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Arduino Based Atmometer for Recording Evaporation

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ABSTRACT

A fabricated atmometer was improved using Arduino and ultrasonic sensor for sensing evaporation. HC-05 Bluetooth module was used to record the change of atmospheric evaporation in atmometer. The study was implemented at Agrometeorological Station and the data gathered were analyzed through T-test to compare the Atmometer with Arduino Sensor versus Atmometer (manual reading) and Open Pan for measuring evaporation.

Based on the results, there is no significant difference between the Open pan and Arduino based atmometer, and between the Atmometer and Arduino based atmometer with a greater p-value of 0.369 and 0.788 respectively. However, there is a significant difference between the Atmometer and Open pan with a p-value of 0.0043 at 95% level of confidence. Since the Arduino with sensor is connected to the atmometer having a positive relationship, it is recommended to use in the field. Thus, both needs calibration and further improvement before using it in measuring evaporation rate disregarding the result of the analysis in comparison to the actual evaporation.

Keywords: atmometer, evaporation, microcontroller, ultrasonic sensor, reliability

INTRODUCTION

The traditional method of farming is undertaken manually, by engaging individual farmers in almost all stages of crop development and monitoring and control of the processes involved at all stages of irrigation farming. From time-to-time, these processes replaced with semi-automated and automated processes, to aid farmers and improve agricultural productivity (Abba et al., 2019).

Precision irrigation involves the accurate and precise application of water to meet the specific requirements of individual plants or management units and minimize adverse environmental impact. It utilizes a systems approach to achieve differential irrigation treatment of field variation as opposed to the uniform irrigation treatment that underlies traditional management systems (Shah & Das, 2012).

Irrigation scheduling enables the irrigator to apply the almost exact amount of water to achieve the goal of providing the needs of crops. This increases irrigation efficiency. A critical element to achieve this, is the accurate measurement of the volume of water applied or the depth of application. A farmer cannot efficiently manage water and maximum efficiency without knowing how much water should be applied (Sherburne Soil and Water Conservation, 2016).

Further, in the field of agriculture, use of a proper method of irrigation is important. The advantage of using this method is to reduce human intervention and still ensure proper irrigation. Most of the irrigation systems are manually operated. These traditional techniques can be replaced with automated techniques of irrigation in order to use the water efficiently and effectively. Conventionally, farmers are required to be present in their fields to do irrigation process. Nevertheless, nowadays farmers need to manage their agricultural activity along with other occupations. A sensor based automated irrigation system provides promising solution to farmers where the presence of a farmer in field is not compulsory during irrigation process.

An automatic irrigation system does the operation of a system without requiring manual involvement of persons. Every irrigation system such drip, sprinkler and surface get automated with the help of electronic appliances and detectors such as computer, timers, sensors and other mechanical device. Atmometer is an instrument for measuring the rate of water evaporation by tracking the crop water use in the field and allow users to know when irrigation should be initiated. The atmometer user selects the maximum amount of water that a crop can use before it needs to be irrigated. Moreover, wireless-based water level monitoring and control systems using Arduino and Bluetooth modules can monitor the levels of water present in any tank (Asha & Srija, 2020).

The Arduino receives the level of information from the sensors and tracts the water level with the predefined level indicators. The Bluetooth module receives the command from the Arduino and at the same time it will be transferred to the registered mobile through Bluetooth. Thus, there is a need to automate atmometer to ease the labor-intensive requirement of monitoring the crop water use of the crop. The use of the localized automated recording atmometer is significant for sound irrigation scheduling and monitoring. This study works as a potential solution to the problems encountered in manual irrigation and monitoring of evaporation. The benefits concentrate to the farmers in areas where there is no standard meteorological data available, in irrigation scheduling of both the farm and extension level to prevent excessive irrigation and insufficient irrigation. The result is also significant to future researchers wherein this study may provide important resources and possible information for parallel studies to be conducted.

Objective of the Study

The general objective of the study is to improve and validate the automated localized atmometer for irrigation scheduling. Specifically, the study aims to:

1. Improved the localized automated recording atmometer;
2. Test the performance of the improved atmometer; and
3. Compare the evaporation measurement with the following;
   a. Arduino Based Atmometer vs Atmometer (Manual Reading)
   b. Arduino Based Atmometer vs Open Pan (Standard)

RELATED WORKS

Estimation of Crop Evapotranspiration (ETc) for specific crops is important for irrigation scheduling and agricultural water management. Alternative methods of estimating Reference Crop Evapotranspiration (ETr) do not require complex calculations or sophisticated data recording equipment. Devices that measure the evaporation of water such as atmometers may be useful which is designed to simulate ET from a plant canopy in a way that agrees closely with a plant’s resistance to ET. Atmometers have been gaining acceptance among irrigators. Figure 1 shows the model of Evapotranspiration Gage (ETG) by Irmak et al. (2005). On the research of Cerezo and Dumalian (2018), an atmometer can be an alternative tool for estimating Reference Evapotranspiration (ET0) because it has several advantages compared to evaporation pans and other data from meteorological stations. It is simple, inexpensive and provides a visual interpretation of ET0. The locally fabricated atmometer consists of PVC pipe, PVC plug, ruler, grinding wheel or carborandum, paint, grab adhesive, plastic tube, recyclable cloth, pen, sight level hose and hose valve. Its height is 30 cm with a diameter of 3” and the grinding wheels or carborandums used are 4”, 5”, 6” in diameter.

Magliulo, d’Andria, and Rana (2003) had concluded that atmometers (ET gage) are suitable for automated irrigation management and represent a feasible solution to the problem quantifying crop water needs. On the basis of reported data, the use of atmometer could be recommended in irrigation scheduling at both farm and extension level, whenever standard data are not available. Hassan et al. (2018) presented an automated irrigation system based on Arduino microcontrollers. In this system, a soil moisture sensor is used to detect and check the soil humidity of the plant. Based on the soil moisture level from the soil, the system will let the water pump to automatic water the plant when it is too dry and turn of the water pump when the soil of the plant is wet.

Furthermore, Rajesh (2021) made an Automatic Irrigation System with an Arduino Uno which will irrigate the plants automatically and keep them healthy even when you are out of the town for weeks or months. In addition, research study of Sarkar et al. (2018) an Arduino Based Automatic Plant Irrigation System with Message Alert wherein in this Plant Watering System, Soil Moisture Sensor checks the moisture level in the soil and if moisture level is low then Arduino switches on a water pump to provide water to the plant. Water pump gets automatically off when system finds enough moisture in the soil. Whenever system switched on or off the pump, a message is sent to the user via GSM module, updating the status of water pump and soil moisture.

The irrigation system involving the ultrasonic sensor is able to automatically start/stop water on the irrigation site based on the water level in the reservoir. The measured sensor values are sent to the Arduino microcontroller for configuring the control algorithm (Ogidan, Onile, & Adegboro, 2019). Mehta et al. (2018) designed a model of automatic irrigation system which is based on microcontroller ATMEGA328. Temperature, light and soil moisture sensors are placed in the field. Sensors sense the respective parameters of the soil and give the information to farmer through HC-05 Bluetooth Module. Farmer gets to know the status of the parameters via Bluetooth Module without going into the field directly on the Smartphone.

In addition, Nikitha et al. (2018) proposed a Bluetooth based smart wireless sensor network for monitoring an Agricultural Environment wherein signals are sent from Smartphone through the Bluetooth HC05 to the Arduino Uno. Pan evaporation is weather measurement system that integrates several climatic conditions including rainfall, humidity, solar radiation, wind, temperature and drought dispersion. The system distinguishes the rates of evaporation based on the weather factor. The rate of evaporation is highest during hot, sunny, windy, and dry days and low during cloudy, calm and humid weather. Although pan evaporation is no longer popular among researchers and scientist due to the emergence of better and more accurate technologies, pan evaporation is popular among farmers who seek to determine the amount of required by their crop (Kiprop, 2018).

Class A tank evaporimeters are used because of their simplicity, low cost and proven ease of application in determining crop water requirements for irrigation scheduling (Stanhill, 2002). Nevertheless, Class A pans must be maintained on a regular basis by renewing the water in the pan to avoid turbidity. They should be kept free of algae or other organic growth because of their effects on evaporation rates. Pans must also be kept fenced to prevent animals from drinking from them. Moreover, pans can also act as a heat source/sink. The heat storage by water in the pan can cause a higher multi-day average evaporation rate rather than the true daily evaporation (Irmak et al., 2005). Atmometers would be appropriate for scheduling deep-rooted irrigated crops in humid regions with long growing seasons in which the irrigation interval is not less than 5–7 days (Knox et al., 2011).

METHODOLOGY

Improving of Atmometer using Arduino Sensor

The main components used in the automation of the fabricated atmometer by the previous researchers Dalas and Guyon (2020), are Arduino UNO board, Ultrasonic sensor, Micro SD adapter, LCD display (16 x 2), and SD card (1064 terabytes). Other components used are Breadboard, Jump wires, 9 volts Battery, and USB connector. These components were also used in this study for further validation and improvement. The device was improved adding the following materials: Hc-05 Bluetooth Module, Micro SD Card Module, 10, 000 mAh Power Bank, 9V Battery, and 12V Blower Fan.

Research Design

The design used in this study bears a close resemblance to the design used by Shakoor (2016). The programming and components installation are done and test at Agrometeorological station and outside the school premises. The project contains two parts which is the hardware and software implementation. To be able to interpret the evaporation rate as prompted by the ultrasonic sensor the microcontroller was programmed and the Arduino Integrated Development Environment (IDE) was used. The idea was based on C++ and thus can be extended using C++ libraries. Arduino programs (sketches) are cross platform, simple, clear and at the same time flexible for advanced programmers. Monk, 2012 have defined programming language used to program Arduinos as a language called C. In Arduino, programs are called as sketch, a list of instructions to be carried out in the order that they are written down.

Data Gathering Procedure

Evaporation rate from the Open pan (standard), Atmometer, and Arduino based atmometer were collected at an Agrometeorological Station. The determination of actual evaporation rate was determined through hook gauge reading in the open pan. Evaporation rate from the atmometer was collected through the sight level tube of the device while data from the Arduino based atmometer was obtained through the application used that was connected on android phones and laptops.

Block Diagram of Arduino Based Atmometer

Figure 1 shows the block diagram of the improved Automatic Recording Atmometer using Arduino UNO in which a 10,000 mAh power bank served as the source of power. The ultrasonic sensor was programmed in the microcontroller where it detects the water level in the atmometer. The detected values of the water level in the atmometer were encoded in the microcontroller unit, which is a platform device called Arduino UNO. The data logger automatically records the change in the level of water every 8am to 2pm every day. The detected water level value and the time were displayed on the phone where the HC-05 Bluetooth module is connected via Bluetooth Application and automatically recorded on the micro SD.

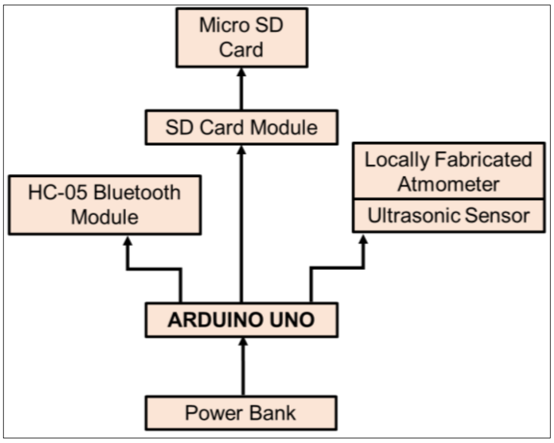


Figure 1. Block Diagram of the Arduino Based Atmometer

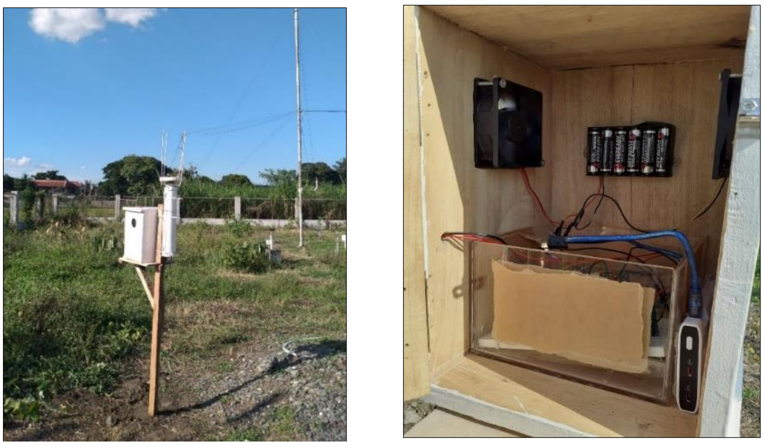
Statistical Tools

The results gathered were analyzed through t-test analysis at 95% level of confidence to test the significance between the evaporation rate measurement that was obtained from the fabricated atmometer, Arduino based atmometer, and open pan.

RESULTS AND DISCUSSION

Description of the Automated Localized Atmometer

After improving the fabricated atmometer, connecting and programming all the components for automation, the preliminary trials was conducted**.** The ultrasonic sensor is installed inside the fabricated atmometer. A prototype housing made up of wood is constructed having two purposes: (1) it serves as support system of the fabricated atmometer, (2) it serves as shield for the Arduino system. Two fans were installed inside the housing that serve as ventilation for the microcontrollers not to overheat. The atmometer is placed on the support system at a height of about 1 meter from the ground. While the modules and microcontroller are placed in an acrylic glass inside the prototype housing and are kept together with wires as shown in Figures 2(a) and (b).



(a) (b)

Figure 2: (a) Installation of the Automated Atmometer; (b) Modules and microcontroller placement

Testing the Performance of Arduino based Atmometer

In preliminary testing, two tests were considered. First was the testing of materials and components (Figure 3(a)). Second was the field testing at Agrometeorological Station (Figure 3(b)) which is the open pan was located. During the preliminary tests of the automated atmometer there were a lot of problems encountered that needed to be resolved first before proceeding in the proper conduct of the study. The problems observed by the researchers is the water in the atmometer is not diminished and/or reduced, the Bluetooth connection is not stable, the detected level of water by the ultrasonic sensor did not matched with level of water shown at the scale of the atmometer and the prototype housing is moving or not steady causing the sensor sending not stable data.

With this problems encountered, a solution were performed to address the problems stated above is to remove the Teflon cloth and was replaced with aluminum foil, some adjustments and corrections on the coding are done, and the atmometer and the prototype housing is fixed to avoid unnecessary motions that can affect the ultrasonic sensor.

(a) (b)

Figure 3: (a) Testing of the components; (b) Field testing

Evaporation Rate Measured at Three Methods

Table 1 shows the mean evaporation rate measured by the different measuring devices used wherein data from the open pan has the highest total of 80.30 mm evaporation, seconded by 58.40 mm from the Atmometer, then followed by the Arduino based atmometer having a total evaporation of 54.40 mm. It can be gleaned in the table that data from the Arduino based atmometer has 2 missing data resulting with 12 samples. This is because the sensors, Arduino, and jump wires are not stable on that day and need recoding and replacement of wires. Negative values were due to heavy rainfall which affects the water level inside the atmometer that recorded by the ultrasonic sensor. To solve the problem, the rainfall data gathered by the Agrometeorological Station is obtained and was added to the data on the same day. This problems affirms on the finding of Irmak et al. (2005) that rainfall may play a significant role in this underestimation because the wetness of the canvass cover and the membrane as well as the accumulation of rainwater that would cause a reduction in the vapor pressure gradient between the plate surface and the surrounding air on rainy days.

It also appears that the total evaporation from the Atmometer Sight level tube and Arduino based atmometer is underestimated compare to the actual evaporation from the open pan. This confirm the study of Magliulo et al. (2003) which state that comparisons with Class 'A' mean weekly ET0 during two consecutive irrigation seasons, indicated a slight underestimation of pan ET0 by the atmometer. On the basis of experimental evidence, atmometer may be used for reliable ET0 estimates under Mediterranean conditions, at both the farm and the extension level, whenever standard meteorological data are not available.

Table 1. Evaporation rate of three measuring method (mm)

Day	Atmometer	Arduino with Ultrasonic Sensor attached inside the Atmometer	Open Pan
1	5.70	2.20	4.60
2	3.50	6.00	6.30
3	5.00	-1.50	6.00
4	3.50	7.50	6.80
5	4.50	-	5.90
6	3.00	-	6.00
7	4.00	8.50	5.30
8	3.50	3.50	7.00
9	3.50	3.50	6.90
10	4.00	3.50	6.20
11	3.50	11.00	6.70
12	3.30	-3.70	5.00

13	8.70	9.70	4.00
14	2.70	4.20	3.60
TOTAL:	**58.40**	**54.40**	**80.30**

Comparison of Atmometer vs Open Pan for Measuring Evaporation

Table 2 provides the mean and the value of t-test wherein it can be seen that open pan yield higher mean of 5.73 mm compared to the atmometer with 4.17mm value. The t-test shows that there is a significance difference between mean value from the atmometer and the open pan (P-value <0.05). This implies that the atmometer need calibration and further improvement before using in measuring evaporation. The results confirm the findings of Diop et al. (2015) which state that values from atmometers need to be calibrated before using them in irrigation scheduling. Most of the study comparing atmometers and the ETo_PM showed that a calibration is needed.

Table 2. Comparison between Atmometer and Open pan.

	Atmometer	*Open Pan*
Mean	4.17	5.73
Variance	2.33	1.18
Observations	14	14
Pooled Variance	1.75	
Hypothesized Mean Difference	0	
Df	26	
t Stat	-3.13	
P(T<=t) one-tail	0.002	
t Critical one-tail	1.70	
P(T<=t) two-tail	0.004	
t Critical two-tail	2.05	

Arduino based Atmometer vs Open Pan for Measuring Evaporation

Table 3 gives the t-test analysis for the evaporation from Arduino and open pan wherein the mean evaporation reference is smaller for Arduino compared to open pan. The mean value of the open pan has no significant difference from the mean of the Arduino (P-value > 0.05). This implies that the Arduino based atmometer in compare to the actual evaporation measured by the open pan can be used for evaporation measurement.

Table 3. Comparison between Arduino and Open Pan

	Arduino	*Open Pan*
Mean	4.53	5.73
Variance	18.92	1.18
Observations	12	14
Hypothesized Mean Difference	0	
Df	12	
t Stat	-0.93	
P(T<=t) one-tail	0.18	
t Critical one-tail	1.78	
P(T<=t) two-tail	0.37	
t Critical two-tail	2.18	

Atmometer vs. Arduino based Atmometer for Measuring Evaporation

Table 4 shows the t-test analysis between the Atmometer Sight Level Tube vs. Arduino w/ Bluetooth Module wherein calculated p-value shows a greater value of 0.788 than 0.05 which means that there is no significant difference between the two variables.

Table 4. Comparison between Atmometer and Arduino

	Atmometer	*Arduino*
Mean	4.17	4.53
Variance	2.33	18.92
Observations	14	12
Hypothesized Mean Difference	0	
Df	13	
t Stat	-0.27	
P(T<=t) one-tail	0.39	
t Critical one-tail	1.77	
P(T<=t) two-tail	0.79	
t Critical two-tail	2.16	

Since the atmometer and the Arduino with Bluetooth module is connected to each other having a positive relationship, both needs calibration and further improvement before using it in measuring evaporation rate disregarding the result of the analysis in compare to the actual evaporation.

The results of the study contradict the findings of Diop et al. (2015) and Knox et al. (2011) wherein correlation between ET from atmometers and ETr_ PM or ET0_ PM estimates were generally good. The results indicated that with the proper regression equation and a good calibration, atmometers could be used to estimate ET for crop water requirement where evapotranspiration estimates are not available from weather stations.

Issues/Problems Drawn out from the Study

The problems encountered by the researchers during observation is the Real Time Clock cannot connect two modules at the same time because it varies the communication to the microcontroller resulting the data on the SD card no indicated time. The LED lights and LCD module cannot be added to the microcontroller due to sufficient pins and the Arduino will be overloaded. The ultrasonic sensor is not stable as well as the jump wires during data gathering. The distance from the Bluetooth application to the system is limited only to 1-2 kilometers. The detected level of water by the ultrasonic sensor did not matched with level of water shown at the scale of the atmometer having a difference of 1-1.2cm as observed during the gathering of data. The ultrasonic sensor can detect the space from its tip to the water level.

CONCLUSION

The results show that there is no significant difference between the evaporation rate of the meteorological devices except for the atmometer compare to the evaporation pans. Since the Arduino and the atmometer is connected with each other, this indicate that the automated localized atmometer need calibration and further improvement and validation before using in measuring evaporation rate and irrigation scheduling. Further works in this study need to be accomplished and this can serve as a basis for comprehensive studies in the future for further improvement and modification. Thus, is just a basic structure of another complete system.

RECOMMENDATIONS

For more improvements of the automated recording atmometer, the following are recommended:

1. Further calibration and improvement of the automated localized atmometer.
2. It is highly recommended to use a floating type water level sensor since it can easily be installed inside the atmometer.
3. A Real Time Clock module that can take numbers of modules at a time. This can be a fundamental device to add in the system for future studies. This can provide a cloud database to save all the data. Readings from all the sensors with date and time can be saved.
4. A Mega 2560 R3 Arduino is recommended to use for wider storage and lots of pins can be installed.
5. A stable prototype housing for better and stable condition because the sensor is very sensitive to movements.
6. A SMS module is suggested for better receiving of data via text using android phones.
7. Further modification and validation of the performance of the Arduino based atmometer should be conducted.

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