Journal of Information Systems Engineering and Management
2025, 10(28s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Hybrid Computational Model of Reflectivity Values and Rain Cell Size for Improved Flood Disaster Prediction: Raw Data Reading Process Implementation

Md Tanvir Hasan[1], Atikah Balqis Basri[2*], Khairayu Badron[3], Dini Oktarina Dwi Handayani[4], Zainab S. Attarbashi[5]

[1] *Department of Information Systems Kulliyyah of ICT, International Islamic University Malaysia, Kuala Lumpur, Malaysia. tanvirhaxan001@gmail.com*

[2] *Assistant Professor, Department of Information Systems Kulliyyah of ICT, International Islamic University Malaysia, Kuala Lumpur, Malaysia. atikahbalqis@iium.edu.my*

[3] *Associate Professor, Electrical and Computer Engineering Department, Kulliyyah of Engineering, International Islamic University Malaysia, Kuala Lumpur, Malaysia. khairayu@iium.edu.my*

[4] *Assistant Professor, Department of Computer Sciences, Kulliyyah of ICT, International Islamic University Malaysia, Kuala Lumpur, Malaysia. dinihandayani@iium.edu.my*

[5] *Assistant Professor, Department of Computer Sciences, Kulliyyah of ICT, International Islamic University Malaysia, Kuala Lumpur, Malaysia. zainab_senan@iium.edu.my*

ARTICLE INFO

Received: 18 Dec 2024

Revised: 10 Feb 2025

Accepted: 28 Feb 2025

ABSTRACT

Climate change effects in Malaysia have been evident over the past few years, with the nation experiencing devastating floods in regions such as Pahang, Johor, Kelantan, and Terengganu. These deadly floods, occurring during the monsoon season, are a direct consequence of global climate change. This research project aims to develop a capability for flood disaster prediction in Malaysia, which has been facing extreme weather. The specific focus of this study is on a preliminary method to read radar data, a crucial component for accurate flood forecasting. The research involves designing a hybrid model that incorporates both radar reflectivity and rain cell size, in conjunction with current flood forecasting models, to improve flood prediction accuracy. The model will utilize radar data and rain gauge data from 2018-2023 to derive parameters essential for simulation purposes. This preliminary method of reading and integrating radar data is expected to enhance the flood prediction model's reliability. The raw data reading shows the size of the cloud and the reading of the reflectivity value.

Keywords: Forecasting Model, Hybrid Model, Radar Reflectivity, Rain Cell Size, Rain Gauge

INTRODUCTION

Climate change has caused numerous problems in Malaysia that seem to come in rapid succession. The similarity which is the manifestation of himself in the most terrible and uninterrupted flooding ranked as the most common happening. These floods are not only destroying the properties but lives of people and properties therein. Among the states that experienced such hardship are the states of Selangor, Pahang, Johor, Kelantan, and Terengganu during the monsoon season [1] ,[2]. The misfortunes of flood control problems are unmistakable given the terrible scenario of the past and vivid images of mass evacuation, loss of lives, and widespread property destruction [3]. These challenges, however, have not derailed the efforts of the existing forecasting systems to improve their system performance and consider measures that will allow them to accurately foretell imminent floods and issue early warnings. Hence, considering the leading ground for the issue of enhanced flood disaster prediction, this research paper goes towards creating a new method: a combination of computational techniques. The model relies on rain cells reflectivity and size for the prediction of rain and floods while residents are informed earlier hence reducing errors during forecasting [4], [5]. The priority of this program is to develop partnerships with the main stakeholders including the Malaysian Meteorological Department and JPS Malaysia and through such cooperation data sets and the required expertise and information can be exchanged thus there will be a smooth execution of the research objectives. Also, the sort of technical skills, that will eventually make a whole different perception of the nature of floods, will be the predictive nature the model will possess [6]. The impact of this project not just the confines of the classroom but the influence on wider society, will be broader. The purpose of this research is to produce an information-rich program using data and computational methods that may provide early warning signs. This recognition and support are often provided to encourage sustainability in disaster management [7]. What is more, the research meets Sustainable Development Goal 13, and it will facilitate the transition of society to the digital world and data management in Malaysia. Consequently, the main objective of such measures is easier to identify.

The current project phase is data collection and pre-processing according to the methodology. Through this comprehensive approach, we aim to lay the groundwork for a robust and effective framework for flood disaster prediction in Malaysia, with far-reaching implications for disaster resilience and sustainability.

Monsoon Session

The monsoon season in Malaysia, particularly the Northeast Monsoon, plays a significant role in causing floods in the country [8],[9],[10],[11]. The Northeast Monsoon typically occurs from early November to March, bringing heavy rainfall to the east coast states of Peninsular Malaysia and western Sarawak, leading to monsoon floods [12]. Floods in Malaysia are also influenced by the southwest monsoon, resulting in abundant rainfall and subsequent flooding, especially in the east coast and southern parts of the Peninsula. The onset of the monsoon season, determined by factors like wind speed and direction, can impact the severity and timing of floods in the region. Understanding the patterns of rainfall intensity, duration, and distribution during the monsoon season is crucial for predicting and mitigating flood risks in Malaysia.

Flood Prediction using Radar

Flood prediction using radar data is a crucial aspect of mitigating the impact of flooding in coastal and inland areas. Radar rainfall measurements provide high-resolution data for flood modeling, offering better representation of rainfall patterns [13]. Additionally, Lidar data aids in delineating flood inundation areas with high accuracy, essential for flood analysis and risk reduction [14]. Radar-based quantitative precipitation estimation (QPE) plays a key role in feeding hydrological models for reliable flash flood predictions, especially during warm-rain events, highlighting the importance of radar data in flood forecasting [15]. Furthermore, deep-learning models, incorporating radar rainfall observations and other data sources, enable fast and detailed flood extent predictions, enhancing flood warning systems and response strategies [16]. Integrating radar data into flood prediction models improves accuracy, aids in land-use management, and informs flood mitigation measures.

Machine Learning for Flood Prediction

Machine learning models, particularly those utilizing radar data, play a crucial role in flood prediction. Various studies have highlighted the significance of machine learning in flood susceptibility modeling [17], short-term flood prediction [18], radar-based rainfall estimation [19], hybridizing ML models for flood prediction [20], and deep-learning flood forecasting tools combining radar rainfall observations with other data sources [21]. These models leverage radar data to enhance flood prediction accuracy, improve computational efficiency, and provide early warnings for flash floods. By incorporating radar data into machine learning algorithms, researchers can develop fast and accurate flood prediction models, enabling better preparedness and mitigation strategies in flood-prone regions.

METHODOLOGY

Dataset

We have radar scan data from 2018 to 2023 of the floods affected area of Kelantan during the months of January, February, November, and December also in Malaysia known as monsoon season [22]. The six years dataset is compiled with numerous daily scans with the timestamp. With the daily scan containing more than a few thousand files, all of them are in the. raw format. The raw data format is unsuitable for reading or analysis. To read the data according to the needs of the project requirements, it is changed to. vol data format. After this process, the data can be read and prepared for the model.

Figure 1 represents the timeline and flood-affected areas. In the current phase, we have access to the data of the Kota Baru, Kelantan area over the last six years. Including, the recent flood that occurred in the Kelantan area on 27th December 2023. To read the data we have used, google colab and Jupiter notebook as IDE and python as a base language. Xradar, cartopy, cmweather, mathplotlib are some of the packages that have been used for this. The flow process shown in Figure 2 shows the process of reading the data involves several steps starting with obtaining radar data from MET Malaysia, installing all libraries, loading data to read the data, extracting and preprocessing relevant radar data, visualizing data by creating the visual plots, analyzing and interpret the visualized data

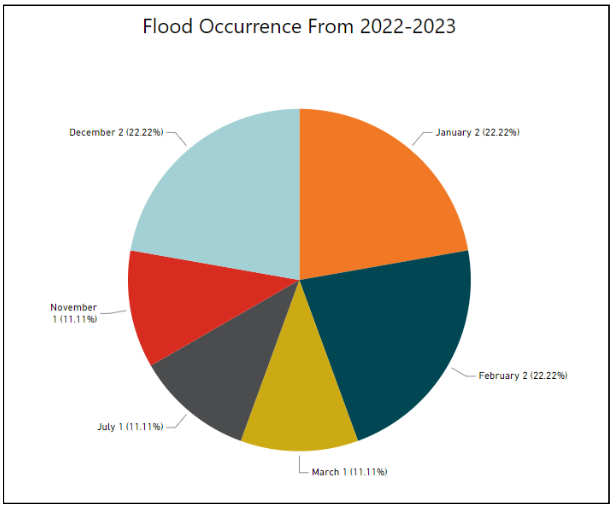

Figure 1: Pie chart of flood occurrences from years 2022-2023

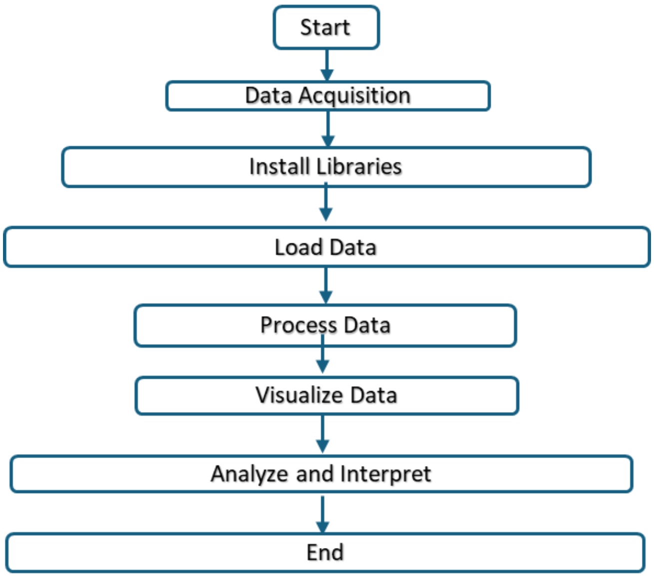

Figure 2: Flowchart of reading the Radar Data

RESULT FINDINGS

For understanding the reading of the data, the amount of reflectivity from the hydrometeors to radar, or even the H [dBZ], the echo amplitude is the very foundation [23]. H [dBZ] is the term used for the precipitation intensity factor, this factor determines how vigorous the falling of rain is with high dBZ values signifying intense rainfall [24], [25]. Through tracking it in the atmospheric changes, we can assess whether the rainfall is becoming heavy or light. The dangerous peaks in dBZ values, denoting the most intense rainfall, could be indicated in severe weather, such as thunderstorms, hail, and strong downpours. On the other hand, low dBZ values may indicate light showers of even dry periods, these facts of different weather situations, and their effects on the island's water system and environment can be known [26].

For the same area of Kota Bharu, multiple scans have been shown in Figures 2, 3, & 4 representing different time frames.

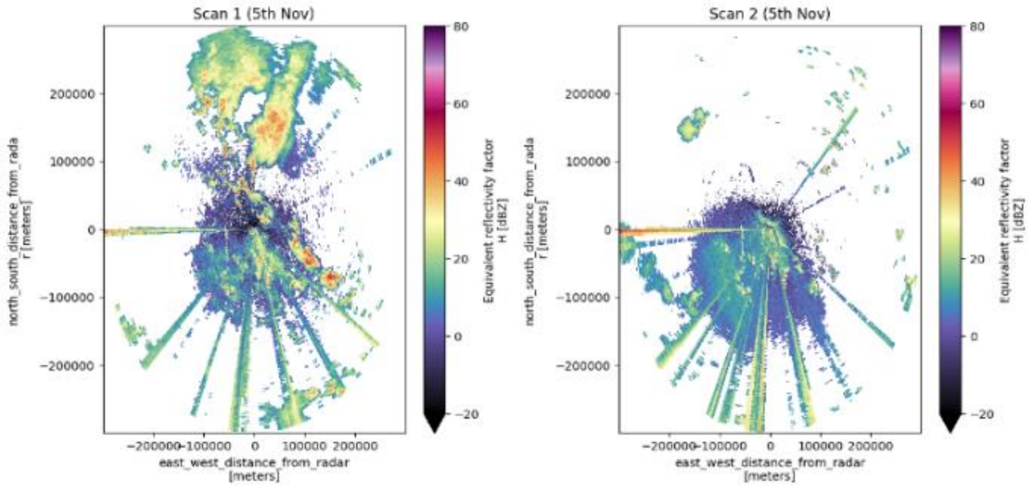

Figure 3: Scan of 5th Nov 2023

The higher reflectivity factor is represented by a deeper color on the graph. Figure 3 shows two scans of 5th Nov, here the reflectivity factor is light in color showing less chance of rainfall. Figure 4 shows the scans of the 20th and Figure 5 shows the scan of the 27th December 2023. Both have higher density of pigments rainfall, greater chances of rainfall, and which eventually leads to flooding. The Kelantan region suffered from floods during the same period (Figure 1).

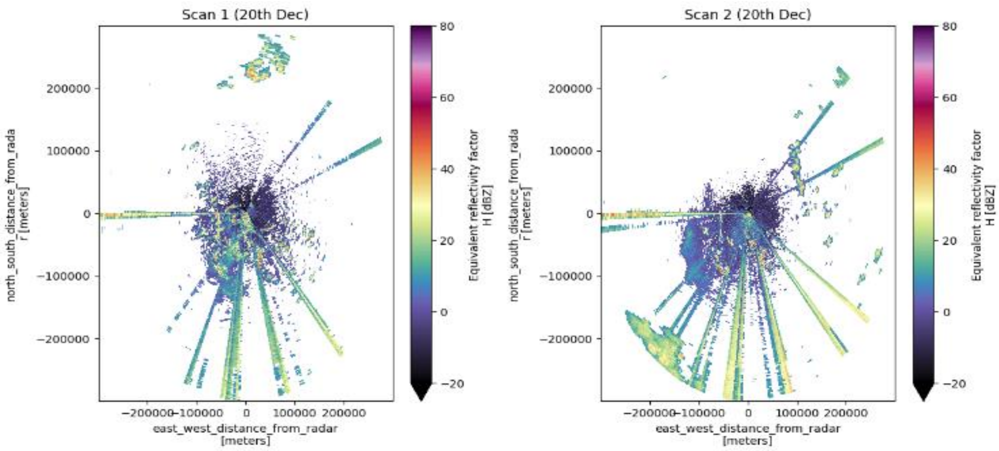

Figure 4: Scan of 20th Dec 2023

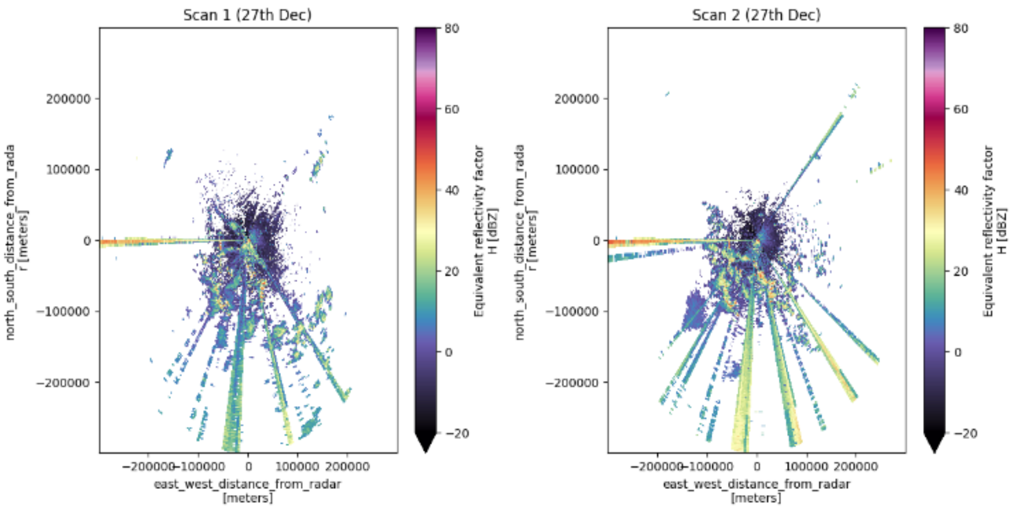

Figure 5: Scan of 27th Dec 2023

Radar systems emit pulses of electromagnetic energy, typically in the microwave frequency range, the scanning process is referred to as radar sweeps. In other words, radar scans are made of multiple radar sweeps [27]. For analysis purposes, it is possible to break down the scan data into multiple sweeps as represented in Figure 6.

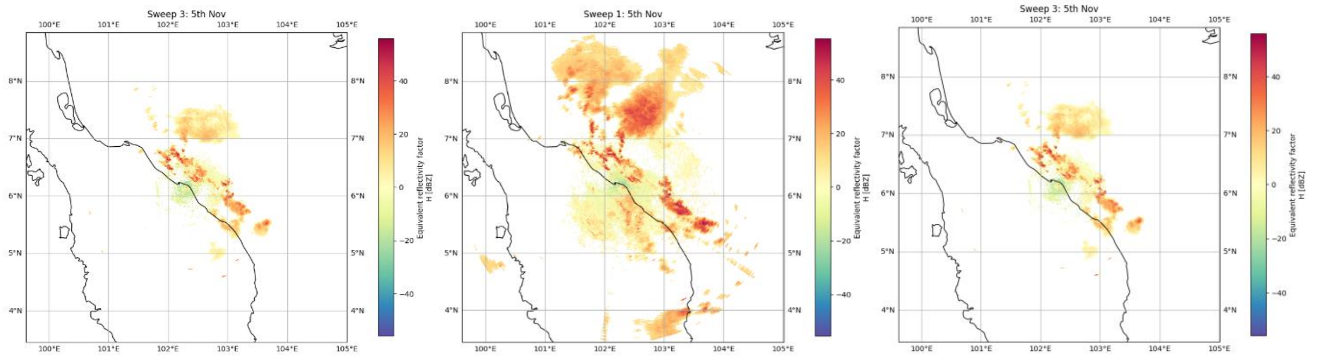

Figure 6: Multiple Sweeps of a scan 1 (5th Nov)

The next course of action includes applying machine learning techniques to that data which has been preprocessed to develop a good working computational model that can predict flood. Which will use the data on reflectivity and rain cell sizes to get a more precise estimate of precipitation. This way, the system can provide forecasts and early warnings about possible flooding with accuracy. For the early analysis, the data was mapped with the rain gauge data provided by the Department of Irrigation and Drainage, Ministry of Energy Transition and Water Transformation. Two locations of rain gauges were analyzed and mapped with the radar data Rumah Kerajaan JPS. at Meranti Kelantan (6021013) And Chabang Ampat at Kelantan (6121015). This is to confirm the occurrence of the rain. And flood. If it is based on the rain gauge only, the possibility of error is higher as during the flood the rain gauge might be swept away, and data are not correctly recorded. As shown in Figure 7 below, the occurrence of rain for the year 2023.

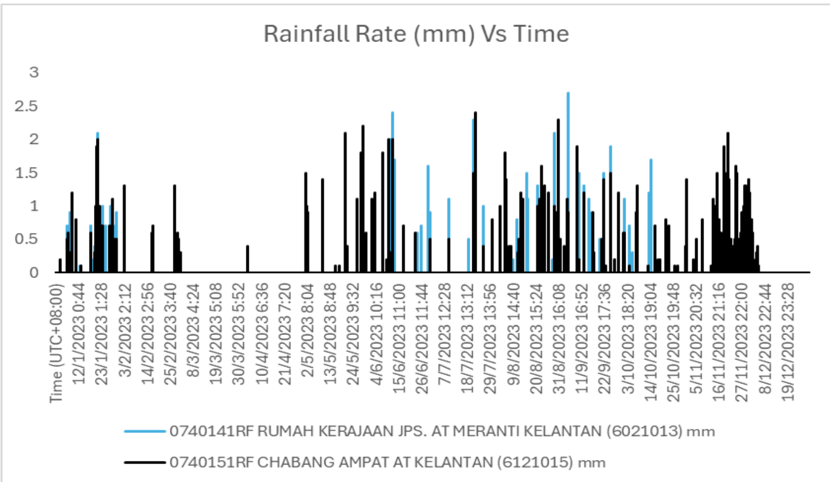

Figure 7: Rain Gauge Data 2023

The average rainfall patterns during the monsoon season in Malaysia exhibit distinct characteristics. Research in Peninsular Malaysia highlights the impact of the northeast and southwest monsoons on monthly rainfall patterns, with an average annual precipitation of 2562.35 mm [28]. Figure 8 shows the rain gauge data of rainfall for the months from 2018 to 2023. This is from the analyses of the rainfall rate from data Rumah Kerajaan JPS. at Meranti Kelantan (6021013) the trends for the rainfall rate for 6 years from 2018 until 2023. Based on the calculation, it can be said that the monsoon session, the wettest period, with peak rainfall in November and December and show that monsoon season typically occurs from early November to March, bringing heavy rainfall to the east coast states of Peninsular Malaysia as the station showing significant increases in rainfall amounts. These findings collectively demonstrate the variability and significance of monsoon seasons in shaping Malaysia's rainfall patterns. This is why this research focuses more on the months of November, December, January, and February, data from radar data to have the model of reflectivity values and rain cell size for improved flood disaster prediction

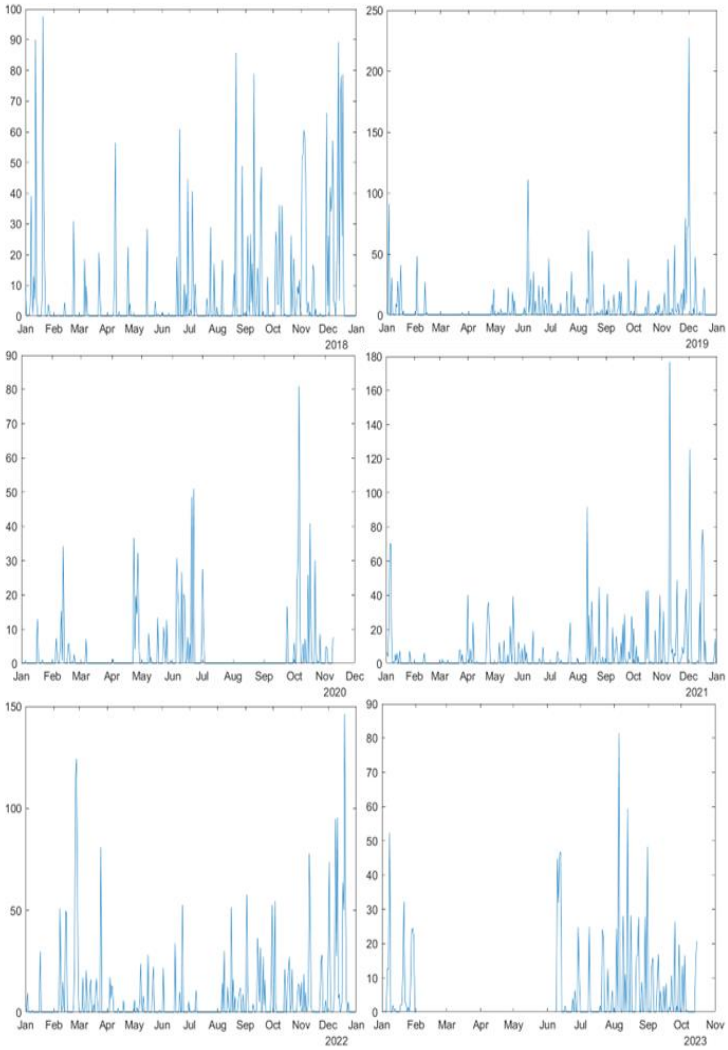

Figure 8: Rain Gauge Data of Rainfall based on month from 2018 until 2023

CONCLUSION

Attaining the radar data and rain gauge data from various floods from 2018 to 2023 is the very first step taken, to compress the datasets to use for the analysis afterward. Now we have data reading and preprocessing which include the construction of a hybrid computational model of prediction of flooding for Malaysia based on the present phase of our research project. In an aim to bring together various key stakeholders, the Meteorological Department of Malaysia (MMD) and JPS Malaysia are the partners that have availed us of the crucial data sources and expertise critical for the successful running of our research activities. Furthermore, the methods of advanced preprocessing have had their effect on cleaning, organizing, and structuring the data for further quantum analysis.

In conclusion, the ongoing data reading and preprocessing phase marks the initial steps towards achieving our research objectives of improving flood disaster prediction in Malaysia. With a clear roadmap for future planning, including the development, validation, and implementation of the computational model, we are poised to make significant strides towards enhancing disaster resilience and sustainability in the region. Through collaboration, innovation, and dedication, we remain committed to advancing the frontiers of flood prediction research and contributing to the broader efforts towards building resilient communities and safeguarding lives and livelihoods against the impacts of climate change.

Acknowledgment

Heartfelt appreciation to the Malaysian Meteorological Department (MetMalaysia) for their collaboration and support, the Department of Irrigation and Drainage, Ministry of Energy Transition and Water Transformation as well as to the Funding Research Grant (FRGS) FRGS/1/2023/TK08/UIAM/03/2 for their financial assistance, without which this research would not have been possible.

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