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Community-based flood alert system using long-range technology for Brgy. San Agustin, San Jose, Occidental Mindoro

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ABSTRACT

Floods are common disasters experienced in almost all parts of the world. The Philippines experienced varying degrees of flood events and almost all parts of the country are monitored during heavy rains and typhoons. As flood events continue to increase in the future, disaster risk management agencies intensifies strategies to mitigate impacts of flood at barangay level. This study presented a flood alert system for Brgy. San Agustin, San Jose Occidental Mindoro, Philippines to inform the community during the risk of flood. The developed system is composed of Arduino Uno microcontroller, Long Range, Global System for Mobile communication Module, water level sensors and temperature-humidity sensors. Once the sensors are activated and detected the water level, it will send alert message to the Global System for Mobile communication module and send flood alert messages to the receiver with response time of not exceeding ten (10) seconds. The simulation programmed in Arduino Uno showed that it is capable of real-time detection of water level and sending alert messages. The performance of the GSM module showed its capability of sending flood alert messages based on the water level detection. The developed system successfully showed its ability to send flood alert messages with corresponding alert description.

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1. INTRODUCTION

Floods are natural disasters imposing major threats to life, property and economy causing economic losses and human suffering (Chaudhary & Piracha, 2021; Cheng, 2004). Floods are considered as one of the most major problems in the countries all over the world. The significant losses of life, livelihood, and infrastructure make flooding a major threat to the economic and social well-being of the flood-prone urban areas (Jonkman, 2005). The varying degrees of climate change impacts cause unpredictable flood frequency and severity (Aerts et al., 2018; Freer et al., 2013; Hirabayashi et al., 2013). Sea level projection from coastal tide gauge and satellite altimeter are expected to rise up to 34.87 and 33.71 cm, respectively, in 2100 (Affandi et al., 2024). With the unpredictable effects of climate change, flood risks will continuously increase placing many cities in the world at great harm. Increasing flood frequency and severity of extreme rainfall has led to the utilization of non-structural approaches for flood mitigation (Breckpot, et al., 2010). Recent technology advances on forecasting rainfall and tracking of storm path helps the community to prepare for possible impacts. But the need for a real time monitoring of flow and water level can be very helpful in decision making and flood prevention and mitigation. Efforts in mitigating adverse impacts of floods have been the subjects of many studies and researches. Monitoring and tracking the path of storms and typhoons open many opportunities on the prediction of flood water level ranging from traditional approaches to state-of-the-art technology based infrastructures. The use of wireless sensor networks, remote sensing, geographical information system, Internet of Things (IoT) based are some of the promising technologies used nowadays.

Over the years, large number of researches and projects concentrated on the development of stronger and smarter flood monitoring and warning systems and methodologies such as the wireless sensor networks (Chang & Guo, 2006; Yeon, et al., 2018), embedded system with middleware (Hughes et al., 2006), IoT based systems (Pandian, 2019), WSN using Zigbee module (Yuwat & Kilaso, 2011), and flood modelling and forecasting using big data analysis (Anbarasan, et al., 2020) were introduced. Awareness of the community on the coming flood events was regarded as the best mitigation measure to avoid damages and severe impacts by communicating on the water level in flood prone areas. Flood early warning system using meteorological data, water levels and remote sensing offers a state-of-the art system as it combines the capability of the simulation and real time monitoring of water level. A system that detects water level and measures the rise of speed of water was used in alerting the residents in Malaysia. The system optimizes the capability of the raspberry Pi in collecting data from the water sensors and transmits signals to Global System for Mobile communication (GSM) module and provides notification to evacuate before the water rises (Shah, et al., 2018). A flood monitoring and alert system that measures the height of water was developed using ultrasonic sensors and gives warning signal thru SMS module (Priya, et al., 2017; Satria, et al., 2017). While a dynamic limited water level flood control was developed in India that provides real world application of internet of things, thru web the signals are received and provide warning and alert messages (Yun & Singh, 2008). A flood early warning system using SMS and web was designed to record rainfall and water level data on flood status to the people in the flood prone area of Garang River, Semarang Malaysia (Windarta, 2010). A same technology was developed to manage the water storage system of dam and lake through sensor signals that can predict the incoming water level. The sensors connected in the lake is connected with IoT Platform that transmits signal and warning massages (Smys, et al., 2020). In addition, an automated flood control system based on wired and wireless communication was developed in Nigeria that can efficiently monitor and control the water level using SCADA as the supervisory component (Inyiama & Obota, 2013). A real time monitoring of water conditions, water level and precipitation level was developed and employed in monitoring the flood in Nakhon Si Thannarat, Thailand. The monitoring system is composed of sensor networks, processing/transmission unit and database application software; the General Packet Radio Service embedded in the system allows communication and transmit measured data to the application server (Sunkpho & Ootamakorn, 2011).

Philippines, being an archipelago is vulnerable to climate change-related hazards with an average of 20 typhoons hitting the country every year, is frequently devastated by calamities resulting to numerous loss of lives, damage to property and billions of economic losses (Santos, 2021). Development of flood early warning system has gained popularity as many low lying areas in the country experiences adverse effects of flood. A real time flood monitoring and early warning system is installed in Ilagan, Isabela. The system uses Arduino, ultrasonic sensors, GSM module in detecting the water level and transmitting signal and warning messages to help the stakeholders mitigate flood casualties (Natividad & Mendez, 2018). Further, an alarm system was developed in monitoring the water level of Salog River in Sorsogon, Philippines; the water level sensors coupled with LED arrays emit light to water level: green for low, orange for medium, and red for high, and a siren that alarms for evacuation signal (Labo et al., 2016). Much of the early warning system developed as flood mitigation infrastructure optimizes the capability of IoT, and wireless sensors. A breakthrough in electronics and sensors is offered by Long range (LoRA) Technology and gaining attention in flood monitoring systems. The flood monitoring system using LoRa Technology offers speed of transmission making it suitable to produce real-time monitoring systems. LoRa is supported by the unlicensed radio bands, and promises kilometers of communication distance and several years of battery life; the Chirp Spread Spectrum technology (Goursaud & Gorce, 2015) makes it robust against a high degree of interference multi-path and Doppler effects (Adelantado, et al., 2017; Peng, et al., 2018). The performance of LoRa was evaluated and found that it is capable of communicating to distances larger than 10km (Liando, et al., 2019).

During typhoons, almost all flood-prone areas in the country are under constant monitoring to secure life and property. San Jose, Occidental Mindoro faces the South China Sea, is the gateway of almost all typhoons passing the country, had suffered varying degrees of flood events since 2018 (San Jose-MDRRMO, 2021). During typhoons, the Disaster Risk Office is constantly monitoring the water levels in flood-prone areas, particularly in Brgy. San Agustin, San Jose Occidental Mindoro. Since the area seats on low-lying agricultural land with the nearby Busuanga River, an increase in the water river causes fear in the community. Floods caused by the river flow down very slowly because of surface retention over the extensive flood plain and the area's gentle slope. The monitoring of the water level requires frequent visits and round-the-clock observation in Brgy. San Agustin. This prompted the researchers to help the MDRRMO in monitoring the water level by offering a flood alert system (FAS) using LoRA Technology and an SMS module. The FAS aims to present a localized warning system to help the community by providing interactive and real-time information on the current water level of the Busuanga River. Specifically, this study aims to: design a prototype that detects the Busuanga River's current water level using LoRA Technology and GSM module; design and develop a flood alert system (FAS) for the surrounding community using SMS; and test the performance of the prototype and the community-based FAS.

2. MATERIALS AND METHOD

2.1. Study area

The study area is located in Brgy. San Agustin, San Jose, Occidental Mindoro. It has a population of 5,019 with 5-9 years old as the age group with the highest population (PSA, 2020). The area is only 10m/32.81feet above sea level and situated in area with moderate to high flood risk levels. Busuanga River passes through San Agustin and is bounded by Mindoro Strait at the lower part and serves as the natural boundary between the municipalities of Rizal and Calintaan. The land use land cover in the study area is dominated by agricultural land and covered by crops. The economic activities focus on agricultural production with palay as the main crops. With its nearness in Busuanga River, the study area seating in low elevation is highly susceptible to fluvial floods. With its geographical location, the barangay is directly affected by the sudden changes in the river flow and sea rises (Paringit & Abucay, 2017). At present, a manual water level monitoring is already installed near the river to monitor the water level in the river. If the sea level rises to 2.0m, the barangay is immediately affected and flooding is expected to happen. Based on San Jose-MDRRMO, the condition of the water level in the barangay is religiously monitored to provide updates to the community.

2.2. Design of community-based food early warning signal

The system architecture of the proposed community-based flood alert system aims to provide real-time flood warning messages that could help the community inform immediately. The technology was installed near the Busuanga River in Brgy. San Agustin, San Jose Occidental Mindoro. The FAS maximized the capability of water level sensors, LoRA technology, and the GSM Module. The LoRA module installed requires less sophisticated transceiver devices and narrow internet bandwidth making it suitable for the community with weak internet connection; it has a large range that controls millions of devices allowing several data rates and sensitivity levels (Ragnoli, et.al, 2020). Since the study area has a weak internet connection, the use of the GSM Module is more convenient to use. The GSM Module is embedded in the FAS to allow the communication of data, signals, and warning messages in real time (Figure 1).

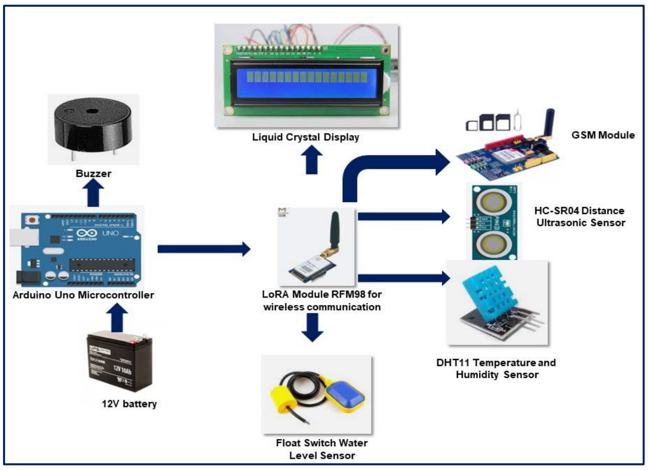

Figure 1. Pictorial diagram of the flood alert system

The system is powered up by a 12V battery installed in a protective box for security purposes. The Arduino Uno microcontroller served as the brain of the technology that commands all the components and peripherals. It sends signals to the LoRA Module, a long-range, low-power wireless platform used in the system that connects all other components wirelessly. The HC-SR04 distance ultrasonic Sensor and DHT11 temperature and humidity sensor receive signals from the LoRA module and have the capability of detecting the water level and measuring the humidity and temperature in the area. From the LoRa Module, the liquid crystal display is installed to indicate the level of the water. While the float sensor acts like a switch that indicates the water level and sends the appropriate signal through a buzzer that sends the water alert level.

2.3. Experimental set-up

To test the reliability and performance of the developed FAS, the system is tested in actual water with varying levels with water sensors placed in a basin. Simulation of the water level is introduced to allow it to rise until it reaches the first sensors for Alert Level 1. An alert message must be received by the connected mobile phone. Another scenario is tested where water is added until it reaches the second sensor and alert messages read the Alert Level II; and lastly, an additional water level scenario was simulated that reaches the third sensor and sends a signal of Alert Level III informing that the water is at a critical level and the siren sounds signalling the need for evacuation. The velocity of the rising water was recorded to estimate how quickly the flood water can rise in each scenario (Table 1).

Table 1. Water level monitoring system of the developed Flood Alert System (FAS)

Alert Level	Level	Simulated depth (inches)	Water level monitoring (Busuanga River as the reference in meters)	Color coding
None	Normal	>1.0	>0.5	Green
I	Alert and stand by	1.10-3.00	0.60-1.50	Yellow
II	Warning and preparing for evacuation	3.01-6.99	1.60-2.50	Orange
III	Danger and evacuate	≤ 7.0	<2.51	Red

The reliability of the network system is evaluated in terms of signal strength, signal-noise ratio, packet loss, and round-trip time. The reaction time of the sensors and response time in the mobile phone and GMS module were recorded to determine if real-time communication was achieved. The timeout was monitored to check if communication was lost, causing delays in real-time communication.

2.4. Implementation of the proposed system architecture

After preparing all the material and system components, the researchers performed an initial test to assess the general functionality of the procured materials. The system architecture is composed of a sensor field, command control, field, and the GSM Module. The sensor field is composed of the Arduino Uno and the LoRA. The command control field consists of the water level sensors and the temperature and humidity sensors that monitor the water level and temperature in the environment. Then the sensors send signals to the GSM Module for the end-users to receive alert messages. In this phase, it is assumed that all electronic systems and components are installed. The coding of the two modules is also initialized in this phase. The configuration and modification are included to ensure the workability of the system. The water level sensors are installed along with the LoRa Module and GSM module connected to an Android phone to check the sending of alert messages (Figure 2).

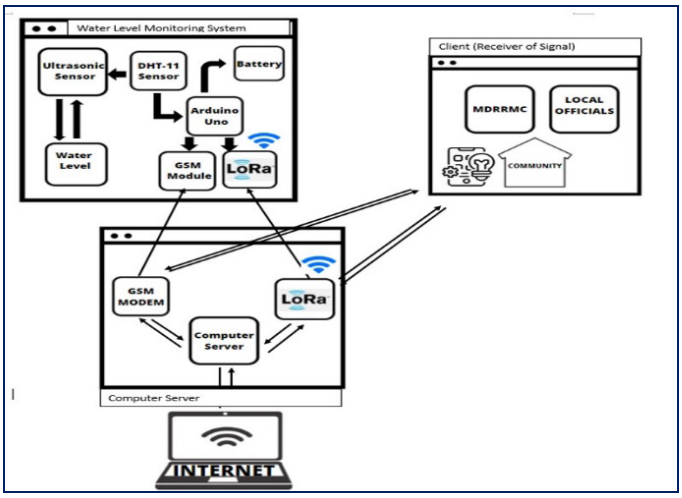

Figure 2. System Architecture

The water monitoring level is composed of an ultrasonic sensor and a DHT11 Sensor that measures the distance of the water level and the temperature of the water. It is controlled by an Arduino microcontroller that processes the signal from the sensors, GSM module, and Long Range (LoRA). Once the sensors are triggered, an output signal is transferred to the microcontroller, activates the connected GSM and Lora module, and sends a water level status to another LoRA and GSM module connected to the server. Then the developed program installed in the computer server analyzed the message received and automatically sent alert messages to the concerned agencies such as MDRRMO, local government officials, and the community.

The proposed system architecture successfully integrated the use of sensors in sending messages based on the water level. As the floater rises, it sends a signal to Arduino Uno with the actual height of the water through wireless communication using the Lora module; then the 2nd Arduino triggers the Lora module and GSM module to send a signal to the mobile phones. The water level can be monitored through mobile phones and as the water rises it sends an alert message to the user, authorities, and other government agencies.

2.5. Performance testing

To test the performance of the FAS, time delay is used for the evaluation and efficiency of the signal. Here are three tests conducted to determine the functionality of the proposed FAS. The tests considered two scenarios: 1) the water level rises quickly, and 2) the water level rises gradually during heavy rains and possible flooding. Test 1 considered the time delay response for the detection of the water level from the sensors and Test 2 considered the time delay response for sending and receiving SMS.

3. RESULTS

3.1. Water level detection

The first test is designed to measure the efficiency and accuracy of time in terms of detecting the water level of the river through the sensors. The testing is done using a basin to determine how the system responds upon the detection of the water level. A corresponding value for height and alert level was initially programmed in the Arduino Uno to represent the actual flood height and alert system. When the water level reaches the default threshold for Level I, Level II, and Level III, a notification indicating the water level is received by the command control. The first test was conducted to determine the response of the water level sensors in the depth of water in the basin (Table 2).

Table 2. Time-delay of water level sensors

Water level sensor		**Temperature and humidity sensors**	
Simulated depth (inches)	Time delay (seconds)	Simulated depth (inches)	Time difference (seconds)
2.0	0:02	2.0	0:04
3.0	0:01	3.0	0:03
4.0	0:02	4.0	0:02
5.0	0:02	5.0	0:02
6.0	0:01	6.0	0:01
7.0	0:01	7.0	0:00
7 and above	0:01	7 and above	0:00

The observed time delay is tolerable since it does not exceed ten (10) seconds. A longer response was observed at the first depth since the sensors were adjusting to the prescribed readings. Based on the results, it can be concluded that the proposed system functions in real-time as soon as the sensors detect the simulated water level, temperature, and humidity.

3.2. Time delay of received text message

This test aims to measure the time–delay in receiving text messages. Once, the sensors read the indicated water level, the command control field sends a signal to the GSM module and sends alert messages to the mobile phones (Table 3).

Table 3. Time-delay of sending text messages

Simulated depth (inches)	**Alert level**	**Alert description**	**Time delay (SMS delivery time, in seconds)**
2.0	I	Alert and stand-by	1.08
3.0	I	Alert and stand-by	1.15
4.0	II	Prepare for evacuation	1.65
5.0	II	Prepare for evacuation	1.80
6.0	II	Prepare for evacuation	1.85
7 and above	III	Evacuate	1.90

The system successfully performed its function to send alert messages. The detected water level has a corresponding alert level and description when received by the system users. The maximum delay time was 1.90 seconds and was observed at the highest simulated depth. The proposed system is concluded to achieve its purpose and can send alert messages in real-time.

3.2. Performance evaluation

During the performance evaluation, the system components, sensors, and command control system were placed near the area and simulations were done considering the required water level. The system is greatly dependent on the microcontroller Arduino Uno. The programming was done before the actual testing and adjustments were considered in the actual tests (Figure 3).

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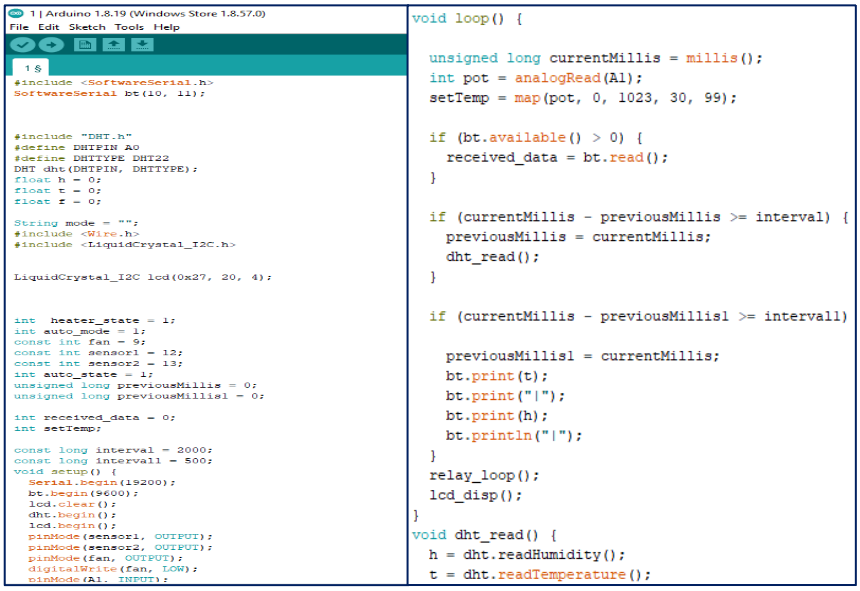

Figure 3. Program in the Arduino IDE

4. DISCUSSION

The system successfully performed its function to send alert messages. The detected water level has a corresThis paper designed a flood alert system using the Lora module and GSM Module that sends SMS or text messages to mobile phones to inform the community and government agencies like MDRRMO about the status of the flood level in Brgy. San Agustin, San Jose Occidental Mindoro. The study area is prone to moderate-high flood risks during typhoons and sea level rise. The site is one of the areas being monitored by the MDRRMO as immediate warning alerts must be given to the community. This study aims to help the local government unit, the MDRRMO, the barangay officials, and the residents of the barangay to have real-time flood monitoring systems that send text messages on the status of the water level and possible actions to be undertaken.

The actual components of the proposed system; consisting of a pair of sensors that work together to determine the actual water level. When the sensors determine the real water level, the information is processed in the Arduino Uno microcontroller, wirelessly communicated over the Lora module, and then passed to the GSM module to produce text messages that alert and notify the residents and the community. There are three alert messages received: alert level I: when the water level is above three (3) feet which means that the residents must be on alert or stand-by status; alert level II: when the water level is above five (5) feet, and the residents must be prepared for possible evacuation; and alert level III: when the water is above seven (7) and the residents must evacuate their areas.

This study further proved the efficiency of microcontrollers on flood alert systems. The water level monitoring system developed by Hassan et al., (2019) using SMS and Arduino board combined the float switch sensors in analyzing the detected water level and translating signals into alert messages. In this study, the water level detected by sensors triggers the Arduino Uno and the microcontrollers to respond and send alert messages based on the default water level. Further, the flood level monitoring developed in Calumpit, Bulacan using float switch sensors and Raspberry Pi and image processing showed effective integration of the electronics components in detecting water level and responding on a real-time basis (Tolentino et al., 2022). This study also focuses on the real-time capability of the developed water level monitoring system.

When the transmission of signals was beyond the expected real-time response, adjustment on the default water level and sensor readings were adjusted and programmed immediately to achieve the desired goals..

5. CONCLUSION

The study successfully produced a flood alert system for Brgy. San Agustin, San Jose, Occidental Mindoro. Using the capability of the Arduino Uno Microcontroller, LoRa, and GSM Module, the proposed system achieved its objective of sending alert messages to the users. The Arduino Uno which serves as the brain of the system sends signals wirelessly to LoRA and sends signals to the water level sensors and temperature/humidity sensors attached to the system. The water level detected is analyzed by the GSM Module and sends a corresponding alert level message. The performance of the proposed FAS was evaluated to determine its efficiency in detecting the water level and sending messages on the alert level. The performance test conducted showed that the detection of water level is real-time while the delivery of alert messages is reliable.

The developed flood monitoring system achieved its design function of sending real-time flood alert messages. The developed FAS can serve as a tool in disaster risk monitoring and mitigation. The capability of the GSM module is optimized to serve the residents without internet connectivity and provide them with alert messages that can save their lives during unforeseen flood events. The use of remote sensing and modern technologies can improve the communication and performance of the flood early warning system.

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REFERENCES

Adelantado, F., Vilajosana, X., Tuset-Peiro, P., Martinez, B., Melia-Segui, J., & Watteyne, T. (2017). Understanding the limits of LoRaWAN. *IEEE Communications Magazine*, *55*(9), 34–40. https://doi.org/10.1109/mcom.2017.1600613

Aerts, J. C. J. H., Botzen, W. J., Clarke, K. C., Cutter, S. L., Hall, J. W., Merz, B., Michel-Kerjan, E., Mysiak, J., Surminski, S., & Kunreuther, H. (2018). Integrating human behaviour dynamics into flood disaster risk assessment. *Nature Climate Change*, *8*(3), 193–199. https://doi.org/10.1038/s41558-018-0085-1

Affandi, M. L. A., Din, A. H. M., & Rasib, A. W. (2024). Sea level rise estimation and projection from long-term multi-mission satellite altimetry and tidal data in the Southeast Asia region. *International Journal of Remote Sensing*, 1–31. https://doi.org/10.1080/01431161.2023.2297179

Anbarasan, M., Muthu, B. A., Sivaparthipan, C. B., Sundarasekar, R., Kadry, S., Krishnamoorthy, S., Samuel, D. J., & Dasel, A. A. (2020). Detection of flood disaster system based on IoT, big data, and convolutional deep neural network. *Kean Publications*, (1248). https://digitalcommons.kean.edu/keanpublications/1248

Breckpot, M., Blanco, T.B., & Moor, B.D. (2010). Flood control of rivers with nonlinear model predictive control and moving horizon estimation. *49th IEEE Conference on Decision and Control* (CDC), 6107-6112.

Chang, N., Guo, D. H. (2006). Urban flash flood monitoring, mapping and forecasting via a tailored sensor network system. *Proceedings of the 2006 IEEE International Conference on Networking, Sensing and Control 2006*, issue 23-25, pp. 757-761

Chaudhary, M. T., & Piracha, A. (2021). Natural Disasters—Origins, Impacts, management. *Encyclopedia*, *1*(4), 1101–1131. https://doi.org/10.3390/encyclopedia1040084

Cheng, C., & Chau, K. (2004). Flood control management system for reservoirs. *Environmental Modelling & Software*, *19*(12), 1141–1150. https://doi.org/10.1016/j.envsoft.2003.12.004

Freer, J., Beven, K. J., Neal, J., Schumann, G., Hall, J., & Bates, P. (2013). Flood risk and uncertainty. In *Cambridge University Press eBooks* (pp. 190–233). https://doi.org/10.1017/cbo9781139047562.008

Goursaud, C., & Gorce, J. M. (2015). Dedicated networks for IoT: PHY / MAC state of the art and challenges. *EAI Endorsed Transactions on Internet of Things*, *1*(1), e3. https://doi.org/10.4108/eai.26-10-2015.150597

Hassan, W. H. W., Jidin, A. Z., Aziz, S. a. C., & Rahim, N. (2019). Flood disaster indicator of water level monitoring system. *International Journal of Electrical and Computer Engineering (IJECE)*, *9*(3), 1694. https://doi.org/10.11591/ijece.v9i3.pp1694-1699

Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., Kim, H., & Kanae, S. (2013). Global flood risk under climate change. *Nature Climate Change*, *3*(9), 816–821. https://doi.org/10.1038/nclimate1911

Hughes, D., Greenwood, P., Coulson, G., & Blair, G. (2006). GridStix: Supporting Flood Prediction using Embedded Hardware and Next Generation Grid Middleware. *Proceedings - WoWMoM 2006: 2006 International Symposium on a World of Wireless, Mobile and Multimedia Networks*, *9*, 10.1109/WOWMOM.2006.49. https://doi.org/10.1109/wowmom.2006.49

Inyiama, H. C., Obota, M. E. (2013). Designing Flood Control Systems Using Wireless Sensor Networks. *International Journal of Engineering Research and Applications*, 3(1), pp. 1374-1382

Jonkman, S. N. (2005). Global perspectives on loss of human life caused by floods. *Natural Hazards*, *34*(2), 151–175. https://doi.org/10.1007/s11069-004-8891-3

Labo, J. J., Floresca, E. E., & Gracilla, L. E. (2016). Development of flood warning system. *International Journal of Engineering Research and Applications*, 6(1), 57-64.

Liando, J. C., Gamage, A., Tengourtius, A. W., & Li, M. (2019). Known and unknown facts of LORA. *ACM Transactions on Sensor Networks*, *15*(2), 1–35. https://doi.org/10.1145/3293534

Natividad, J. G., & Mendez, J. M. (2018). Flood monitoring and early warning system using ultrasonic sensor. *IOP Conference Series Materials Science and Engineering*, *325*, 012020. https://doi.org/10.1088/1757-899x/325/1/012020

Pandian, A. P. (2019). Enhanced edge model for big data in the internet of things based applications. *Journal of trends in Computer Science and Smart Technology (TCSST)* 1(1), 63-73. https://doi.org/10.36548/jtcsst.2019.1.006

Paringit, E.C., Abucay, E.R. (2017), LiDAR Surveys and Flood Mapping of Magbando River, Quezon City: University of the Philippines Training Center for Applied Geodesy and Photogrammetry. *UP Training Center for Applied Geodesy and Photogrammetry (TCAGP).* 201pp

Peng, Y., Shangguan, L., Hu, Y., Qian, Y., Lin, X., Chen, X., Fang, D., & Jamieson, K. (2018). PLORA: a passive long-range data network from ambient LORA transmissions. In *Proceedings of the 2018 Conference of the ACM Special Interest Group on Data Communication* (https://doi.org/10.1145/3230543.3230567; pp. 147–160). https://doi.org/10.1145/3230543.3230567

Priya, S. J., Akshaya, S., Aruna, E., Julie, J. A. M., Ranjani, V. (2017). Flood monitoring and alerting system, International Journal of Computer Engineering & Technology, 8(2), p.15

Ragnoli, M., Barile, G. Leoni, A., Ferri, G., Stornelli, V., (2020). An autonomous low-power LoRa-based flood-monitoring system. *Journal of Low Power Electronics and Application*, 10 (15), https://doi.org/10.3390/jlpea10020015

Santos, G. D. C. (2021). 2020 tropical cyclones in the Philippines: A review. *Tropical Cyclone Research and Review*, *10*(3), 191–199. https://doi.org/10.1016/j.tcrr.2021.09.003

Satria, D., Yana, S., Munadi, R., Syahreza, S. (2017). Prototype of google maps-based flood monitoring system using Arduino and GSM module, *International Research Journal of Engineering and Technology*, 4(10).

Shah, W. M., Arif, F., Shahrin, A., & Hassan, A. (2018). The implementation of an IoT-Based flood alert system. *International Journal of Advanced Computer Science and Applications*, *9*(11). https://doi.org/10.14569/ijacsa.2018.091187

Smys, N. D. S., Basar, N. D. A., & Wang, N. D. H. (2020). CNN based Flood Management System with IoT Sensors and Cloud Data. *Journal of Artificial Intelligence and Capsule Networks*, *2*(4), 194–200. https://doi.org/10.36548/jaicn.2020.4.00

Sunkpho, J., & Ootamakorn, C. (2011). Real-time flood monitoring and warning system. *Songklanakarin Journal of Science and Technology*, *33*(2) 227-235. https://rps.wu.ac.th/detail/10002810

Tolentino, L.K., Baron, R.E., Blacer, C.A., Aliswag, J.M., De Guzman, D.C., Fronda, J.B., Valeriano, R.C., Quijano, J.F., Padilla, M.V., Madrigal, G.A., Valenzuela, I., & Fernandez, E.O. (2023). Real time flood detection, alarm and monitoring system using image processing and multiple linear regression. Journal of Computational Innovations and Engineering Applications, 7(1). https://doi.org/10.2139/ssrn.4319789

Windarta, J., Pawitan, H., Subrata, I. D. M., Purwanto, M. J. J., & Suripin. (2010). Flood Early Warning System develop at Garang River Semarang using Information Technology base on SMS and Web. *International Journal of Geomatics and Geosciences*, 1(1). http://iirc.ipb.ac.id/handle/123456789/40568

Yeon, S., Kang, J., & Lee, I. (2018). A study on real-time flood monitoring system based on sensors using flood damage insurance map. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences/International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-3/W4*, 569–571. https://doi.org/10.5194/isprs-archives-xlii-3-w4-569-2018

Yun, R., & Singh, V. P. (2008). Multiple duration limited water level and dynamic limited water level for flood control, with implications on water supply. *Journal of Hydrology*, *354*(1–4), 160–170. https://doi.org/10.1016/j.jhydrol.2008.03.003

Yuwat, C. Kilaso, S. (2011). A wireless sensor network for weather and disaster alarm system, *Proceedings of International Conference on Information and Electronics Engineering, IPCSIT 6*, pp.1-5

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