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Arduino-Based Rainfall and Flood Monitoring System With Real-Time Alert Notification

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Abstract- The objective of this research is to develop an Arduino-based rainfall and flood monitoring system with real-time alert notification to address the challenges faced by the affected residents of the outlying areas of the Davao region. It focuses on using Arduino technology for the areas affected by floods that can be easily monitored with an SMS alert notification and a buzzer system. This research employed an experimental approach, starting with the design and assembly of the prototype, followed by sensor accuracy testing and data collection over multiple trials. The findings revealed that the prototype accurately measured water level according to three categories: caution, warning, and danger; this category also achieves a 100% success rate in sending SMS alerts and providing timely warnings to the buzzer during moderate and critical rainfall events. The data logged on a microSD card confirmed the system's consistent performance in tracking environmental conditions. In conclusion, the prototype reliably shows a rainfall and flood monitoring solution that ensures real-time alerts to the affected communities, significantly contributing to disaster preparedness and response of the local communities. Some of the suggestions for future upgrades are further testing under a variety of conditions, integrating the system with IoT platforms to manage data better, programs across the community to understand and develop the most effective response mechanisms, and system expansion for a greater spatial coverage by having multiple sensors along with a monitoring station network..

Index Terms-Arduino technology, rainfall, flood, monitoring system

I. INTRODUCTION

Floods have remained an inconvenient and increasingly threatening natural disaster throughout the globe, where many lives, properties, and sources of income face intense threats, especially for people living near overflowing rivers and continued heavy rainfall. In Davao City, certain communities always experience severe flooding of their homes every time there is heavy rainfall, an event that leads to loss of property and alteration of business as usual. The current traditional flood manual monitoring system is quite slow and inefficient as it cannot transfer info/data to the residents immediately thus they are left with minimal time and chance to respond properly. This points towards the importance of requiring a much quicker and more effective solution in the immediate aftermath.

In recent years, floods in different South Asian Association for Regional Cooperation (SAARC) countries have led to a humanitarian crisis that revealed the plight of the suffering of people affected by climate change. Due to the recent floods caused by heavy rains, river banks have been breached and many villages in Bangladesh have been flooded; around 400,000 families have been affected with at least 30 individuals losing their lives (Paul, 2019). As it stands, floods in Assam, India affected fifty lacs, of which the majority still survive in the relief camps even though the flood water has retreated (Mahanta, 2019). In the same regard, 78 people have died because of floods in Bihar, India and measures against diseases have been taken (Kumar, 2019). Even so, frequent occurrences of bad weather especially in Sri Lanka have led to many fatalities and necessitated people displacement, especially from the Nuwara Eliya and Ratnapura regions (Disaster Management Center, 2019). These calamities provide the rationale for the imperative of disaster risk management and climate change adaptation in South Asia plans and policies.

Flooding is considered one of the most serious and widespread natural hazards due to its devastating effects, which endanger lives and cause property damage in affected areas. According to the Local Disaster Risk Reduction and Management Council (LDRRMC, 2021), typhoons might affect the Municipality of San Leonardo, Nueva Ecija, due to its geographical location. Eight barangays along the Pampanga and Peñaranda Rivers are also susceptible to flooding, resulting in loss of life and agricultural productivity, in addition to damaging private and public properties. An early warning system is an adaptive measure for climate change, using integrated communication systems to help communities prepare for hazardous climate-related events. The PRB covers the provinces of Bulacan, Pampanga, and Nueva Ecija, which often suffer from periodic extensive flood damage. Zamboanga City, a large urban center in western Mindanao, has experienced climate-related disasters in recent years, including tropical cyclones, extreme rain, and drought. For example, a drought in Zamboanga City caused by a strong El Niño in 2015-2016 led to water reservoirs leaking, exacerbating the loss of livelihoods for local and regional farmers.

For instance, the Davao region has again received heavy rainfall and flooding, proving that the region is very volatile against natural calamities. The latest weeks of flooding due to heavy rain, with the incitement of a low-pressure area, led to six people's deaths. NDRRMC (2024) identified one dead, six individuals injured, and one more missing in Davao de Oro. Furthermore, in implementing its appropriate task, the Office of Civil Defense (OCD) estimated that 262 barangays involving 278,000 residents had greatly suffered, and the requisite structures of affected families were demolished (Punongbayan & Suelto, 2024). Similar calamities of flooding were recorded last November 2023, January 2021, and December 2017, affecting the lives of thousands in this city (Apalisoc, 2024). This problem again proves the need to employ better ways of dealing with floods and disasters throughout the outlying communities of the Davao region.

Flood monitoring technology faces critical gaps, particularly in rural and remote areas. While urban centers benefit from advanced systems, these outlying communities often lack access to similar resources. According to Natividad and Mendez (2018), most flood monitoring systems rely on one-way communication, where local communities must access updates via websites. This method requires internet-enabled devices like smartphones or computers, which many individuals cannot afford. As a result, communities often remain unaware of rising water levels in nearby rivers, leading to overflow, property damage, and loss of life.

To aid this problem, the study conducted by Satria, et al. (2017), numerous studies have explored the development of early warning systems leveraging mobile communication and information-based technologies. The rapid growth of mobile devices and machine-to-machine communication has paved the way for more sophisticated and accessible solutions in disaster management. Research has demonstrated that mobile-based technologies, such as flood monitoring systems and SMS-based early warning systems, can be highly effective in delivering timely alerts. These systems offer communities a reliable method to receive critical information about impending disasters, especially in areas with limited internet access. They represent a significant step forward in using mobile technology for proactive disaster preparedness and mitigation.

Although there have been advancements in flood monitoring technologies, a gap remains in integrating Arduino-based systems with SMS notifications for timely alerts. Current methods are often slow and ineffective for prompt disaster response. This research seeks to bridge that gap by designing a flood and rainfall monitoring solution that uses Arduino technology and SMS alerts to improve the effectiveness of early warnings. By doing so, the study aims to enhance community preparedness and disaster response in areas prone to flooding.

II. STATEMENT OF THE PROBLEM

This study aims to develop an Arduino-based rainfall and flood monitoring system with real-time alert notification to address the challenges faced by the affected residents of the outlying areas of the Davao region. Specifically, this study seeks to answer the following question:

What is the percentage of successful trials of Arduino-based rainfall and flood monitoring system in terms of:
- HC-SR04 sensor's detection;
- raindrop sensor's detection;
- timely activation of the audible alert system; and
- promptness of the alert notification?

What is the percentage of successful trials of the alert notification in terms of:
- critical flood level; and
- safe water level?
-

What is the percentage of successful trials of analog value sent by raindrop sensor based on the water level in terms of:
- dry condition (no rain);
- light rain;
- moderate rain; and
- heavy rain?
-

What is the water level indicated from the alert notification in terms of:
- caution category of critical flood level;
- warning category of critical flood level; and
- danger category of critical flood level?

Is there a significant difference between the indicated water level from alert notification and the average water level of the maximum and minimum values set on the device that triggers the alert system in terms of:
- caution category of critical flood level;
- warning category of critical flood level; and

- danger category of critical flood level?

Hypothesis
To answer objectively the problem of the study, the following hypotheses
were tested at 0.05 level of significance which states that:

HO1: There is no significant difference between the actual water level and the water level indicated in the alert notification in the caution category of critical flood level.
HO2: There is a significant difference between the actual water level and the water level indicated in the alert notification in the warning category of critical flood level.
HO3: There is a significant difference between the actual water level and the water level indicated in the alert notification in the danger category of critical flood level.

Significance of the Study
The Arduino-based rainfall and flood monitoring system with real-time alert notification addresses the critical need for efficient, affordable, and timely disaster management solutions. By integrating Arduino technology with sensors and real-time data acquisition, the system provides accurate rainfall and flood level monitoring. The real-time alert notification feature enables prompt dissemination of critical information to be affected communities, enhancing preparedness and reducing the risk of damage and loss of life. This prototype is particularly significant for flood-prone and resource-limited areas, offering a cost-effective, scalable solution for early warning and disaster response.

Scope and Delimitation of the Study
The scope of our research was the development of an Arduino-based rainfall and flood monitoring system with real-time SMS alert notifications and a buzzer for immediate local alerts aimed at enhancing disaster preparedness in flood-prone areas. The system integrated various sensors to monitor rainfall and water levels, automatically sending alerts to pre-configured phone numbers via SMS and activating the buzzer when critical thresholds are detected. The main goal was to provide early warnings to communities at risk of flooding, thereby reducing the impact of potential disasters.

The device could detect and measuring water levels and rainfall levels, with specific thresholds to categorize the severity of the situation as "No Rain," "Light Rain," "Moderate Rain," or "Heavy Rain." It decreased human intervention by automatically monitoring environmental conditions and triggering alerts through SMS and the buzzer when necessary, using a microcontroller to manage sensor data and send notifications via the SIM800L GSM module.

This study was limited to a specific geographic area vulnerable to flooding, where the prototype will be implemented and tested. Further study is required to adapt the system to different environmental conditions and geographical locations. The system's effectiveness is evaluated based on its accuracy, response time, and the efficiency of SMS notifications and buzzer alerts.

Literature Review
This section contains literature and empirical studies relevant to the study. These were selected for their relevance and significance to the topic under investigation. The discussion follows the following topics: flood and rainfall monitoring, Arduino-based smart flood monitoring systems, and the effectiveness of alert notification systems. sensors to measure water levels and flow rates. Noureldin et al. (2020) mention that the modern system increasingly uses the Internet of Things to obtain real-time data to deliver accurate alerts and quick responses. Several ultrasonic sensors and pressure-based sensors are used for highly accurate water-level measurement. Flood prediction accuracy is the work of Perera et al. (2019) on making flood predictions based on weather conditions and previous events using machine learning and artificial intelligence. Other community-based flood monitoring systems in vulnerable areas have also been effective, including community-based systems such as mobile applications for alerting people in time (Johar et al., 2019). For example, these sensors that run on solar energy and low-power communication protocols such as LoRa play a vital role in ensuring a continued monitoring process, especially in remote or resource-poor places (Wei et al., 2020). An advantage of integrating these flood monitoring systems into smart city infrastructures is having an opportunity to connect flood management to other urban services such as control of traffic and even emergency response systems (Liu et al., 2020). These technological improvements in IoT, analytics from data, and the precision of sensors have advanced the efficiency and scalability of flood monitoring systems.

Flood and Rainfall Monitoring
Among all the natural disasters, flooding and heavy rainfall pose a very fatal danger to lives, property, and the economy. Various natural disasters like floods are disastrous, thus the importance of a flood monitoring system and early warning. Based on the UNDRR (2020) study, flood early warning systems are critical lifesavers by lowering the fatality and residence damage risk through timely signalization and evacuation steps.

Arduino-Based Monitoring Systems
Arduino is an open-source electronics platform for developing different monitoring systems; it is cheap, easy to use, and flexible. Arduino boards can connect with diverse sensors and modules; due to this, they are ideal for real-time data acquisition. Thus, the study focused on the usefulness and affordability of Arduino in flood monitoring solutions.

Effectiveness of Alert Notification Systems

Alert notification systems play a crucial role in disaster management by providing timely information to the public and authorities. Short Message Service (SMS) – Alert System in the management of disasters. When coordinating with the instructors, the use of SMS alerts was excellent because a massive number of people could be informed within a short period, especially those in rural areas with poor internet connectivity. Stating further about their findings, the researchers established that the alert made through the short message service enabled the affected population to respond faster thus cutting the rate of deaths and injuries. Further, empirical research done by Goodwin et al. (2014) assessed the effectiveness of an SMS flood alert system in South Laos. It adopted flood monitoring sensors to send out alerts to residents in vulnerable areas within the shortest time possible. A higher success rate was also recorded for the timely delivery of accurate alerts for the evacuation and preparedness of the communities.

III. METHOD

This section outlines the research methodology, which is divided into four phases: Phase I: Preparation and assembly of the Arduino-based rainfall and flood monitoring system, focusing on the mechanical and structural design of the prototype. This phase involved constructing the physical framework and integrating key components, such as the raindrop sensor, HC-SR04 ultrasonic sensor, and LCD I2C display. Phase II: Sensor testing, which evaluated the accuracy and reliability of the system's sensors. This step ensured that the raindrop sensor correctly measured rainfall intensity and the HC-SR04 sensor precisely monitored water levels, providing the foundation for real-time flood monitoring. Phase III: Data gathering and analysis, where performance data was collected over multiple trials to assess the system's efficiency in tracking rainfall and flood conditions. This phase also evaluated the effectiveness of SMS integration and the buzzer alarm in notifying communities of potential flood risks. Phase IV: Product design, focusing on refining the aesthetics and user experience of the system to ensure practical deployment in real-world scenarios.

Research Design

This study used functionality tests on the features of the Arduino-based Rainfall and Flood Monitoring System with Real-Time Alert Notification. In rainfall detection, the features that were examined through functionality tests were sensor accuracy, response time, and audible alert system for moderate to heavy rainfall. At the flood detection level, the features that were investigated were sensor accuracy, response time, and buzzer activation for critical flood levels. Furthermore, the study utilized descriptive statistics specifically standard deviation to evaluate how far water levels reported from the alert notifications deviate from the maximum and minimum set values to trigger the alert system.

In this system, the HC-SR04 ultrasonic sensor will detect the water level, and the raindrop sensor will monitor rainfall conditions. When the water level reaches a critical point or rainfall is detected, the system, controlled by a microcontroller, will send real-time alerts via the SIM800L module. The LCD 20x4 will display relevant information such as water levels, rainfall status, and system timestamps, with the help of the RTC DS-3231 module to ensure accurate timing. Data collected from the sensors will also be stored on a microSD card for future analysis. According to Murty and Fauzan (2021), automation in monitoring systems like this can enhance resource management by providing timely, accurate data, reducing manual intervention, and improving overall system efficiency. This system would not only benefit flood monitoring efforts but also contribute to more efficient water resource management by limiting wastage and responding to the environment.

Design Concept

Figure 1 shows the flowchart of the Arduino-based rainfall and flood monitoring system with real-time alert notification. After completing the coding and hardware integration, the system underwent rigorous testing to identify any potential issues. The compact prototype featured precise placement of components, including sensors, communication modules, and power supply.

The initial deployment focused on verifying the accuracy and reliability of the prototype's core features. Key functionalities such as the raindrop sensor's detection capability, the HC-SR04's measurement of water levels, and the real-time alert system using the SIM800L module for SMS notifications were tested. The system was further evaluated to ensure proper synchronization between components such as the DS3231 RTC module for time tracking and the LCD I2C display for user-friendly output.

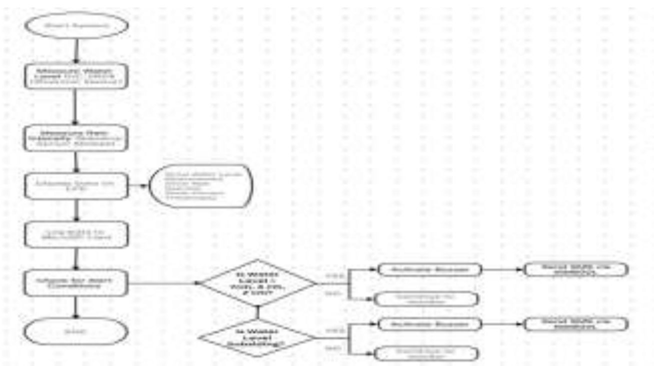

Figure 1. Flowchart of Arduino Smart Flood Monitoring System

This process not only validated the concept but also confirmed that the wiring, power supply, and system logic worked cohesively. Following adjustments and optimization based on the trial results, the system was proven to be operational and effective in sending real-time alerts during heavy rainfall or flooding, providing a practical tool for disaster preparedness.

Phase I. Designing and Assembling of the Prototype
Materials. This prototype will use an Arduino Uno R3, 5v and 12v adaptor, HC-SRO4 ultrasonic sensor, RTC module DS-3231, raindrop sensor, 20x4 LCD screen, breadboard, jumper wires, memory card module, DC buck converter, SIM800L module, buzzer and recycled materials like plywood and plastic container.

Building Up of the System Structure
Figure 2 shows a system structure that provides a stable, secure frame, and holds and protects the internal components.

Figure 2. System Structure

Building Up of the System Structure
Figure 3 shows the wiring system of the prototype, which consists of Arduino Uno R3, a 20x4 LCD screen, an HC-SRO4 ultrasonic sensor, a raindrop sensor, and a buzzer. The wiring system was networked by attaching the sensors to the Arduino Uno R3 using a breadboard, setting up the entire system. The system then will automatically process data from the sensors synchronously, displaying and distributing the real-time data to the 20x4 LCD screen and SMS integration for monitoring.

Figure 3. Wiring System

Attaching the SIM800L v2 Module
Figure 4 shows the wirings of the SIM800L v2 module that is connected to the Arduino Uno R3 with an antenna attached to the SIM800L v2 module for signal reception. The SIM800L module is programmed to send text message alerts to specific residents in flood-prone areas when rainfall reaches moderate levels.

Figure 4. SIM800L v2 Module

Soldering the Buck Converter for SIM800L v2 Module
Figure 5 shows the soldering of the buck converter of the SIM800L v2 module for voltage regulation.

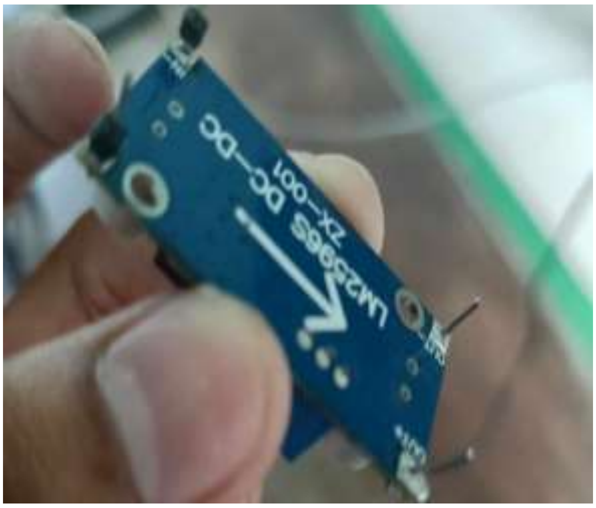

Figure 5. SIM800L v2 Module

Coding
Figure 6 shows the circuit design of the prototype, which is programmed using the Arduino Uno R3 microcontroller to control various sensors. The system includes a raindrop sensor that detects rainfall intensity, categorizing it as light, moderate, or heavy. The water level is measured using an HC-SR04 sensor based on distance. A 20x4 LCD I2C screen displays real-time information, including the water level, rainfall severity, time (via the RTC DS-3231 module), and date. Additionally, the system sends SMS notifications through the SIM800L module to alert residents when rainfall intensity reaches light, moderate, or heavy levels.

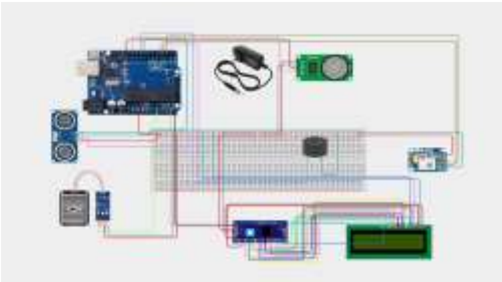

Figure 6. Circuit Design

Phase II. Testing of Indicators

The Arduino-based rainfall and flood monitoring system with real-time alert notification will be tested using dormant water in a plastic container that acts as the riverbed; the sensor will be tested to simplify the debugging process. Once the sensor is fully functional and performs according to what is expected then the next sensor will be subjected to testing. The next steps will be for:

- Input and Output Connection
- Detection of the Actual Water Level
- Error Detection of the System
- Testing the Flood Level Set on the System

Waste Disposal

All the segregated waste—non-biodegradable was gathered, sealed, and put in a black trash bag. After that, it was then delivered to Barangay 28-C's Material Recovery Facility for appropriate disposal.

Phase III. Data Gather and Analysis

Data Collection

In answering the underlying questions posted in this study, the researchers gathered the data by following these procedures:

- The success of the functionality test of the Arduino-Based Rainfall and Flood Monitoring System in terms of the HC-SR04 sensor's detection was examined as the HC-SR04 could detect water level.
- The success of the functionality test of the Arduino-Based Rainfall and Flood Monitoring System in terms of the raindrop sensor's detection was checked as the raindrop sensor could detect water on the raindrops module.
- The success of the functionality test of the Arduino-Based Rainfall and Flood Monitoring System in terms of timely activation of the audible alert system was examined as the audible alert system activated when the water level increased to the maximum distance (caution category of critical flood level) between the sensor's location and the surface of the water to trigger the system.
- The success of the functionality test of the Arduino-Based Rainfall and Flood Monitoring System in terms of the promptness of the alert notification was examined as the monitoring system sent alert notifications without delay.
- The researcher made 10 trials for procedures 1, 2, 3, and 4. Table 1 presents the collected data from the functionality test of the features of the monitoring system.

Table 1. Collected Data from the Functionality Test of the Features of the Monitoring System

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
HC-SR04 sensor's detection	/	/	/	/	/	/	/	/	/	/
Raindrop Sensor's detection	/	/	/	/	/	/	/	/	/	/
Timely activation of the audible alert system	/	/	/	/	/	/	/	/	/	/
Promptness of the alert notification	X	/	/	/	/	/	X	/	/	/

- The success of the functionality test of the alert notification in terms of critical flood level was examined as the monitoring system sent an SMS when the water level reached critical flood level.
- The success of the functionality test of the alert notification in terms of safe water level was examined as the monitoring system sent an SMS when the water level is less than the critical flood level.
- The researcher made 10 trials for procedures 6 and 7. Table 2 presents the collected data from the alert notification.

Table 2. Collected Data from the Alert Notification

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Critical Flood Level	/	/	/	/	/	/	/	/	/	/
Safe Water Level	/	/	/	/	/	/	/	/	/	/

- The success of the functionality test of the analog value sent by the HCSR-04 in terms of dry conditions (no rain) was examined as the raindrop sensor was dry and the circuit was opened.

- The success of the functionality test of the analog value sent by the HCSR-04 in terms of light rain was examined as light raindrops fell on the sensor.
- The success of the functionality test of the analog value sent by the HCSR-04 in terms of moderate rain was examined as more water landed on the sensor.
- The success of the functionality test of the analog value sent by the HCSR-04 in terms of moderate rain was examined as water fully covered with water.
- The researcher made 10 trials for procedures 9, 10, 11, and 12. Table 3 presents the collected data from the functionality test of the mentioned feature of the monitoring system.

Table 3. Collected Data from Analog Value Sent by the HCSR-04 Sensor

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Dry condition (no rain)	/	/	/	/	/	/	/	/	/	/
Light Rain	/	/	/	/	/	/	/	/	/	/
Moderate Rain	/	/	/	/	/	/	/	/	/	/
Heavy Rain	/	/	/	/	/	/	/	/	/	/

- When the distance between the sensor's height and the water level was between 7 cm and 4 cm, the system sent a caution category of critical flood level. The water level indicated from the alert notification was noted. The researcher made 10 trials to collect the data.
- When the distance between the sensor's height and the water level was between 4 cm and 2 cm, the system sent a warning category of critical flood level. The water level indicated from the alert notification was noted. The researcher made 10 trials to collect the data.
- When the distance between the sensor's height and the water level was between 2 cm and 0 cm, the system sent a danger category of critical flood level. The water level indicated from the alert notification was noted. The researcher made 10 trials to collect the data.
- The researcher made 10 trials for procedures 14, 15, and 16. Table 4 presents the collected data from the functionality test of this feature of the monitoring system.

Table 4. Collected Data on the Water Level Indicated by the Alert Notification

Category of Flood Level	T1 (in cm)	T2 (in cm)	T3 (in cm)	T4 (in cm)	T5 (in cm)	T6 (in cm)	T7 (in cm)	T8 (in cm)	T9 (in cm)	T10 (in cm)
Caution	5.00	6.24	6.60	6.26	6.92	6.94	6.58	6.24	5.12	4.44
Warning	3.20	3.40	3.52	3.74	2.62	2.84	3.20	2.28	2.06	2.18
Danger	1.72	1.91	1.65	1.83	1.86	1.91	1.70	1.84	1.48	1.50

Data Analysis

The collected data of success trials of using the Arduino system in monitoring rainfall and flood level detection in terms of features such as sensor accuracy, response time, and sending of alert notification were in the form of a checklist, that is, the goal of the functional testing. The researcher counted the success of each feature and divided it by the number of trials, that is, the number of trials was 10.

The collected data on the water level that were indicated from the alert notification utilized descriptive statistics specifically the mean and the standard deviation.

Table 5 presents the average water level of the maximum and minimum values set on the device that triggers the alert system in terms of caution, warning, and danger category of critical flood level.

Table 5. Average of Water Level of the Maximum and Minimum Values Set on the Device

Critical Flood Level Category	Range		Average
Caution	Maximum Value	7cm	5.50
	Minimum Value	>4cm	
Warning	Maximum Value	4cm	3.00
	Minimum Value	>2cm	
Danger	Maximum Value	2cm	1.00
	Minimum Value	0	

Moreover, the collected data on the water level indicated by the alert notification were analyzed through the Shapiro-Wilk test to evaluate whether the data set was normally distributed. Table 6 presents the Shapiro-Wilk test for water level indicated from the alert notification The result of the Shapiro-Wilk test showed that each data set was normally distributed. Hence, a parametric test which was an independent t-test was used to further analyze the data.

Table 6. Test of Normality

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Water Level Indicated from Alert Notification for Caution Category of Critical Flood Level	.294	10	.015	.865	10	.086
Water Level Indicated from Alert Notification for Warning Category of Critical Flood Level	.190	10	.200*	.933	10	.475
Water Level Indicated from Alert Notification for Danger Category of Critical Flood Level	.215	10	.200*	.890	10	.171

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Phase IV. Product Design

Using carefully chosen materials that improves both visual appeal and practicality, the prototype demonstrates an aesthetic balance of beauty and functionality. The plastic Carabao grass gives a natural touch and a garden-like atmosphere that brings life to the design.

The PVC pipe and the roof were painted white to give them a clean, modern appearance while still serving its function as the casing/protector of the HCSR-04 ultrasonic sensor. To achieve a more natural look, the green paint on the base flooring is used to give the artificial grass greater depth.

To highlight the design above, the legs and the structure foundations were painted black to provide a strong, striking contrast to the lighter colors. The inclusion of hinges provides easy access to the system, making the prototype both aesthetically pleasing and practical.

IV. RESULT AND DISCUSSION

This section presents the results of the study and provides a comprehensive discussion based on the data collected throughout the research process.

The analysis focuses on the effectiveness and reliability of the Arduino-based Rainfall and Flood Monitoring System, highlighting the system's capabilities in real-time data collection and alert notifications.
Table 7 presents the percentage of successful trials of functionality tests of the features of the monitoring system.

Table 7. Percentage of Successful Trials from the Functionality Test of the Features of the Monitoring System

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Percentage of Success Trials
HC-SR04 sensor’s detection	/	/	/	/	/	/	/	/	/	/	100%
Raindrop Sensor’s detection	/	/	/	/	/	/	/	/	/	/	100%
Timely activation of the audible alert system	/	/	/	/	/	/	/	/	/	/	100%
Promptness of the alert notification	X	/	/	/	/	/	X	/	/	/	80%

Based on Table 7, the result shows that the percentages of successful trials on the HC-SR04 sensor’s detection, raindrop sensor’s detection, and timely activation of the audible alert system are 100%, 100%, and 100% respectively. Meanwhile, the percentage of successful trials on the promptness of the alert notification is 80%. This is aligned to the limitation of this feature being dependent on the signal. Overall, these features of the monitoring system have successfully passed in terms of functionality. This means that the Arduino-Based Rainfall and Flood Monitoring System has the potential to enhance resource management by providing timely, accurate data, and reducing manual intervention.

Table 8 presents the collected data from the alert notification.

Table 8. Collected Data from the Alert Notification

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Percentage of Success Trials
Critical Flood Level	/	/	/	/	/	/	/	/	/	/	100%
Safe Water Level	/	/	/	/	/	/	/	/	/	/	100%

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Referring to Table 8, the percentages of successful trials of the alert notification are all 100%. Overall, this feature of the monitoring system has successfully passed in terms of functionality.

Table 9 presents the percentage of successful trials of the analog value sent by the HCSR-04 sensor.

Table 9. Percentage of Successful Trials of the Analog Value Sent by the HCSR-04 Sensor

Parameter	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Percentage of Success Trials
Dry condition (no rain)	/	/	/	/	/	/	/	/	/	/	100%
Light Rain	/	/	/	/	/	/	/	/	/	/	100%
Moderate Rain	/	/	/	/	/	/	/	/	/	/	100%
Heavy Rain	/	/	/	/	/	/	/	/	/	/	100%

As presented in Table 9, the result shows that the percentages of successful trials of the analog value sent by the HCSR-04 sensor in terms of dry conditions (no rain), light rain, moderate rain, and heavy rain are all 100%. This means that the Arduino-Based Rainfall and Flood Monitoring System can indicate the rainfall intensity correctly.

Table 10 presents the descriptive statistics of the water level indicated by alert notifications. As shown in Table 10, the mean and standard deviation of the water level indicated by the alert notification for the caution category of critical flood level are 6.03 cm and 0.89 cm. Also, the mean and standard deviation of the water level indicated from the alert notification for the warning category of critical flood level is 2.90 cm and 0.60 cm. Meanwhile, the mean and standard deviation of the water level indicated by the alert notification for the danger category of critical flood level are 1.74 cm and 0.16 cm.

Table 10. Descriptive Statistics of the Water Level Indicated from Alert Notification

Descriptive Statistics

	N	Mean	Std. Deviation
Water Level Indicated from Alert Notifcation for Caution Category of Critical Flood Level	10	6.0340	.86959
Water Level Indicated from Alert Notifcation for Warning Category of Critical Flood Level	10	2.9040	.59724
Water Level Indicated from Alert Notifcation for Danger Category of Critical Flood Level	10	1.7400	.15832
Valid N (listwise)	10		

Table 11 presents the descriptive statistics of the average water level of the maximum and minimum values set on the device that triggers the alert system. As shown in Table 11, the mean and standard deviation of the average water level for the caution category of critical flood level are 5.50 cm and 0.00 cm. Also, the mean and standard deviation of the average water level for the warning category of critical flood level are 3.00 cm and 0.00 cm. Meanwhile, the mean and standard deviation of the average water level for the danger category of critical flood level are 1.00 cm and 0.00 cm.

Table 11. Descriptive Statistics of the Average Water Level

Descriptive Statistics

	N	Mean	Std. Deviation
Average Water Level of the Maximum and Minimum Values Set on the Device that Triggers the Cation Alert System	10	5.5000	.00000
Average Water Level of the Maximum and Minimum Values Set on the Device that Triggers the Warning Alert System	10	3.0000	.00000
Average Water Level of the Maximum and Minimum Values Set on the Device that Triggers the Danger Alert System	10	1.0000	00000
Valid N (listwise)	10		

Table 12 presents the results of the independent t-test of the water level indicated from alert notification for caution, warning, and danger category of critical flood levels and the average water level of the maximum and minimum values set on the device that triggers the alert system.

Table 12. Independent T-test

As shown in Table 12, the p-value for the water level for the caution category of critical flood level is 0.068 (p>0.050). With this, the null hypothesis should not be rejected. Hence, the water level indicated from alert notification for the caution category of critical flood levels has no significant difference (6.03 cm ± 0.87 cm) compared to the average water level of the maximum and minimum values set on the device that triggers the alert system (5.50 cm ± 0.00 cm), t(18)=1.94,p=0.068. Moreover, the p-value for the water level for the warning category of critical flood level is 0.617 (p>0.05). With this, the null hypothesis should not be rejected. Thus, the water level indicated from alert notification for the warning category of critical flood levels has no significant difference (2.90 cm ± 0.60 cm) compared to the average water level of the maximum and minimum values set on the device that triggers the alert system (3.00 cm ± 0.00 cm), t(18)=-0.51, p=0.617. Furthermore, the p-value for the water level for the warning category of critical flood level is less than 0.001 (p<0.05). With this, the null hypothesis should be rejected. Therefore, the water level indicated from alert notification for the warning category of critical flood levels has a significant difference (1.74 cm ± 0.16 cm) compared to the average water level of the maximum and minimum values set on the device that triggers the alert system (1.00 cm ± 0.00 cm), t(18)=14.78, p<0.001.

This means that the water level indicated by the alert notification is sometimes different from the average water level for the caution, warning, and danger category of critical flood levels. This result is aligned with the functionality of the monitoring system to trigger the alert system at any value within the water level set on the device.

V. CONCLUSION

Based on the results, the following conclusions are drawn by the researcher:

- The percentages of successful trials on the HC-SR04 sensor's detection, raindrop sensor's detection, and timely activation of the audible alert system are all 100%. Meanwhile, the percentage of successful trials on the promptness of the alert notification is 80%. Overall, these features of the monitoring system have successfully passed in terms of functionality. This means that the Arduino-Based Rainfall and Flood Monitoring System has the potential to enhance resource management by providing timely, accurate data, and reducing manual intervention.
- The percentages of successful trials of the alert notification are all 100%. In general, this feature of the monitoring system has successfully passed in terms of functionality.
- Percentages of successful trials of the analog value sent by the HCSR-04 sensor in terms of dry condition (no rain), light rain, moderate rain, and heavy rain are all 100%. This means that the Arduino-Based Rainfall and Flood Monitoring System can indicate the rainfall intensity correctly.
- The mean of the water level indicated by the alert notification for the caution category of critical flood level is 6.03 cm. Also, the mean of the water level indicated from the alert notification for the warning category of critical flood level is 2.90 cm. Meanwhile, the mean of the water level indicated by the alert notification for the danger category of critical flood level is 1.74 cm.
- The water level indicated from alert notification for the caution category of critical flood levels has no significant difference (6.03 cm ± 0.87 cm) compared to the average water level of the maximum and minimum values set on the device that triggers the alert system (5.50 cm ± 0.00 cm), t(18)=1.94,p=0.068. Moreover, the water level indicated from alert notification for the warning category of critical flood levels has no significant difference (2.90 cm ± 0.60 cm) compared to the average water level of the maximum and minimum values set on the device that triggers the alert system (3.00 cm ± 0.00 cm), t(18)=-0.51, p=0.617. Furthermore, the water level indicated from alert notification for the warning category of critical flood levels has a significant difference (1.74 cm ± 0.16 cm) compared to the average water level of the maximum and minimum values set on the device that triggers the alert system (1.00 cm ± 0.00 cm), t(18)=14.78, p<0.001.

Recommendations

For further research:

- Using a rain gauge to accurately gather data for rain intensity
- Using battery and solar powered for rural communities that don't have access to electricity
- Incorporating the data logs from the SD card to analyze patterns over time, and eventually could predict flood risks
- Using the internet or IO for a more reliable way of receiving real-time alerts.

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