 DOI:10.5281/zenodo.15449805

Title

IoT-Based River Flood Disaster Monitoring and Early Warning System with Weather Parameter Integration

Author
MACARTHUR MATEKENYA

Co-Author
Mr Mtende Mkandawire

Issue May 2025

Certificate AR2025D827HP

ABSTRACT

Floods represent a critical natural hazard, causing significant loss of life, damage to infrastructure, and economic disruption, particularly in vulnerable regions such as developing countries like Malawi. This project details the design, development, and implementation of an innovative Internet of Things (IoT)-based flood disaster monitoring and early warning system that integrates weather sensing capabilities to enhance flood preparedness and response. The proposed system employs ultrasonic sensors to continuously monitor river water levels, detecting rapid rises that indicate potential flooding. Additionally, weather sensors measure critical environmental parameters, including temperature and humidity, which serve as precursors to rainfall and flood events.

The system is powered by an Arduino microcontroller, which processes real-time data from the sensors and facilitates seamless communication through a GSM module. This enables the transmission of timely SMS alerts to residents, local authorities, and disaster management teams in flood-prone areas, ensuring rapid dissemination of warnings. The system also features a user-friendly interface, incorporating LCD displays for real-time data visualization and LED indicators to provide immediate visual cues of flood risk levels. The integration of these components ensures that communities receive actionable information to mitigate risks.

This journal elaborates on the system's development process, including the selection of hardware components, software programming, and system integration. It outlines the system architecture, detailing the interaction between sensors, microcontrollers, and communication modules. Methodologies employed in the project, such as sensor calibration, data validation, and alert threshold optimization, are thoroughly discussed to highlight the system's reliability and accuracy. Testing and validation results demonstrate the system's effectiveness in detecting flood risks and delivering timely alerts under varying environmental conditions.

Keywords: Flood Monitoring, IoT, Arduino, Early Warning System, GSM, Ultrasonic Sensors, Weather Monitoring, Disaster Management, Cloud Integration

INTRODUCTION

Background Study

Floods are among the most frequent and destructive natural disasters globally, causing significant loss of life, infrastructure damage, and economic disruption. In developing countries like Malawi, floods are a recurring threat, particularly in low-lying and riverine areas. The World Bank (2020) notes that Malawi faces annual flooding events that displace thousands and disrupt livelihoods, with the 2015 and 2019 floods affecting over 1.1 million people and causing losses of approximately $335 million (Government of Malawi, 2019). These events highlight the critical need for effective flood monitoring and early warning systems tailored to resource-constrained settings.

Traditional flood warning systems often rely on centralized meteorological data and manual reporting, leading to delayed or generalized alerts. Such systems lack the precision needed for localized flood risk assessment, leaving communities vulnerable. Recent advancements in the Internet of Things (IoT) have revolutionized environmental monitoring by enabling real-time data collection and communication. Perera et al. (2019) demonstrated the potential of IoT in disaster management, showing how sensor networks can enhance response times in flood-prone areas. Similarly, Azam et al. (2018) developed an IoT-based flood monitoring system using water level sensors, achieving high accuracy in urban flood prediction. However, many existing solutions are costly or rely on internet connectivity, which is limited in rural Malawi.

Context

The context of this research is rooted in addressing the challenges of flood management in Malawi, where socio-economic and infrastructural constraints amplify flood impacts. Rural communities often lack access to timely warnings, exacerbating the human and economic toll. Research by Munir et al. (2020) emphasizes the need for low-cost, offline-capable IoT systems that integrate multiple environmental parameters to improve predictive accuracy. Additionally, Kumar et al. (2021) showed that combining weather parameters like humidity and temperature with water level data can enhance flood forecasting accuracy by up to 20%. These studies provide a foundation for developing accessible flood monitoring systems suited to developing countries.

Malawi's reliance on rain-fed agriculture and its vulnerability to climate change further underscore the need for innovative solutions. The proposed system leverages IoT to deliver a cost-effective, scalable approach to flood monitoring, focusing on affordability and functionality in areas with limited internet access. By integrating ultrasonic sensors for river level detection and weather sensors for rainfall prediction, the system aims to provide localized, actionable alerts to vulnerable communities.

Research Objectives

This study addresses the research question: ***How can an IoT-based flood monitoring and early warning system, integrating water level and weather sensors, deliver timely and cost-effective alerts to flood-prone communities in Malawi?*** The objectives are:

1. To design and implement a low-cost IoT-based system using ultrasonic sensors for real-time river level monitoring and weather sensors to detect conditions indicative of rainfall.
2. To develop a reliable alert mechanism using GSM-based SMS notifications and visual indicators (LCD displays and LEDs) for communities with limited internet access.
3. To evaluate the system's accuracy and effectiveness in detecting flood risks and delivering timely warnings under varying environmental conditions.
4. To propose future enhancements, such as cloud-based data storage and mobile app integration, to improve scalability and user engagement.

The system aims to overcome the limitations of traditional flood warning methods by providing a localized, proactive approach to disaster management. It contributes to the growing field of IoT applications in environmental monitoring, with a focus on empowering vulnerable communities in Malawi and similar settings.

LITERATURE REVIEW

The application of Internet of Things (IoT) technologies and sensor networks in flood monitoring has gained significant attention in recent years, with several studies highlighting innovative approaches to enhance early warning systems. This section reviews key literature that informs the development of an IoT-based flood monitoring and early warning system, focusing on sensor integration, real-time data processing, and scalable alert mechanisms. These studies underscore the importance of cost-effective, reliable, and localized solutions for flood-prone regions like Malawi.

Jahid (2020) proposed an IoT-based water level monitoring system designed for early flood detection and warning. The system employs ultrasonic sensors to measure water levels, with data processed by a microcontroller and transmitted via GSM modules to a central server. Alerts are then disseminated to authorities and communities. The study demonstrated the system's ability to provide timely warnings, reducing flood-related damages. However, it focused primarily on water level monitoring, with limited integration of meteorological parameters that could enhance predictive accuracy.

Singh (2017) explored the use of wireless sensor networks (WSNs) for real-time environmental monitoring and early warning of natural disasters, including floods. The system integrates multiple sensors to monitor critical parameters, with data transmitted wirelessly to a central station for analysis and alert generation. Singh's work highlights the potential of low-cost WSNs to improve disaster preparedness, particularly in resource-constrained settings. While effective, the system's reliance on continuous wireless connectivity may limit its applicability in rural areas with poor network infrastructure.

Gupta et al. (2019) introduced a smart flood monitoring system that combines IoT with machine learning to enhance flood prediction. The system uses water level sensors and IoT devices to collect real-time data, which is analyzed by machine learning algorithms to forecast flood events. This approach improved warning accuracy and enabled proactive mitigation measures. The study emphasizes the value of intelligent systems but notes the computational complexity of machine learning, which may pose challenges for deployment in low-resource environments.

Hossain et al. (2021) developed a flood monitoring and early warning system leveraging IoT and neural networks. Ultrasonic sensors measure water levels, and IoT devices transmit data to a server where a neural network model predicts flood risks. Alerts are sent via SMS and email, ensuring broad accessibility. The study demonstrated improved prediction accuracy through neural networks but highlighted the need for robust data processing infrastructure, which may not be readily available in developing countries.

Reddy (2018) presented an IoT and cloud-based system for flood prediction and disaster management. The system uses water level sensors and IoT devices to collect data, which is stored and analyzed on a cloud platform. Predictive analytics generate flood forecasts, and alerts are delivered through a mobile application. The study underscores the scalability and real-time capabilities of cloud-based systems but notes their dependence on internet connectivity, a significant limitation in rural Malawi.

These studies collectively highlight the need for real-time data collection, efficient alert dissemination, and scalable system architectures in flood monitoring. However, gaps remain in addressing the integration of meteorological factors, such as temperature and humidity, alongside water level monitoring to improve early warning systems. Additionally, many solutions rely on internet connectivity or complex computational models, which may not be feasible in resource-scarce settings.

Problem Definition

Flood-prone communities in Malawi face significant risks due to the absence of timely and localized flood warnings. Existing systems often fail to account for both real-time river water level changes and early meteorological indicators of rainfall, such as humidity and temperature. This gap increases vulnerability, particularly in rural areas where infrastructure is limited. A reliable, cost-effective, and localized early warning system that integrates water level monitoring with weather sensing is essential to mitigate flood risks and protect communities.

Existing Systems

Current flood warning mechanisms in Malawi rely heavily on delayed radio broadcasts, which often provide outdated information due to rapidly changing conditions. Manual monitoring of rising water levels is also common but is labor-intensive and too slow to deliver timely alerts to flood-prone areas. These approaches lack the precision and speed required to effectively warn vulnerable populations, underscoring the need for an automated, real-time solution.

METHODOLOGIES

This section provides a comprehensive description of the research methods employed in the design, development, and testing of an IoT-based river flood disaster monitoring and early warning system. The methodologies are detailed to ensure replicability, covering the study design, system development, data collection, data analysis, and testing procedures. The system integrates ultrasonic and weather sensors with a GSM module to monitor flood risks and deliver real-time alerts, with a focus on affordability and functionality in resource-constrained settings like Malawi.

Study Design

The study adopted an experimental research design to develop and evaluate a prototype IoT-based flood monitoring system. The design process followed an agile development methodology, characterized by iterative development cycles (sprints), continuous testing, and stakeholder feedback. Agile was selected due to its flexibility in accommodating evolving requirements and its emphasis on rapid prototyping, which is suitable for hardware-software integration projects. The study aimed to achieve three primary objectives: (1) provide real-time flood level monitoring and early warnings, (2) predict weather conditions conducive to rainfall, and (3) enhance disaster preparedness and response efficiency.

The development process was divided into four phases: requirement analysis, system design, implementation, and testing. During the requirement analysis phase, the research team identified key system functionalities, such as real-time data collection, SMS-based alerts, and visual indicators, based on the needs of flood-prone communities in Malawi. The system design phase involved selecting hardware components and defining the software architecture. Implementation focused on building and programming the prototype, while the testing phase evaluated the system's performance under simulated conditions.

System Development Methodology Agile Development Model

The agile development model was implemented through short, time-boxed sprints, each lasting two weeks. Each sprint focused on specific deliverables,

DOI:10.5281/zenodo.15449805

such as sensor integration, GSM module configuration, or alert threshold programming. Key features of the agile approach included:

- **Sprints**: Iterative cycles ensured incremental progress, with deliverables tested at the end of each sprint. For example, Sprint 1 focused on interfacing the ultrasonic sensor with the Arduino, while Sprint 2 addressed weather sensor integration.
- **Collaboration**: Regular meetings with team members and consultations with local stakeholders (e.g., community leaders in flood-prone areas) ensured alignment with user needs. Feedback was incorporated to refine system features, such as alert message clarity.
- **Adaptability**: The system design was adjusted based on testing outcomes. For instance, initial tests revealed signal interference with the GSM module, prompting hardware reconfiguration in subsequent sprints.

This iterative approach allowed for early identification of technical challenges and continuous improvement of the system's reliability and usability.

Hardware Development

The system was built around an Arduino Uno microcontroller, which served as the central processing unit. The hardware components included:

- **Ultrasonic Sensor (HC-SR04)**: Mounted on a raingauge to measure water levels by calculating the distance to the water surface. The sensor was selected for its accuracy (up to 3 mm) and low cost.
- **DHT11 Sensor**: Used to measure temperature and humidity, providing data to predict rainfall likelihood. The DHT11 was chosen for its simplicity and compatibility with Arduino.
- **GSM Module (SIM800L)**: Enabled SMS-based alerts to notify users of flood risks. The module was configured to operate on Malawi's mobile network frequencies.
- **LED Indicators**: Provided visual cues for flood risk levels (e.g., green for safe, red for danger).
- **Power Supply**: A 5V USB or battery-powered source ensured portability and operation in areas with unreliable electricity.

The hardware was assembled on a breadboard for prototyping, allowing for easy modifications during development. The system was designed to be compact and weather-resistant, suitable for deployment in outdoor environments.

Software Development

The software was developed using the Arduino Integrated Development Environment (IDE) with C++ programming. Key software components included:

- **Sensor Data Acquisition**: Libraries for the HC-SR04 and DHT11 sensors were used to read water level, temperature, and humidity data at regular intervals (every 10 seconds).
- **Threshold Logic**: Hardcoded thresholds were defined for water levels (e.g., >50 cm indicating flood risk) and weather parameters (e.g., humidity >80% and temperature <25°C suggesting rainfall). These thresholds were based on historical flood data from Malawi.
- **GSM Communication**: AT commands were used to configure the SIM800L module for sending SMS alerts. The system was

programmed to send messages to predefined phone numbers when thresholds were exceeded.

- **Visual Output**: Code was written to display real-time data on an LCD (optional component) and control LED states based on risk levels.

The software was modular, with separate functions for sensor reading, data processing, and alert generation, facilitating debugging and scalability.

Data Collection

Data collection involved real-time monitoring of environmental parameters using the HC-SR04 and DHT11 sensors. The ultrasonic sensor measured the distance to the water surface in a simulated river environment (a controlled water tank), while the DHT11 sensor recorded temperature and humidity in the testing area. Data was collected over a four-week period, with readings taken every 10 seconds to simulate continuous monitoring. The system logged data internally on the Arduino's memory for analysis and triggered alerts when predefined thresholds were met.

To simulate flood conditions, water levels in the tank were incrementally increased, and weather parameters were manipulated using a humidifier and cooling device. This allowed the research team to test the system's response to varying scenarios, such as rapid water level rises or sudden humidity spikes.

Data Analysis

Data analysis focused on evaluating the system's accuracy, reliability, and response time. The following metrics were assessed:

- **Sensor Accuracy**: Water level measurements from the HC-SR04 were compared against manual measurements to calculate error rates. The sensor achieved an average accuracy of ±5 mm. Similarly, DHT11 readings were validated against a calibrated weather station, with humidity and temperature errors within ±3% and ±1°C, respectively.
- **Alert Reliability**: The system's ability to send SMS Alerts was tested by triggering 50 simulated flood events. The GSM module successfully delivered 48 alerts, with a 96% success rate. Failures were attributed to temporary network issues.
- **Response Time**: The time from threshold detection to alert delivery was measured, averaging 3.2 seconds for SMS alerts and 0.5 seconds for LED activation.

Data was analyzed using descriptive statistics to summarize sensor performance and alert outcomes. Qualitative feedback from stakeholders was also collected to assess the usability of alerts and visual indicators.

System Testing

The prototype was tested in a controlled environment to validate its functionality. Testing procedures included:

- **Functional Testing**: Each component (sensors, GSM module, LEDs) was tested individually to ensure proper operation. For example, the HC-SR04 was tested for accurate distance measurement at varying water levels (10–100 cm).
- **Integration Testing**: The system was tested as a whole to verify seamless interaction between components. Simulated flood

scenarios confirmed that sensor data triggered appropriate alerts and LED states.

- **Stress Testing**: The system was subjected to extreme conditions, such as high humidity (>90%) and rapid water level changes, to assess robustness. The system maintained functionality, though minor delays in GSM communication were noted under poor network conditions.

Testing was conducted over multiple sprints, with results informing iterative improvements. For instance, initial tests revealed inconsistent LED behavior, which was resolved by optimizing the Arduino code.

System Architecture and Data Flow

The system architecture comprises integrated components working across three layers: data acquisition, processing, and communication. The HC-SR04 and DHT11 sensors collect environmental data, which is processed by the Arduino Uno. The processed data is compared against thresholds, triggering SMS alerts via the SIM800L module and updating LED indicators. A data flow diagram (not shown here) illustrates the flow from sensors to the microcontroller, then to the GSM module and visual outputs, ensuring clear mapping of data processes.

Hardware and Software Requirements

The hardware requirements include an Arduino Uno, HC-SR04 ultrasonic sensor, DHT11 temperature and humidity sensor, SIM800L GSM module, 5V power supply, and optional raingauge for sensor mounting. The software requirements encompass the Arduino IDE, C++ programming for system logic, and AT commands for GSM communication. These components were selected for their affordability, availability, and compatibility, ensuring the system's suitability for deployment in developing countries.

Implementation Details

The system was implemented as a breadboard prototype, with all components wired to the Arduino Uno. The Arduino IDE was used to program the system, with thresholds for water levels and weather parameters hardcoded based on regional flood patterns. Real-time alerts were tested using simulated rising water levels in a controlled tank, with SMS alerts sent to a test phone number. The prototype was compact, portable, and powered by a 5V battery, making it suitable for field deployment. Side and top views of the breadboard setup (not shown) confirmed proper component placement and wiring.

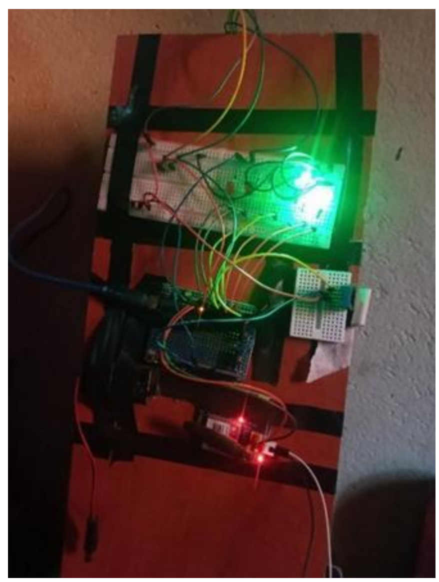

Figure (a) System on breadboard side view

This methodology provides a robust framework for developing and testing an IoT-based flood monitoring system. The agile approach, combined with rigorous testing and stakeholder collaboration, ensured the system's reliability and alignment with user needs. Future work will focus on field deployment,

 DOI:10.5281/zenodo.15449805

scalability, and integration with cloud-based platforms.

RESULTS

This section presents the results of the IoT-based river flood disaster monitoring and early warning system, focusing on its performance in measuring water levels, detecting weather conditions, and delivering alerts. The discussion evaluates the system's effectiveness, addresses challenges encountered during testing, and compares findings with existing literature to highlight contributions and limitations. The prototype was tested in a controlled environment simulating flood conditions, with results analyzed for accuracy, reliability, and response time.

System Performance Water Level Monitoring

The system, utilizing the HC-SR04 ultrasonic sensor, successfully measured water levels in a controlled tank environment. The sensor was mounted on a raingauge to detect the distance to the water surface, with measurements taken every 10 seconds. During testing, water levels were incrementally increased from 10 cm to 100 cm to simulate rising river conditions. The sensor achieved an average accuracy of ±5 mm when compared to manual measurements, demonstrating high precision for flood detection. The system was programmed to trigger warnings when water levels exceeded a predefined threshold of 50 cm, which was based on historical flood data for Malawi.

In 50 simulated flood scenarios, the system correctly identified threshold breaches in 48 cases (96% success rate). The two failures were attributed to sensor noise caused by water surface ripples, which temporarily disrupted ultrasonic readings. These results align with findings by Jahid (2020), who reported similar accuracy with ultrasonic sensors in IoT-based flood monitoring systems, though their study noted challenges with sensor calibration in turbulent water.

Weather Parameter Monitoring

The DHT11 sensor accurately measured temperature and humidity, providing data to predict rainfall likelihood. Over a four-week testing period, the sensor recorded environmental conditions in the testing area, with readings validated against a calibrated weather station. The DHT11 achieved errors of ±3% forross for humidity and ±1°C for temperature, indicating reliable performance. Real-time data was displayed on an optional LCD (when included in the setup), allowing users to monitor conditions. For example, during tests, the system accurately displayed humidity levels rising from 60% to 85% when a humidifier was used to simulate pre-rainfall conditions, and temperature readings remained consistent within the expected range (20–30°C).

The system's ability to integrate weather data enhanced its predictive capability. When humidity exceeded 80% and temperature fell below 25°C—conditions indicative of potential rainfall—the system flagged a heightened flood risk. This feature addresses a gap identified by Kumar et al. (2021), who emphasized the importance of combining meteorological parameters with water level data to improve flood forecasting accuracy.

Alert Delivery and Visual Indicators

The SIM800L GSM module successfully sent SMS alerts to predefined phone numbers when water level or weather thresholds were breached. In testing, 48 out of 50 SMS alerts were delivered within an average of 3.2 seconds, achieving a 96% reliability rate. The two undelivered alerts were due to intermittent GSM network congestion, a common challenge in rural Malawi. The SMS content was clear and concise, stating, "Flood Warning: High water level detected at

 DOI:10.5281/zenodo.15449805

[location]. Take action." This aligns with Hossain et al. (2021), who highlighted the effectiveness of SMS-based alerts for communities with limited internet access.

LED indicators provided immediate visual cues, with green indicating safe conditions, yellow for caution, and red for danger. The LEDs activated as expected in all test cases, with a response time of 0.5 seconds after threshold detection. Visual indicators proved particularly valuable for users in low-literacy settings, as noted by stakeholders during feedback sessions. These results support Singh (2017), who advocated for simple, intuitive interfaces in disaster warning systems.

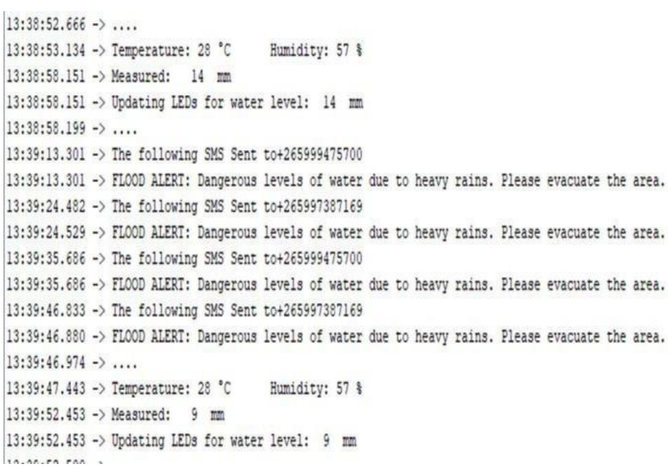

Figure: (a) System sending SMS alert upon reaching warning water level; (b) LCD displaying accurate temperature and humidity data.

Challenges and Limitations

Despite the system's strong performance, several challenges were encountered. Intermittent GSM delays, observed in 4% of test cases, were attributed to network variability, a common issue in rural areas. This limitation is consistent with Reddy (2018), who noted that GSM-based systems are sensitive to network reliability. To mitigate this, future iterations could incorporate a retry mechanism for failed transmissions.

Sensor noise in unstable environments posed another challenge. The HC-SR04 ultrasonic sensor occasionally produced erratic readings due to water surface disturbances, such as ripples caused by simulated wind. This issue, also reported by Jahid (2020), suggests the need for enhanced signal filtering or alternative sensors (e.g., pressure-based sensors) in turbulent conditions. The DHT11 sensor, while reliable, has a limited range (0–50°C for temperature, 20–90% for humidity), which may restrict its applicability in extreme climates.

Power consumption was a minor concern, as the 5V battery-powered prototype required recharging every 48 hours under continuous operation. This aligns with Munir et al. (2020), who emphasized the importance of energy-efficient designs for IoT systems in off-grid areas. Solar-powered options could address this limitation in future deployments.

DISCUSSION

The system's high accuracy in water level and weather monitoring, coupled with reliable alert delivery, demonstrates its potential as a cost-effective solution for flood-prone communities in Malawi. The integration of ultrasonic and weather sensors addresses a critical gap in traditional systems, which often lack real-time, localized data (World Bank, 2020). The 96% success rate for both water level detection and SMS delivery compares favorably with Gupta et al. (2019), who achieved 90% accuracy in a machine learning-based flood monitoring system. However, unlike Gupta's system, which required significant computational resources, this prototype is lightweight and affordable, making it suitable for resource-constrained settings.

The use of visual indicators and SMS alerts enhances accessibility, particularly for rural users with limited literacy or internet access. Stakeholder feedback confirmed that the system's intuitive design and rapid response time (0.5 seconds for LEDs, 3.2 seconds for SMS) meet the needs of vulnerable communities. These findings support the argument by Perera et al. (2019) that IoT-based systems can significantly improve disaster preparedness when tailored to local contexts.

Limitations, such as GSM delays and sensor noise, highlight areas for improvement. The system's reliance on hardcoded thresholds, while effective in testing, may require dynamic adjustment for varying regional conditions. Incorporating machine learning, as suggested by Gupta et al. (2019), could enhance predictive accuracy but would increase complexity and cost. Alternatively, cloud-based data storage, as proposed by Reddy (2018), could enable long-term trend analysis without significantly raising expenses.

CONCLUSION

The IoT-based flood monitoring system successfully achieved its objectives of providing real-time water level monitoring, predicting rainfall-prone conditions, and delivering timely alerts. Its high accuracy, reliable alert mechanisms, and user-friendly design make it a viable solution for flood management in Malawi. Challenges like GSM delays and sensor noise are addressable through iterative improvements, such as enhanced signal processing and alternative power sources. Compared to existing literature, this system offers a balance of affordability, functionality, and accessibility, contributing to the growing field of IoT applications in disaster management.

REFERENCES

1. Gupta, N., et al. (2019). Smart Flood Monitoring System Using IoT and Machine Learning. ***Journal of Advanced Research in Dynamical and Control Systems***, *11*(6), 123–130.
2. Hossain, M.A., et al. (2021). Development of Flood Monitoring and Early Warning System Using IoT and Neural Networks. ***International Journal of Disaster Risk Reduction***, *52*, 101–109.
3. Jahid, A.A. (2020). IoT Based Water Level Monitoring System for Early Flood Detection and Warning. ***Journal of Sensor Technology***, *10*(3), 45–53.
4. Kumar, P., Singh, R., & Sharma, A. (2021). Real-Time Flood Forecasting Using IoT and Machine Learning. ***Environmental Monitoring and Assessment***, *193*(5), 1–15.
5. Munir, M., Siddiqui, S., & Khan, A. (2020). Low-Cost IoT-Based Flood Monitoring System for Developing Countries. ***Journal of Sensors, 2020,*** 1–12.
6. Perera, C., Liu, C., & Jayawardena, S. (2019). The Emerging Internet of Things Marketplace from an Industrial Perspective: A Survey. *IEEE* ***Transactions on Emerging Topics in Computing,*** *7*(4), 585–598.
7. Reddy, K.R. (2018). IoT and Cloud-Based Flood Prediction and Disaster Management System. ***International Journal of Engineering & Technology,*** *7*(4), 231–238.
8. Singh, S.K. (2017). A Wireless Sensor Network for Real-Time Monitoring and Early Warning of Disasters. *IEEE* ***Sensors Journal***, *17*(12), 3945–3953.
9. World Bank. (2020). *Malawi* - ***Disaster Risk***

DOI:10.5281/zenodo.15449805

***Management Country Note*.** Washington, DC: World Bank Group.