Evapotranspiration-based Irrigation System using Raspberry Pi for Capsicum Annuum "Bell Pepper" Plant Nursery

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***Abstract*—The Philippines' economy relies highly on the output of the agricultural sector. The country, being positioned near the equator, have two seasons; wet and dry season. Since then, tropical countries around Asia has been suffering drought brought upon by the El Niño wherein the impact is concentrated on the agricultural sector. In this paper, the use of a Raspberry Pi in controlling an automated irrigation system is explored. Parameters such as temperature, humidity, wind speed, and radiation are taken into account in using an Evapotranspiration (ET) based irrigation system. Evapotranspiration relies on the use of specialized equations, namely: Hargreaves-Samani and Penman-Monteith in determining the amount of water loss through evaporation and transpiration of the plant. The microcontroller determines the minimum amount of water and controls the flow of water in a dripper style configuration through the use of a water pump.**

***Index Terms*—Evapotranspiration; Penman-Monteith; Hargreaves-Samani; Humidity; Wind Speed; Temperature; Radiation.**

I. INTRODUCTION

One major source of remuneration in order to suffice peoples need is through the use of Agriculture. Agricultural sector needs improvement particularly in the irrigation area wherein proper watering of the plants is needed the most. Since we all know that water is a renewable source, without it there is no life. Evapotranspiration (ET), the amount of water needed to sustain a life of a plant, can be consider as an alternative way for irrigation. Many studies [1-5] have been conducted and presents promising results in the implementation of ET-Based irrigation. The quantification of water consumption requires knowledge of the evaporation of water from the earth and plant surfaces as well as how water is consumed by plants by way of transpiration. The combination of these two phenomena, namely surface evaporation and transpiration, are collectively referred to as evapotranspiration. Evapotranspiration (ET) is the largest consumer of irrigated water and quantifying the amount of ET occurring in an area provides water managers a valuable tool for quantifying water consumption.

Nursery irrigation ensures that every plant in your irrigation system receives the same amount of water and fertilizer, regardless of location, for a uniform, high-quality crop. Pressure differential system maintains uniform flow rate at different inlet working pressures, ensuring exact 2 distribution of water and nutrients. Valve checking feature in drippers ensures that irrigation lines stay full and do not drain into the lowest lying plants. With an evapotranspiration system, the right amount of water is easily obtainable and could save time and water. The crops evapotranspiration and the water in the soil would be the input to the fuzzy controller. There are many factors gathered to get the actual value of reference evapotranspiration like humidity, wind speed, temperature and solar radiation.

The objective of the study is to develop an alternative tool for irrigation, Evapotranspiration-based Irrigation System for Plant Nursery using Raspberry Pi. The system must gather air temperature, wind speed, and humidity. The environmental parameters were the basis for the ET-based system using the standardized ETo equation. The study use the two empirical formulas for computing the reference evapotranspiration and compare the two ETo estimation equation and conventional irrigation in terms of water conservation techniques that are widely used in the Philippines.

II. MATERIAL AND METHODS

Proper irrigation is important in the Philippines for it is known as an agricultural country. Nursery irrigation is used by common men or starting farmers with small amount of land to nurture, it ensures that all plant in a nursery receives the same water. A proper irrigation scheduling technology, specifically for nursery, is helpful for farmers to reduce water consumption and in return save money and time in growing crops. The irrigation control system uses humidity, wind speed, temperature and solar radiation to properly schedule the irrigation. The different factors can be gathered through the controller in the site where it would be implemented.

A. Conceptual Framework

Figure 1 shows the conceptual framework wherein the environmental parameters are the inputs of the system and it will be process by the microcontroller to compute for the water loss based from the ET empirical equations. The environmental parameters being monitored are temperature, wind speed, humidity, and solar radiation of the surrounding environment.

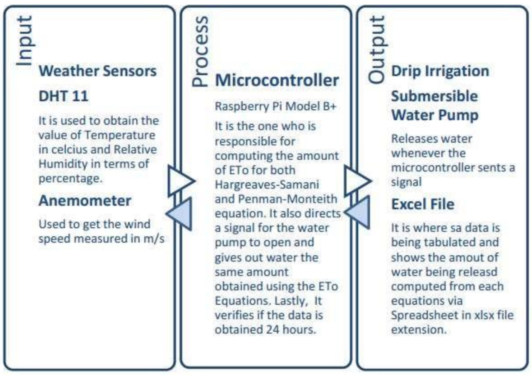

Figure 1: Conceptual Framework

Evaporation can occur at any temperature level. Warmer air affects the speed of evaporation. As the warm air passes through, it transports some of its energy to the water molecules. As the temperature increases, it also increases the evaporation speed. Provided no moisture is added to the air, as air temperature increases relative humidity decreases. Soil moisture content is the parameter in characterizing the amount of water available for plants in soil. If the soil has high moisture and a warm air passes by, it intensifies the heat compared to soil with low moisture, it can cool down faster. In a controlled system, only the temperature and humidity changes. It both affects the evaporation process in the system. The temperature affects the speed of evaporation while the humidity affects the water content in soil.

B. Formulas and Parameter

The empirical formulas that were considered are the Penman-Monteith equation and the Hargreaves-Samani Equation. The Penman-Monteith Equation and Hargreaves-Samani equation as stated as follow Equation 1 and Equation 2 [6,7]:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

where: ET_o reference evapotranspiration, *mm day*$^{-1}$,
R_n net radiation at the crop surface, *MJ m*$^{-2}$ *day*$^{-1}$
G soil heat flux density, *MJ m*$^{-2}$ *day*$^{-1}$
T mean daily air temperature at 2 m height, *°C*
u_2 wind speed at 2 m height, *m s*$^{-1}$
e_s saturation vapour pressure, *kPa* e_a actual vapour pressure,kPa
e_s - e_a saturation vapour pressure deficit, *kPa*
D slope vapour pressure curve, kPa *°C*$^{-1}$
g psychrometric constant, *kPa °C*$^{-1}$

$$ET_0 = 0.0135(KT)(R_a)\sqrt{T_{max} - T_{min}}(T_{ave} + 17.8) \quad (2)$$

where: **T(max)** is maximum absolute temperature during the 24-hour period,°C.
T(min) is minimum absolute temperature during the 24-hour period,°C.
T(ave) is average absolute temperature during the 24-hour period,°C.
KT is Empirical Coefficient, 0.19.
Ra is Extraterrestrial radiation, MJ m^{-2} day^{-1}.

C. Experimental Setup

For testing the different equations, the authors simulated three different plant irrigation method. To simulate these conditions, three test beds are used; one for testing the Penman- Monteith, one for the Hargreaves-Samani, and one for the conventional method. The authors used a 4 x 4 seedling tray for each method. Figure 2 shows the actual setup for the irrigation system in testing the Penman-Monteith and Hargreaves-Samani equation. The setup is composed of a 4 x 8 seedling tray that is divided in half to accommodate both of the irrigation method.

Figure 2: Actual set-up for the two equations

The wind speed that is used in the equations are measured by an anemometer, while the temperature and humidity is measured by the DHT11 sensor as shown in figure 3. The values or data gathered by these sensors are the input to the equations in computing the ET or evapotranspiration which is then processed by the Raspberry Pi Python code.

Figure 3: Anemometer and DHT11 Sensor

D. Process of Gathering Data

Figure 4 shows the environmental sensors are connected to the microcomputer wherein the sensor data undergo signal processing and then stored in the database. The environmental data from the database were used for the computation of the ET based from the empirical formula being considered. The microcomputer controls the actuator that main function is to irrigate the plants based on the computed water loss. It was composed of a solenoid valve that controls the water flow and a flow meter that determines that amount of water that passed through the valve. With this regard, the amount of water needed for irrigation can be control.

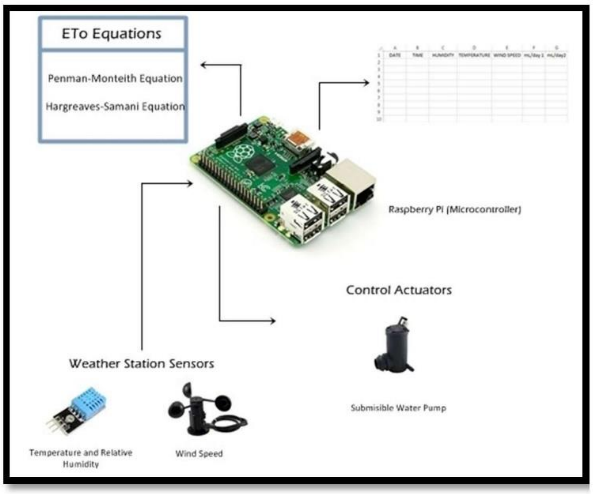

Figure 4: System Process

III. Results and Discussions

Table 1 presents the weekly summary of the amount of water used for irrigation based from the two equations and the conventional method. The amount of water used for the conventional method are fixed to 7 liters of water. Based on the results in Table 1, it is observed that Hargreaves – samani equation has a higher water consumption compared to Penman- Monteith equation. In addition, the conventional method had the highest amount of water usage.

Table 1
Weekly Summary of Data Gathered

Week	Penman-Monteith (mL)	Hargreaves-Samani (mL)	Conventional (mL)
1	1847.8757	4352.5869	7000
2	1862.1915	4343.4368	7000
3	1851.2635	4238.0827	7000
4	1844.1776	4430.1231	7000
5	1854.8418	4273.5668	7000
6	1875.1268	4645.392	7000
Total	11135.4769	26283.1883	42000

Table 2 shows the difference of the amount of water from the two different techniques employed in the irrigation system compared with the conventional method. It shows that the highest amount of water saved was by using penman-monteith formula with respect to traditional and the Hargreaves-Samani Equation.

Table 2
Difference of the amount of water from different Techniques

Technique comparison	Amount of water (mL)
Saved water Between Traditional and Penman-Monteith (mL)	30864.5231
Saved water Between Traditional and Hargreaves-Samani (mL)	15716.8117
Saved water Between Penman-Monteith and Hargreaves-Samani (mL)	15147.7114

Figure 5 shows the observed seedling height for every setup and based from the weekly results of the height of the plants under test, the authors inferred the following statistical hypotheses: Null hypothesis: There is no significant difference on the average height of the plants based on proposed treatments (Penman-Monteith Hargreaves-Samani) and that of the conventional method. Alternative hypothesis: At least one of the proposed treatment will result to a significant difference on the average height of the plants under test

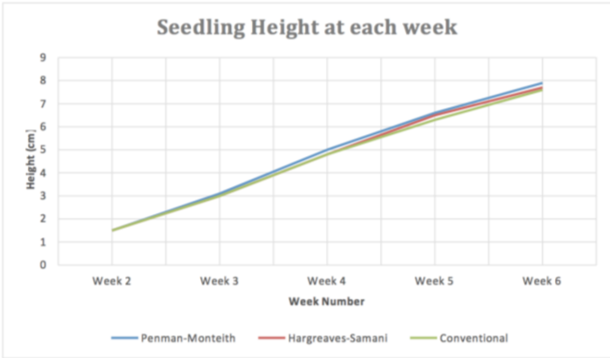

Figure 5: Seedling Height at each week

With a 5% level of significance, a one-way Analysis of Variance (ANOVA) yielded a p-value that supports the claim of the null hypothesis. There is no sufficient evidence to refute the basis of a significant difference on the average height of the plants from any of the methods proposed.

IV. Conclusion

The goal of this research is to test, compare and evaluate the two widely known irrigation system evapotranspiration equations, namely,Penman-Monteith Equation and Hargreaves-Samani Equation to apply the appropriate value of water at the appropriate time. Using different sensors like DHT11 in order for us to gather values for Humidity (%) and Temperature (ºC) and Anemometer for the wind speed (m/s), these parameters were needed to compute for the Evapotrasnpiration value ETo. The calculated value of ETo will be same amount of the water the pump will disseminate. Using this implemented system, the authors will be able to know how much water we need for the Bell pepper seedling. The authors concluded that using the ET-based irrigation system will not affect the physiological growth, specifically its height, of the seedling thus conserves more water comparing to the conventional way of planting. ET-based irrigation is really needed by the nursery plants especially those crops who's sensitive in the amount of water being applied. Using the system, it enhanced the foundation or growth of the seedling starting from its own seed. It is also concluded that Hargreaves-Samani consumes 40.48 % more water compared to the Penman-Monteith equation, thus making Penman-Monteith the most effective technique in this study.

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