hydrodynamic model and numerical weather predictions," Water resources research, 56(7). doi: 10.1029/2019wr025583.

Mohd Sidek, L. et al. (2020) "Flood hydrograph generation for kenyir dam using hydrological modeling system," in Water Resources Development and Management. Singapore: Springer Singapore, pp. 64–75.

Munawar, H. S., Hammad, A. W. A. and Waller, S. T. (2022) "Remote sensing methods for flood prediction: A review," Sensors (Basel, Switzerland), 22(3). doi: 10.3390/s22030960.

Nastiti, K. D. et al. (2015) "The application of rainfall-runoff-inundation (RRI) model for inundation case in upper citarum watershed, west java-Indonesia," Procedia engineering, 125, pp. 166–172. doi: 10.1016/j.proeng.2015.11.024.

Nevo, S. et al. (2022) "Flood forecasting with machine learning models in an operational framework," Hydrology and earth system sciences, 26(15), pp. 4013–4032. doi: 10.5194/hess-26-4013-2022.

Osman, S. et al. (2018) "Application of stochastic flood forecasting model using regression method for Kelantan catchment," MATEC web of conferences, 203, p. 07001. doi: 10.1051/matecconf/201820307001.

Parsian, S. et al. (2021) "Flood hazard mapping using fuzzy logic, Analytical Hierarchy Process, and multi-source geospatial datasets," Remote sensing, 13(23), p. 4761. doi: 10.3390/rs13234761.

Perera, E. D. P. and Lahat, L. (2015) "Fuzzy logic-based flood forecasting model for the Kelantan River basin, Malaysia," Journal of hydroenvironment research, 9(4), pp. 542–553. doi: 10.1016/j.jher.2014.12.001.

René, J.-R. et al. (2014) "Assessing the potential for real-time urban flood forecasting based on a worldwide survey on data availability," Urban water journal, 11(7), pp. 573–583. doi: 10.1080/1573062x.2013.795237.

Rohmat, F. I. W. et al. (2022) "Flood modeling and baseline study in urban and high population environment: A case study of Majalaya, Indonesia," Urban climate, 46(101332), p. 101332. doi: 10.1016/j.uclim.2022.101332.

Ruhiat, Y. (2022) "Forecasting rainfall and potential for repeated events to predict flood areas in Banten province, Indonesia," Journal of measurements in engineering, 10(2), pp. 68–80. doi: 10.21595/jme.2022.22363.

Samantaray, S., Sahoo, A. and Agnihotri, A. (2023) "Prediction of flood discharge using hybrid PSO-SVM algorithm in Barak River basin," MethodsX, 10, p. 102060. doi: 10.1016/j.mex.2023.102060.

Shada, B., Chithra, N. R. and Thampi, S. G. (2022) "Hourly flood forecasting using hybrid wavelet-SVM," Journal of soft computing in civil engineering, 6(2), pp. 1–20. doi: 10.22115/scce.2022.317761.1383.