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Article

Localized Remote Sensing Device for Rainfall Precipitation Monitoring

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Abstract: Rainwater harvesting is considered a small-scale water resource that generates electricity. Its potential energy for generation is proportional to the volume of rainwater and depends on rainfall. Rainfall precipitation data is also used to forecast the water supply for agricultural purposes. The memorandum circulars (MC #032 and MC #046-A, s. 1974) of the National Irrigation Administration (NIA) in the Philippines were reiterated in MC #043 and MC #049, s. 2006, which mandates installing a rain gauge at each water source in the agricultural irrigation system. Since no localized rain gauge is installed, precipitation data may be collected from PAGASA. However, data may have discrepancies when applied to irrigation purposes, as it can be heavy rain in one location but not significantly different in intensity at nearby locations, even a few hundred meters away. The variability of rainfall across locations indicates that rainfall data from one place may not apply to nearby locations when assessing the capacity of electrical generation and water supply forecasting. The study develops a rainfall-monitoring device using remote sensing technology to provide realistic, localized monitoring. The device was solar-powered and could provide data in real-time continuously, even without sunlight, for three (3) days. The device's data reading was validated through testing and experiments. The device's measurements were validated and compared with the manual rainfall measurements, which were observed simultaneously. Results show no significant difference between the manual measurement and the device reading.
Keywords: rain gauge, remote sensing, rainwater harvesting, rainfall precipitation

1. Introduction

The importance of rainfall lies in its contributions as a primary source of water for plants; eventually, it fills the rivers. Rainfall is a needed resource, but it is also a threat. Therefore, it is essential to understand the natural phenomenon of rainfall [1].

Considering the global water cycle, rainfall precipitation is the widely recognized fundamental component. From a physical point of view, although rainfall precipitation affects ocean salinity, it is closely related to atmospheric circulation through the release of latent heat. The direct significance of rainfall to human survival is known, as it is the primary source of drinking water. It is also vital to most human activities and has direct and indirect economic dimensions. The agricultural sector is probably the most sensitive to rainfall, although several other sectors of the economy are also largely dependent on freshwater [2]. In managing water resources and agribusiness, rainfall precipitation also has economic value, playing a key role [3]. Furthermore, it is fundamental to the global cycle and the issue of climate change. In the water cycle, the water vapor condenses into clouds from which precipitation may fall. Returning water from the atmosphere to the surface is the primary source of freshwater and is vital to life on Earth [3].

It is already known that rain is variable over time. There are cases where, when trying to stay in one place, it does not rain there at all times. It was also observed that even during the rainy season, rainfall intensity varies, ranging from light to extreme. Typically, the strongest periods of rain occur over a relatively short period. This variability is a type of rainfall visible on a larger scale, occurring during months of the wet season or years of the dry season. Another variability of rain is defined by where it occurs, which can range from heavy rain in a particular area to none at all, or it can be significantly different in intensity a few kilometers away or even within nearby locations, only a few hundred meters apart [1].

Because excessive rainfall can endanger life and property, while a small amount of precipitation can cause droughts that harm agriculture and lead to famine, a system for monitoring rainfall provides a form of protection. However, measuring and monitoring rainfall precipitation are crucial to our well-being [3]. So then, the validity and reliability of rainfall observations should be considered. The most common method of measuring precipitation was the total rainfall depth over a given period, expressed in millimeters (mm). For example, when determining the precipitation in millimeters of rain that fell over one (1) hour, one (1) day, one (1) month, or one (1) year [1].

Rainwater harvesting was considered a small-scale water resource. It was found that rainfall harvesting could be a potential source of electrical energy [4]. This study computed the feasibility of using rainwater collected as an equivalent to electrical energy. The energy equivalent of rainwater collection was proportional to the building height in the Philippines and to the time and volume of water an individual consumed. Continuous rainfall data should be collected locally to accurately estimate the energy equivalent of rainwater harvesting. It further means that rainfall at one location will not be applied to other areas when computing the rainwater energy equivalent.

1.1. Different Types of Rain Gauges

Rain gauges at ground level provide pointwise measurements of rainfall. Although rain gauge measurements may have numerous problems with the instruments used, data measured at ground level are generally considered more accurate than precipitation estimates from other data sources [5].

The Tipping Bucket Rain Gauge (TBRG) is a device used to measure precipitation using a siphon-controlled tipping bucket rain gauge (RIMCO 7499 series). In a TBRG, the rain falls into the collecting funnel and is directed through a siphon control unit. It has a two-component bucket mounted in unstable equilibrium, where the falling rain discharges as a steady stream. The TBRG method measures the volume of each compartment bucket as the equivalent rainfall of 0.20 mm. [6].

The method for weighing the rainwater collected in the buckets uses the Weighing Rain Gauge (WRG for short). The calculated difference in the amount of rainwater accumulated over time was treated as the rain rate. The accuracy of rain rate measurements is related to the precision of measuring the accumulated water that drains into the measurement chamber from the catchment basin at the sampling interval [6].

An optical rain gauge (ORG) instrument measures the scintillation of infrared light produced by liquid water drops as they fall between a light source and a receiver [7]. The variation of light intensity caused by a given drop is a function of drop size, fall velocity, shape, and the coherence of the light source [6].

Another method of measuring rainfall precipitation is through a multivariable sensor as an automatic weather observing system. This method is known as the Present Weather Detector (PWD). It combines an optical sensor, a capacitive device rain sensor with a double plate, and a thermistor. The optical sensor in this PWD uses forward scattering to measure precipitation amount, visibility, and type, and comprises an optical receiver and transmitter [6].

A rain gauge, initially developed by Joss and Waldogel (1967), uses radar reflectivity to measure drop size. This is the Joss–Waldvogel disdrometer (JWD for short) [8]. An impact-type device measured the drop size with a Styrofoam cone with a sampling cross-sectional area of 50 cm2 [6].

The 2-D video disdrometer method (2DVD for short) comprises two line-scan cameras with a 34.1 kHz rate perpendicular to each other and two light sources. The two (2) light sheets are spaced 6.2 mm vertically from the virtual measurement area of 10 cm × 10 cm [9]. In this system, the measurement is recorded when the three-dimensional shape information of particles passes the sampling area. These are the size, shape, volume, oblateness, and equivalent drop diameter [6].

1.2. Accuracy and Discrepancy of Rain Gauges

The primary source of sampling error for TBRG is in its sampling principle. During the rainfall series, TBRG cannot capture minor temporal variations [10]. It was recorded that there are substantial errors in the one (1) minute estimates at low rain rates. The error decreases substantially as the rainfall timescale increases [11]. The tipping bucket system is a relatively simple device. However, there are still many possible sources of error. Tipping bucket gauges mostly use two (2) buckets that alternately fill and empty to measure rainfall. If there is any mechanical asymmetry between the two buckets, it will lead to measurement errors. During heavy or strong rainfall, the time it takes the bucket to dump and, as it starts, to refill can lead to measurement errors. The high rainfall rates will lead to rapid movement to fill and dump. This mechanical movement of the rain gauge can lead to water loss during accumulation.

Another problem with bucket rain gauges is the mechanism jamming or clogging. This problem is common due to the presence of frogs, insects, or other objects that can enter the mechanism [2].

The Weighing Rain Gauge's (WRG) rainfall measurement is invalid when the collecting pan drains while it is filled with water [6]. WRG is higher, generally considered expensive, and requires more maintenance than a tipping bucket gauge [2].

Regarding the measurement principle, the Optical Rain Gauge (ORG) was limited in its application. This is because ORG is not advisable when the season produces frozen precipitation particles. There are models of ORG that provide uncertainty estimates when used at specific precision levels. Furthermore, compared to other gauges, ORG overestimates the rain rate when there are more small drops. It underestimates the rain rate when raindrops are larger and when the ORG reading is biased high due to higher winds [6], [7].

Problems are identified with the Present Weather Detector (PWD) readings. One of the problems was that it produced false precipitation at relative humidity levels above 70%. Additionally, the PWD overestimates precipitation intensity at higher wind speeds [6]. At the same time, the accuracy of the Joss–Waldvogel disdrometer (JWD) was sensitive to background noise. The reading of JWD underestimates the small raindrops in heavy rain, and when many raindrops hit the Styrofoam [6], [8].

The method of a 2-D video disdrometer cannot measure drops smaller than 0.2mm. This is because of the size of its 2-DVD resolution, which is one (1) pixel of linear CCD. The 2-DVD size causes errors in detecting small drops. Some of its readings may be counted more than once when small drops pass across the measurement area, while others may not be [12]. It was also observed that wind could affect its accuracy by distorting the spatial distribution of raindrops. This may occur when raindrops pass through the measurement area of the measuring device. [6], [13].

1.3. Importance of Remote Sensing Techniques

Most published recommendations for addressing the water crisis in the Philippines suggest that the solution lies in improving the efficiency of water management, particularly in the agricultural sector [14]. Another was the recommendation for continuous data collection to determine water availability from rivers and rainfall, accounting for climatic and terrestrial changes [15]. In the Philippine setting, the National Irrigation Administration (NIA) utilizes a 5-year moving average to determine river discharge. This is the maximum amount of water available and is primarily estimated from analysis of rainfall data and river water profiles [15]. However, stream flow data are not being collected; therefore, outdated data are used to predict water availability.

Water discharge and rainfall data are water profiles that provide information needed to manage and operate any water system [15]. The water system encompasses agricultural irrigation systems, domestic water consumption, and other related uses. It plays a significant part in issues of food sufficiency and farming activities. Therefore, monitoring and observing the stream's water discharge and rainfall precipitation are to be considered.

The Philippine government's water management project is an old program implemented by the National Irrigation Administration. Memorandum orders were issued to properly manage the country's water system. These are Memorandum Circular #032 and MC #046-A s. 1974. These memorandum circulars require the use of measuring devices in all National Irrigation Systems for water management and are reiterated in Memorandum Circulars #043 and #049, s. 2006. The installation of measuring devices in all National systems, consisting of one rain gauge per water-master division and one direct-reading measuring device (staff gauge) per gatekeeper section, was required [16]. These measuring devices measure irrigation water flow and rainfall.

Remote sensing data is widely used to determine rainfall. Remote sensing applications were also used for soil moisture measurements and other data collection and studies, including water delivery scheduling for agricultural irrigation, snow cover extent assessment, snow water equivalent, short-term and seasonal snowmelt runoff forecasts, and surface water inventories [17]. The importance of remote sensing data and geographic information systems is increasing as tools in water resources development and hydrological studies. The required hydrological study and analysis data can be easily obtained using remote sensing techniques. The use of remotely sensed data offers a significant advantage for hydrological modeling. It can be generated in the temporal and spatial domains, which is crucial for a successful model analysis, validation, and prediction [18].

Wireless sensors are highly recommended for remote areas where data monitoring is hazardous or otherwise challenging. This technology varies across applications, such as enhancing sensor flexibility, and can also increase network robustness. Furthermore, wireless technology is economically beneficial because it reduces operational costs and the complexity of maintenance [11]. With this, the Wireless Sensor Network (WSN) is an important technology today. It performs with low-power electronics in the field of micro-sensor technology. WSNs have numerous advantages for application in supervision, particularly for monitoring critical environments, such as profiling bodies of water [19].

The device's remote-sensing system for monitoring the water profile uses a microcontroller circuit. A microcontroller is primarily designed to precisely measure, store, and transmit instrument output, including real-time communication for monitoring systems [20]. It features lower power consumption, is very easy to assemble, and has an economical price [21], [22]. Water quantities, such as temperature, humidity, distance, or height, can be measured using available electronic sensors connected to a microcontroller circuit. When measuring remote bodies of water, these sensors are usually recommended because they are suited for highly sophisticated environmental and industrial applications. Remote bodies of water refer to streams, rivers, ponds, canals, and even oceans. A system could collect data. Measured data is transmitted to a centralized management system via satellite, cellular, or radio communications. The digital sensor system provides long-term durability, accuracy, and rapid time-to-first-measurement. This makes remote water level measurement systems more convenient [23].

Sensors with ultrasonic systems are widely used and have numerous applications, particularly for detecting objects and measuring distance. It features an Ultrasonic Transmitter that emits ultrasonic waves that travel through the air. Any material object that is exposed to the ultrasonic wave is then reflected toward the sensor. In its ultrasonic module, the reflected wave is detected and processed by the program installed on the system. The integration of mobile phones into remote sensing has simplified data collection, as they have become an integral part of human life, serving multiple needs [21]. Short Message Service (SMS) is sent and received on a modern mobile phone, and, via its system, Appropriate Attention (AT) commands originate from the microcontroller. Inside the microcontroller is a circuit designed to control and interface with hardware devices. Before being displayed, the SMS is generated, received, and decoded by this microcontroller circuit. The complete SMS gateway system can be set up for various applications. Some examples are Remote Data Collection Systems and Smart Home Systems. The Main program communicates with Mobile Equipment (ME) via the Global System for Mobile Communications (GSM) protocol, which is used to send and receive SMS messages. A typical ME can be a GSM modem or a mobile phone that interfaces with a microcontroller [24]. This GSM modem is just like a mobile phone. It has a specialized modem that accepts a SIM card and operates over a subscription to a mobile operator [25]. Meanwhile, the AT command protocol communicates over a serial line discipline. These are the basic commands for communication with the GSM mobile phone [24]. It is commonly utilized to transmit information in audio-to-video format. Meandering is the capacity to use a GSM telephone number in another GSM [26]. General Packet Radio Service (GPRS) is another feature in remote sensing systems. It is a packet-oriented mobile data service used in 2G and 3G cellular communications systems and (GSM) communications [27].

Automation for water level switching is a controller using a Smart system. This process automatically activates the control, with continuous updates transmitted via GSM, such as SMS notifications [28]. For an application involving automatic switching that varies with water levels, the signal is sent to the built-in analog-to-digital (A/D) converter in a microcontroller. This converter converts the signal into digital data using programming [25]. Data transmission and communication are methods used by the GSM-SMS. This SMS (Short Message Service) format is suitable for monitoring and profiling areas for field data collection. The system's excellent features included wireless data transmission and sound quality, low costs, low workload, and high accuracy. The design for each module was structured for the monitoring system. In the form of messages, the system takes the liberty of a GSM network [19].

The remote sensing process involves activity in the water; through its sensor, the detector detects the water level, for example, and sends the signal to the microcontroller unit. The microcontroller circuit in this remote sensing device sends a signal to the GSM modem, which then sends an SMS to the mobile phone as a notification alert to the designated person. The current water level status is sent as an alert message to the person in charge, who has a mobile number configured in the microcontroller's AT command [28].

A microcontroller enables a device to remotely sense the required data and transmit it without the need for a human on site. This system will be implemented by supplying solar power to energize the remote sensing device, which contains sensors and circuits. Solar panels are composed of cells made from semiconductor materials, such as cadmium telluride or silicon. This material's electrons are energized when light falls on it. When energy is generated in the solar panel, electrical charges flow, which is known as electrical current. The solar panel typically combines a dozen solar cells in an electrical circuit to produce a usable voltage and power. This power can serve as a source of emergency energy, as it can be stored in a battery, for instance, and later utilized. This renewable electricity is generated by solar panels that depend on the sun's light intensity. Because solar energy relies on sunlight, it is less effective on cloudy days. The standard method for optimizing power collection from solar panels is to back up the systems with batteries that store excess power for later use [30].

2. Materials and Methods

The study developed a remote sensing device to monitor rainfall. It was conducted to provide the data collection needed to consider rainwater as a small-scale water resource for electrical power generation. Simultaneously, this project addresses the required devices for water management by the National Irrigation Administration (NIA) as stated in NIA Memorandum Circulars since 1974. These are the rain gauges, water-level, and discharge-measuring devices for all water resources supplying irrigation farms in the Philippines.

2.1. Device Configuration

The measurement error in rainfall measurements is affected by ground elevation and the device's distance from buildings and trees [31]. To minimize measurement error in rainfall, it is recommended that the device be set to a standard height of 0.30 meters above the ground. These suggested minimum rainfall requirements were considered, as the locally fabricated device has its microcontroller circuit, including the sensors and other activating sensors, installed inside the device’s enclosure, which is 0.30 meters (12 inches) above the ground. The prototype rainfall-measuring device is shown in Figure 3.

The 5W peak solar panel supplied power to the device using a 6V, 2300mAh battery. The device automatically reads and sends data on rainfall precipitation. The device system automatically drains the water after the precipitation reading to ensure an accurate measurement. No precipitation reading was recorded despite actual rain, as indicated by the device's rain sensor. Through Arduino, the rainfall precipitation reading from the device was sent via SMS at 9:00 AM and 2:00 PM. However, suppose it rains during data transmission. In that case, the device will wait until the rain stops before measuring the rainfall precipitation inside the device’s bucket.

The device's system uses sensors that detect the presence of water in the funnel and bucket. After reading the precipitation, the system automatically drains the bucket by opening the servo motor.

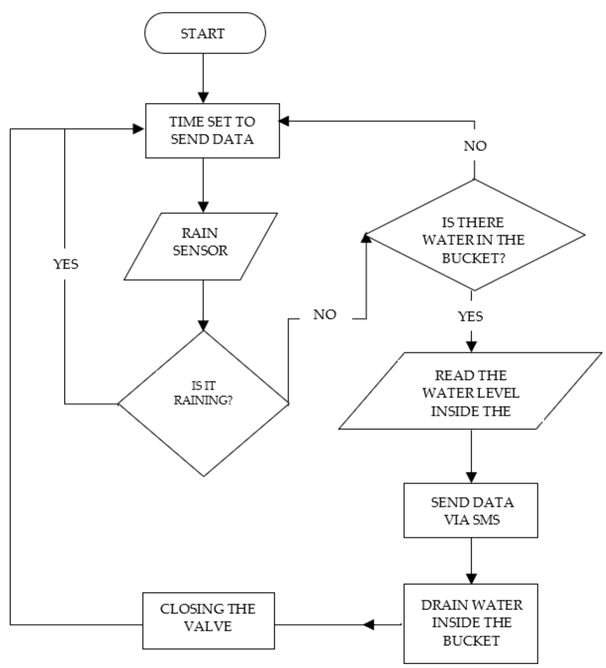

Figure 1. System Flow of the Automated Rainfall Measuring Device

As shown in Figure 1 above, the system of rainfall monitoring devices was programmed to automatically send precipitation readings at the scheduled times, 9:00 AM and 2:00 PM. The sending schedule was the same as the PAGASA monitoring system. Figure 1 further shows that there will be no precipitation reading if rain remains. The device will measure precipitation only when the rain stops. After reading the precipitation, the device sends the reading via SMS, and the servomotor automatically opens to drain the bucket and then closes the valve. This process was repeated to ensure continuous data collection.

A solar panel was designed to supply the prototype water precipitation monitoring device. The system's hardware is powered by a 12V battery, which is protected by a solar charger controller that safeguards both the battery and the entire system. The solar power supplies energy to the Arduino UNO R3, which is equipped with an ATMega328p board, set up to control the HR-SC04 ultrasonic sensor and the SIM900A Dual GSM module. The device's electronic circuit uses a DC-to-DC buck converter to convert the 12V battery voltage to a 5V DC output. The GSM modules, rain sensor, servomotor valve, and ultrasonic sensors are connected to the microcontroller using the printed circuit board.

2.2. Rainfall Precipitation Measurement

Two (2) measurements were taken in the rainfall precipitation experiment: automatic readings from the device and manual measurements. These measurements were collected to validate the device reading. The rainfall precipitation sent by the device was computed using equation (4) shown below [32].

$$\boldsymbol{V_F = A\ x\ h} \quad (1)$$
$$\boldsymbol{V_B = \pi r^2 d} \quad (2)$$
$$\boldsymbol{V_F = V_B} \quad (3)$$
$$\boldsymbol{h = \frac{A}{\pi r^2 d}} \quad (4)$$

Where;

V_F - is the volume of the funnel

V_B – is the volume of the bucket

A - is the area of the funnel (326.7 cm2)

r - radius of the bucket (cm)

d – depth of the water inside the bucket (cm)

h – height of the funnel equal to the rainfall precipitation (mm)

2.3. Data Validation

Data validation was performed using a statistical method to test for significant differences between the two variables. The two values were the data measured by the device and the manual measurements observed. These two data sets were observed simultaneously in an experiment. These are the rainfall precipitation values obtained by manual measurement and by the device.

2.4. Solar Panel and Battery Sizing

The solar panel(s) and battery sizing are crucial for ensuring the device's power supply remains uninterrupted. When designing the size of photovoltaic (PV) modules, their location will be the starting point, because PV performance is directly proportional to the amount of sunlight it receives, which is called solar irradiance [33] – [36] (Concord Battery Corp.). Solar irradiance is the light intensity from the sun in Watts per square meter falling on a panel’s flat surface at the specific location of the application. In the Philippine setting, it is recommended that the solar irradiance at the PV flat surface be measured at any given time, equivalent to approximately 4.5–5.5 kWh/m²/day [33]–[36]. Another factor to consider in PV and battery sizing is the Depth-of-Discharge (DoD) and the Number of Days of Autonomy. To provide the necessary electrical energy using solar energy, the battery storage system is designed to determine the Days of Autonomy. Typically, the Days of Autonomy are equivalent to seven (7) days without any sunlight. However, for a time considered as a moderate level of storage, autonomy applications may use three (3) to four (4) days of storage [33] – [36]. The allowable depth of discharge of a battery storage system is the maximum fraction of its capacity that can be withdrawn. The typical Depth-of-Discharge of a good, new battery is 0.8. [33] – [36]. The battery and PV sizing are computed using Equations (5) and (6) shown below [33]–[36].

$$E_{bat} = \frac{T_1\ x\ DA}{DoD} \quad (5)$$
$$PV = \frac{Tl}{DI} \quad (6)$$

Where;

Ebat: battery capacity (Whr/day)

Tl: total Watt hour per day (Whr/day)

DA: Number of recommended days of Autonomy (3 days)

DoD: Depth-of-Discharge of the battery (80%)

PV: Photovoltaic Size

DI: Daily Insolation (5.42Watts/m2)

3. Results

3.1. Locally Fabricated Rainfall Precipitation Monitoring Device

Figure 2 below shows the body of the completed remote sensing device used to monitor rainfall. The locally fabricated device is powered by solar energy, enabling the system to operate for up to three (3) hours without sunlight. The device enclosure protects the system circuit against rain and wind. It was covered with a shade protector made of galvalum material.

The remote sensing device shown in Figure 3 stands at a total height of 34 inches (0.86 m). The device's stand and bucket are 12 inches, making the funnel height equal to 10 inches. As shown in Figure 3, the device's enclosure, which contains the circuits that detect and determine precipitation, including the microcontroller circuit and sensors, is installed 12 inches (0.30 m) above the ground. The device enclosure's height is as suggested by the standard height of 0.30 m [31].

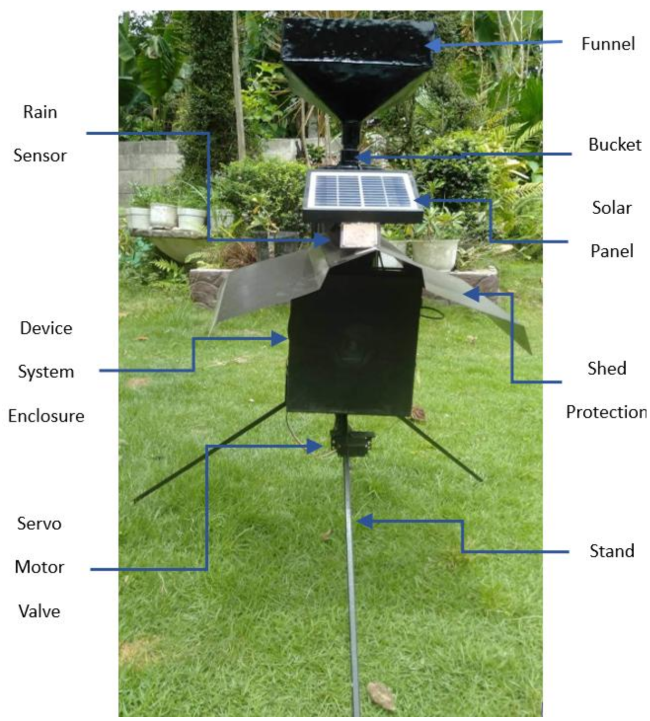

Figure 2. Body Part of Automated Rainfall Measurement Device

Figure 3. Height Dimension of the Automated Rainfall Measurement Device

3.2. Observed Rainfall Precipitation and Data Validation

The manual and device rainfall measurements were taken simultaneously during testing to determine the significance of the difference between them. The first test of the device measurement was done manually by pouring water into the device bucket. The device was programmed to measure the water level inside the bucket, and a manual depth measurement was also performed. The second measurement was taken during the rain. The device will automatically measure the water depth in the bucket and send the result via SMS at the programmed time. A simultaneous manual measurement was also performed in this experiment. These two types of measurements were conducted to evaluate and validate the fabricated device.

Data validation refers to the statistical analysis used to verify rainfall measurements and compare manual and device measurements. The statistical results in Table 1 below show the paired variables and manual and device measurements of rainfall. At the significance level, $\alpha = 0.05$, the result's significant value of 0.629 is greater than the significance level 0.05 (0.629 < 0.05). The results of this study further show that the paired values of manual and device rainfall measurements were statistically and significantly the same.

3.3. Energy Consumption

Tables 2 and 3 below provide summaries of the remote sensing device's connected load for rainfall monitoring, as well as recommended battery and solar panel sizing. Although the electronic parts of the device did not consume all the energy for 24 hours, the computation for sizing the solar panel and battery was assumed to be at 24-hour continuous loads. This is to provide a spare electrical power source within the battery bank in case of continuous low charging due to insufficient sunlight. The total power load connected, as shown in Table 2, was 14.91 watt-hours per day, which recommends a one (1) 3-watt peak solar panel and one (1) 12-volt, 5-ampere-hour battery, as shown in Table 3 below.

Table 1. Hypothesis and Paired Samples Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	VAR00004 - VAR00005	-.09167	0.43669	.17828	-0.54994	0.36661	-.514	5	0.629

Table 2. Load Computation

Parts	Rated Voltage	Quantity	Rated Ampere	Operation hours, day	Watt Hr / Day
Servo Motor	4.8-6V	1	60.4mA	24	6.958
SIM900A	3.4 -4.5 V	1	1.5mA	24	0.120
Arduino UNO	5V	1	50mA	24	6.000
Rain sensor	3.3-5V	1	15mA	24	1.260

JSN-SR04T-2.0 (Ultrasonic Sensor)	DC 3.0-5.5V	1	> 8 mA	24	0.576
Total					14.91

Table 3. Recommended Battery and Solar Panel Size

Total Load (Whr/day)	Total Energy Operation (Amp-Hr)	Recommended Battery Size (Amp-Hr)	Peak Power (Watt Peak)	Recommended PV Size (Watt Peak)
14.91	4.65	12V, 5Amp.Hr	2.75	3WPeak

4. Conclusions and Recommendations

The reading from the automated rainfall-measuring device is one of the most important validations of the locally fabricated device. Using the ten (10) trials of paired values, the manual measurement, and device measurement, this study recommends using this device for rainfall monitoring. This research study enables the mandatory, immediate installation of measuring devices and rain gauges in the irrigation system in the Philippines. This has been the government's memorandum circular since 1974 and was reiterated in 2006. Since this device can be replicated, it could be used in all water resources across the country. At the same time, the measured data could serve as secondary data for hydrological studies related to agricultural irrigation and energy-related research.

Although this device has been tested and experimentally validated, further testing is still recommended to validate its data reading. This study further recommended the problems encountered during the fabrication and testing. If a rainfall-measuring device is fabricated, it is recommended that the bucket part have no connection couplings, as the conversion of sound into depth measurement is affected. To secure the measured data, it is also recommended that an additional device feature, such as a data logger, be provided. The data logger will secure the data measurements even if there is no SMS load in the GSM Module.

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References

1. Gires, A. (2018). How do we measure rainfalls? https://kids.frontiersin.org/articles/10.3389/frym.2018.00038
2. Michaelides, S., Levissani, V., Anagnostou, E., Bauer, P., Kasparis, T., Lane, J.E., “Precipitation: Measurement, Remote Sensing, Climatology and Modeling,” Atmospheric Research, vol., 94, No.4, pp. 512–533, 2009. DOI: 10.1016/j.atmosres.2009.08.017
3. Kidd, A., and Huffman, G., “Review Global Precipitation Measurement,” Wiley Online Library, vol., 18, pp. 334–353, 2011. DOI: 10.1002/met.284
4. Andres, J.F., Loretero, M.E., “Energy Equivalent of Rainwater Harvesting for High-Rise Building in the Philippines,” Civil Engineering and Architecture, vol. 9, No. 1, pp. 74 - 84, 2021. DOI: 10.13189/cea.2021.090106
5. Gilewski, P. and Nawalany, M., (2018). “Inter-Comparison of Rain-Gauge, Radar, and Satellite (IMERG GPM) Precipitation Estimates Performance for Rainfall-Runoff Modeling in a Mountainous Catchment in Poland,” MPDI Water, vol., 10, No.11, pp. 1665, 2018. DOI: 10.3390/w10111665
6. Liu, X.C., Gao, T.C. and Liu, L, “A Comparison of Rainfall Measurements from Multiple Instruments”, Atmospheric Measurement Techniques, vol. 6, No. 1, pp. 519 – 546, 2013. DOI: 10.5194/amt-6-1585-2013
7. Nystuen, J. A., “Relative Performance of Automatic Rain Gauges under Different Rainfall Conditions”, Journal of Atmospheric and Oceanic Technology, vol. 16, No. 8, pp. 1025–1043, 1999. DOI: 10.1175/1520-0426(1999)016%3C1025:RPOARG%3E2.0.CO;2
8. Tokay, A., Kruger, A., and Krajewski, W. F., “Comparison of Drop Size Distribution Measurements by Impact and Optical Disdrometers,” Journal of Atmospheric and Oceanic Technology, vol. 30, No. 8, pp. 1672 – 1690, 2001. DOI: 10.1175/JTECH-D-12-00163.1
9. Kruger, A. and Krajewski,W. F., “Two-Dimensional Video Disdrometer: A Description,” Journal of Atmospheric and Oceanic Technology, vol. 19, No. 5, pp. 602 – 617, 2002. DOI: 10.1175/1520-0426(2002)019%3C0602:TDVDAD%3E2.0.CO;2
10. Habib, E., Krajewski, W. F., and Kruger, A. “Sampling Errors of Tipping Bucket Rain Gauge Measurements,” Journal of Hydrologic Engineering, vol. 6, No. 2, pp. 159–166, 2001. DOI: 10.1061/(ASCE)1084-0699(2001)6:2(159)

11. Wang, J., Fisher, B. L., and Wolff, D. B., "Estimating Rain Rates from Tipping-Bucket Rain Gauge Measurements," Journal of Atmospheric Oceanic Technology, vol 25, No.1, pp. 43–56, 2008. DOI: 10.1175/2007JTECHA895.1
12. Nespor, V., Krajewski,W. F., and Kruger, A., "Wind-Induced Error of Raindrop Size Distribution Measurement using a Two-dimensional Video Disdrometer", Journal of Atmospheric Oceanic Technology, vol. 17, No. 11, pp. 1483–1492, 2000. DOI: 10.1175/1520-0426(2000)017<3C1483:WIEORS>3E2.0.CO;2
13. Leijnse, H. and Uijlenhoet, R., "The Effect of Reported High Velocity Small Raindrops on Inferred Drop Size Distributions and Derived Power Laws," Atmospheric Chemistry and Physics, vol. 10, pp. 6807–6818, 2010. DOI: 10.5194/acp-10-6807-2010.
14. Inocencio, A., Barker, R., "Current Challenges in Agricultural Water Resource Development and Management in the Philippines," DLSU Business & Economics, vol. 28, pp. 1-17, 2018. DOI: https://www.dlsu.edu.ph/wp-content/uploads/2019/03/1-inocencio-072418.pdf
15. Maglinao, A.R., Cablayan, D.M., Undan, R.C., Moya T.B., and Pascual, C.M., "Main Irrigation System Management for Rice-Based Farming Systems in the Philippines," IIMI-IRRI, pp. 59 – 97, 1990. DOI: https://cgspace.cgiar.org/bitstreams/181730cb-adbf-4a30-8739-823f58d815ff/download
16. Julian, S.I., "Water Management in Philippine Irrigation System. Technical Report: Philippines," pp. 283-290. https://www.jircas.go.jp/sites/default/files/publication/tars/tars9-_283-290.pdf
17. RANGO, A., "Application of Remote Sensing Methods to Hydrology and Water Resources," Hydrological Sciences Journal, vol. 39, No. 4, pp. 309-320, 1994. DOI: 10.1080/02626669409492752
18. Mustafa, B. Y.M., Amin, M.S.M., Lee, T.S. and Shariff, A.R.M, "Evaluation of Land Development Impact on a tropical Watershed Hydrology Using Remote Sensing and GIS," Journal of Spatial Hydrology, vol. 5, No. 2, pp. 16-30, 2005.
19. Abdullah, U., and Ali, A., "GSM Based Water Level and Temperature Monitoring System," International Journal of Recent Development in Engineering and Technology, vol. 3, No.10, pp. 311-317, 2016. https://www.jetir.org/papers/JETIR1610048.pdf
20. Mounika, J., Siva, K.R.N., "Water Monitoring System Based on GSM," International Advanced Research Journal in Science, Engineering and Technology, vol. 3, No.7, pp. 233-236, 2016. https://iarjset.com/upload/2016/july-16/IARJSET%2048.pdf
21. Kansara, K. Zaveri, V., Shah, S., Delwadkar, S., Jani, K., "Sensor Based Automated Irrigation System with IOT: A Technical Review," International Journal of Computer Science and Information Technologies, vol. 6, pp. 5331-5333, 2015. http://dx.doi.org/10.13140/RG.2.1.3342.3129
22. Patel, N., Lanjewar, R.B., Mathurkar, S.S., Bhandekar, A.A., "Microcontroller Based Drip Irrigation System Using Smart Sensor," 2013 Annual IEEE India Conference (INDICON), Mumbai, India, 2013, pp. 1-5, DOI: 10.1109/INDCON.2013.6726064.
23. Senix Corporation (2018), Remote Water Level Sensor https://senix.com/remote-water-level-sensor-applications/?gclid=EAIaI QobChMIjtLa6MKI3AIVyxwrCh2tbgFFEAAYASAAEgJbDBwE. Date Accessed: February 15, 2020.
24. Chowdhury, E.H., Atahary, T., Khadem, S.K., "Design and Development of Microcontroller Based SMS Gateway for GSM Mobile;" University of Liberal Arts Bangladesh, Dhanmondi, India, 2018. https://www.reasearchgate.net/publication/242049549 Design and Development of Microcontroller Based SMS Gateway for GSM Mobile
25. Yuvarani, T.S., and Archana, R., "Water Level Monitor, Control and Alerting System Using GSM in Dams and Irrigation System Based on Season," International Journal of Scientific & Engineering Research, vol 7, no. 4, pp. 135-137, 2016. https://www.studocu.com/row/document/university-of-ghana/embedded-system/water-level-monitor-control-and-alerting-system-using-gsm-in-dams-and-irrigation-system-based-on-season/13587624
26. Sathishkumar, V.S., et al., "LABVIEW Based Thermal Power Plant Monitoring and Controlling Using GSM Technology," International Journal of Intellectual Advancements and Research in Engineering Computations, vol. 6, no. 1, pp. 225-230, 2018. www.ijiarec.com.
27. Al-ALi, A.R., Zualkerman, I., Aloul F., "A Mobile GPRS-Sensors Array for Air Pollution Monitoring," IIEE Sensors Journal, vol. 10, no. 10, pp. 1666-1671, 2010. DOI: 10.1109/JSEN.2010.2045890.
28. Pudasaini, S., Pathak, A., Dhakal, S., Paudel, M., "Automatic Water Level Controller with Short Messaging Service (SMS) Notification," Internation Journal of Scientific and Technology Research, vol. 4, no. 9, pp. 1-4, 2014.
29. Johari, A., et al., "Tank Water Level Monitoring System using GSM Network," International Journal of Computer Science and Information Technologies, vo. 2, no.3, pp. 1114-1120, 2011.
30. Metcalfe, T., "How Do Solar Panels Works," http://www.nbcnews.com/mach/amp/ncna957231. Date Accessed: February 15, 2020.
31. Australian Government, Bureau of Meteorology, "Observation of Rainfall," http://www.bom.gov.au/climate/cdo/about/rain-measure.shtml. Date Accessed: March 8, 2022.
32. Kern, W. F., Bland, J.R., "Volume for which V=Bh", Solid Mensuration with Proofs, 2nd Ed., of John Willy & Sons, Inc., 1987, pp. 18-42.
33. Bhatia, A., "Design and Sizing of Photovoltaic Systems," CED, info@cedengineering.com Date Accessed: January 16, 2022.
34. Japan International Cooperation Agency, and Department of Energy Renewable Energy Management Bureau. "Manual for Solar Photovoltaic Training," Annex 3: Solar PV technology Training Text, 2009.

35. Khamisani, A.A., “Design Methodology of Off-Grid PV Solar Powered System – A Case Study of Solar Powered Bus Bar,” Eastern Illinois University, https://www.eiu.edu/sustainability//energy/Design%20Methodology%20of%20Off-Grid%20PV%20Solar%20Powered%20System_5_1_2018.pdf Date Accessed: January 13, 2022.
36. Concord Battery Corporation, “Battery Sizing Tips for Stand-Alone PV Systems,” https://batterymanagement.concordebattery.com/BatteryDocs/sunextenderbatterysizingtips.pdf Date Accessed: January 16, 2022.