Construction of an in-situ smart device that measures some basic environmental factors for agricultural monitoring

To cite this article: T.A. Adagunodo *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **173** 012023

Construction of an in-situ smart device that measures some basic environmental factors for agricultural monitoring

T.A. Adagunodo, J.J. Ajigbotosho, L.N. Obafemi, M.R. Usikalu, S.A. Akinwumi, W.A. Ayara

Department of Physics, Covenant University, Ota, Ogun state, Nigeria

theophilus.adagunodo@covenantuniversity.edu.ng

Abstract. Most of the rural agricultural and extension officers have no access to the daily variations in meteorological data that affect the growth and yield of crops. This is as a result of little or no access to the data that could be used to predict the best agricultural practices for optimum output in the rural environments. In this work, a portable and user friendly smart Automated Weather Station (AWS) was constructed. The device that is programmed with Arduino UNO is capable of measuring the temperature, relative humidity and moisture content of the soil. The performance evaluation of the device was observed in the laboratory and on-site (Covenant University farm) both on the sunny and rainy days respectively. It was revealed that there is positive linear relationship between the volume of water added to the soil sample and the soil moisture content in the laboratory measurements. The on-site measurements showed that the temperature is inversely proportional to the relative humidity and soil moisture content. This device is efficient in taking the short-term essential parameters that could improve the yield of agricultural products in the rural environments if properly utilized.

Keywords: Agricultural monitoring, Relative humidity, Moisture content, temperature, In-situ smart AWS,

1. Introduction

The impact of solar heat radiation on climate diurnal variations cannot be underrated [1]. This effect causes variations in the moisture content, relative humidity and soil temperature, which are the chief environmental factors that sustain the plant growth. The contributions of soil temperature to the soil properties are not limited to plant growth alone, it also contributes to the seed germination, physical and chemical constituents of soil, solute diffusion, absorption of water and nutrition, as well as a medium of exchange between the atmosphere and the topsoil [2]. Crops respond to soil temperature differently and as such have different impact on plant growth [1].

The plant-soil interactions are capable to influence the soil moisture variations. Soil moisture has many favourable advantages to plant growth. It takes part in the biochemical processes that occur in the plant. Water serves as carrier of nutrients within the plant, it regulates the internal temperature of the plant, and maintains the turgidity of the fruits and leaves of the plants [3]. A high level of soil moisture needs to be maintained if the ecological systems would retain more water in the subsurface [4].

Humidity can simply be defined as the amount of water in the atmosphere. Relative humidity is one of the factors that can affect the growth of plants. Different species of plants have different humidity ranges in which they can germinate well. Humidity affects plant growth because it affects when plants open or close their stomata. The stomata are responsible for plant's transpiration.

There are sophisticated Automated Weather Station (AWS) that are capable to measure some weather parameters in all seasons. Apart from the fact that this AWS is cumbersome, which is only capable of ex-situ measurements, it is considered too expensive in a developing nation like Nigeria. Few previous works have been recorded in the applications of weather parameters to monitoring of agricultural products [5-8], most of the works from SW Nigeria is based on the impacts of weather parameters on loss of signal in communication environment, which have been reviewed in Refs. [9-13]. However, this work was designed to construct a portable AWS that is capable to measure the three (3) basic weather parameters (temperature, soil moisture and relative humidity), which are vital for sustainability of crops. This device is capable to take remote measurements while the data are retrieved through the aid of cloud technology without staying on the field with the portable device.

2. Materials and Methods

In order to construct a device that monitors soil moisture, humidity and temperature, there are some essential components that are required. These are an Arduino, a soil moisture sensor probe, a humidity sensor, a Liquid Crystal Display (LCD), a temperature sensor and WIFI adapter among others. The moisture sensor probe is a two probe sensor made of pure nickel. The nickel is chosen because of its strength against corrosivity and its fair conductive properties when buried in the subsurface. The temperature and humidity sensor that was used in this study was a DHT11 sensor, which uses a thermistor to measure temperature. The Arduino UNO was used for coding the software section of the device, and then the LCD that displays the values of the three parameters to be measured by the device. A simple circuit diagram for this setup is presented in Fig.1.

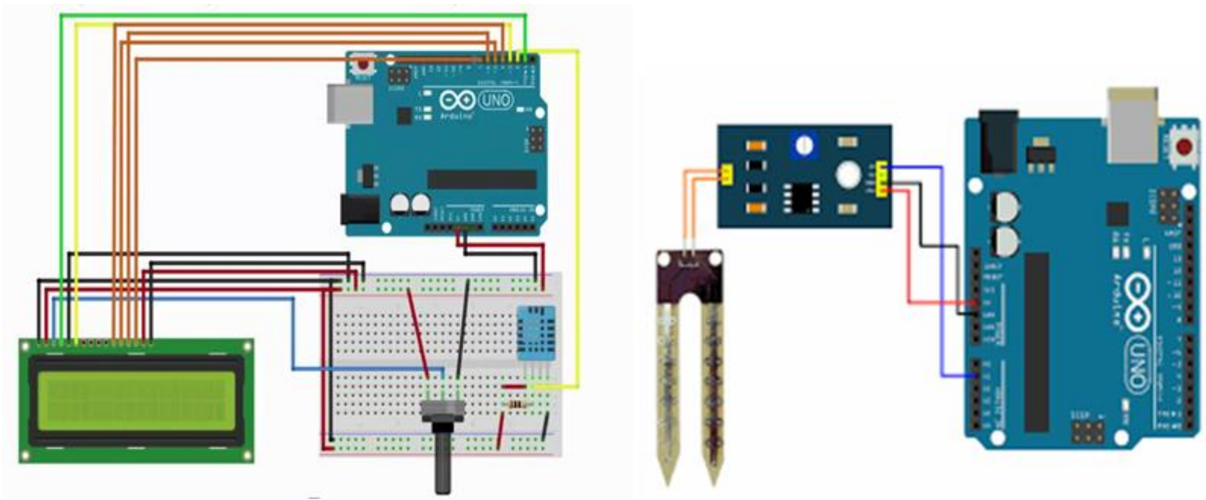

Fig. 1. A simple circuit diagram for the smart device.

The soil moisture sensor has two probes that are used to measure the moisture content of the soil. The two probes measure the soil moisture by allowing electric current to go through the soil, which gives the resistance value. The DHT11 consists of a temperature and humidity sensor, which uses the thermistor. A thermistor is a kind of variable resistor that measures temperature by measuring the change in resistance of the soil. For the measurement of humidity, the component that senses humidity has two electrodes, with a moisture holding substrate in between them. The conductivity of the holding substrate changes as humidity varies. These changes in resistance are processed and measured by an integrated circuit and then it will be read by the processor. The coded microcontroller then processes the information and sends it to the LCD.

3. Results and Discussion

After the construction of the device, it was tested in the laboratory for performance evaluation and later taken to the Covenant University (CU) farm field measurements. The laboratory setup of the device was shown in Fig. 2, while the laboratory measurements of temperature, humidity and soil moisture were presented in Table 1. The measurements in air and with soil samples (dry and wet) were presented. The result of measurements in air and that of dry soil sample showed no value for the moisture content. However, a known volume of water ranging from 2.0 to 10.0 ml was added consecutively to the dry soil sample. It was revealed that there is positive linear relationship between the volume of water added to the soil sample and the soil moisture content. This shows the effectiveness of the sensors.

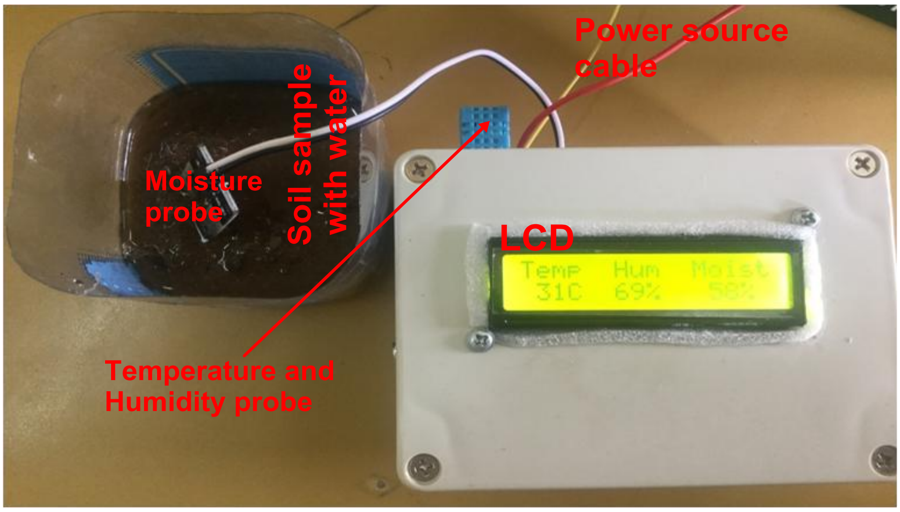

Fig. 2. Laboratory setup of the smart device

Table 1. Laboratory measurement from the smart device

Sample	Temperature (°C)	Humidity (%)	Moisture content (%)
Measurement in air	32.00	72.00	0
Dry soil sample	32.00	73.00	0
Soil sample with water (2.0 ml)	32.00	71.00	5.00
Soil sample with water (4.0 ml)	32.00	71.00	10.00
Soil sample with water (6.0 ml)	32.00	71.00	26.00
Soil sample with water (8.0 ml)	32.00	70.00	56.00
Soil sample with water (10.0 ml)	31.00	70.00	63.00

The field measurements taken at the CU farm recorded the data for a sunny and rainy days respectively. The results showed varied responses of the device to different weather conditions. The spatial variations of each data for the two periods were presented in Figs. 3 to 8 respectively.

Fig. 3 shows the spatial variation of humidity on a rainy day in CU farm. It was revealed that the southeastern part of the map has the lowest value which increases upwardly towards the northwestern and southwestern regions of the study area. There are two points on the map with clustered contour lines. These points depict the highest humidity values. Fig. 4 shows the spatial variation of moisture on a rainy day in CU farm. The south-east region of the map has the lowest soil moisture content, which increases towards the western part of the CU farm. The two points on the map with clustered contour lines depicts the zones with high soil moisture contents. Fig. 4 is similar to the relative humidity map (Fig. 3), because the two parameters are directly proportional to each other. Fig. 5 shows the spatial variation of temperature on a rainy day in CU farm. It was revealed that the western part of the map has the lowest temperature values, which increases downwardly towards the southeastern region of the map. The two points on the map with clustered contour lines showed the minimum values for temperature. The spatial variation on CU farm showed that temperature is inversely proportional to relative humidity and soil moisture.

Fig. 6 shows the spatial variation of humidity on a sunny day in CU farm. It was revealed that the eastern part of the map has the lowest humidity content, which increases towards the western region of the map. Fig. 7 shows the spatial variation of moisture content on a sunny day in CU farm. It was shown that the eastern part of the map has the lowest moisture content, which increases towards the western region of the map. Fig. 8 shows the spatial variation of temperature on a sunny day in CU farm. This map showed that the temperature decreases in NE – SW direction.

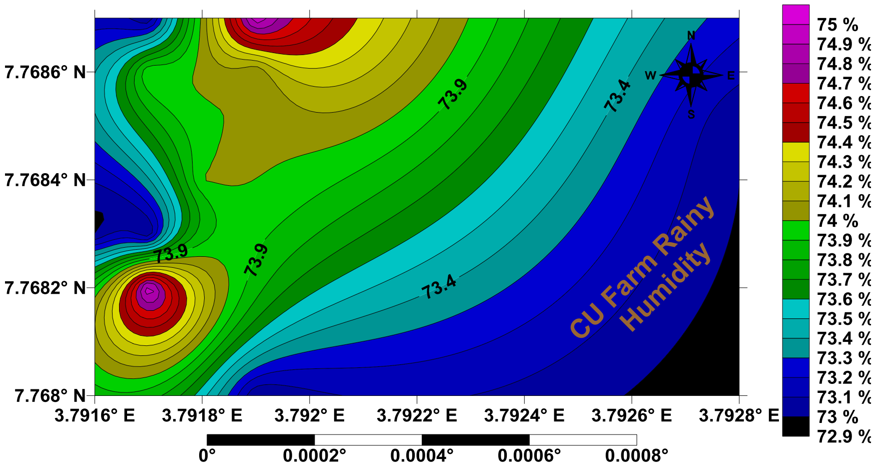

Fig. 3. Variation of humidity in CU farm during the rainy period.

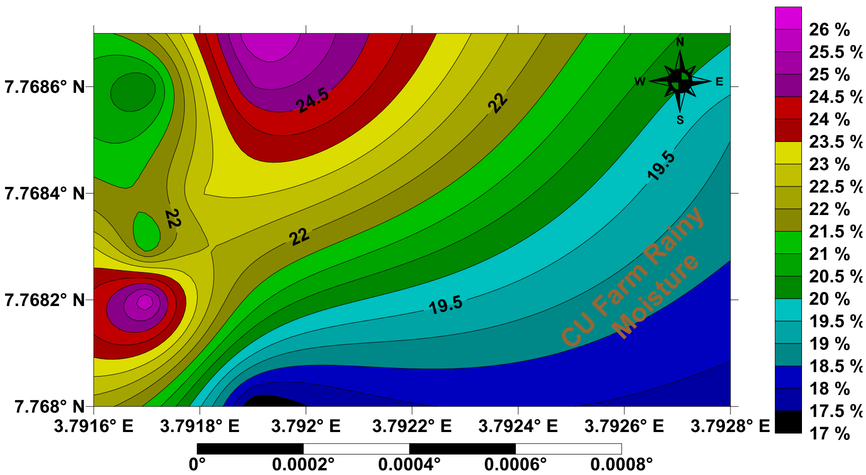

Fig. 4. Variation of soil moisture in CU farm during the rainy period.

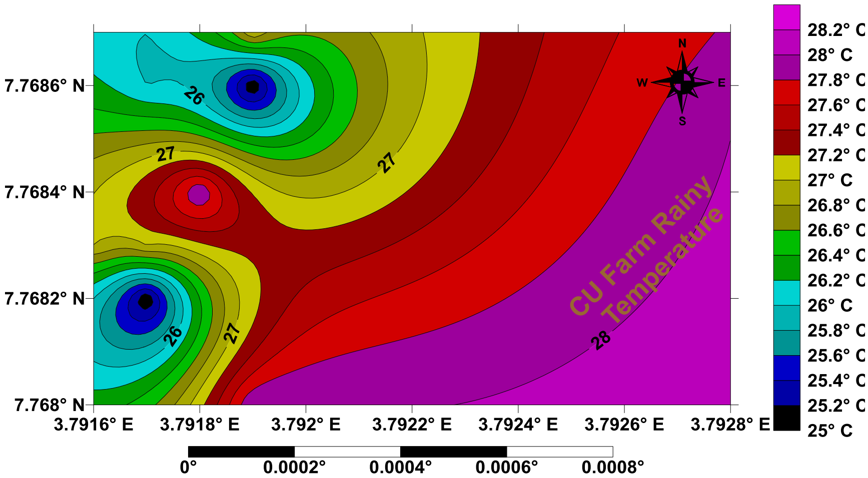

Fig. 5. Variation of temperature in CU farm during the rainy period.

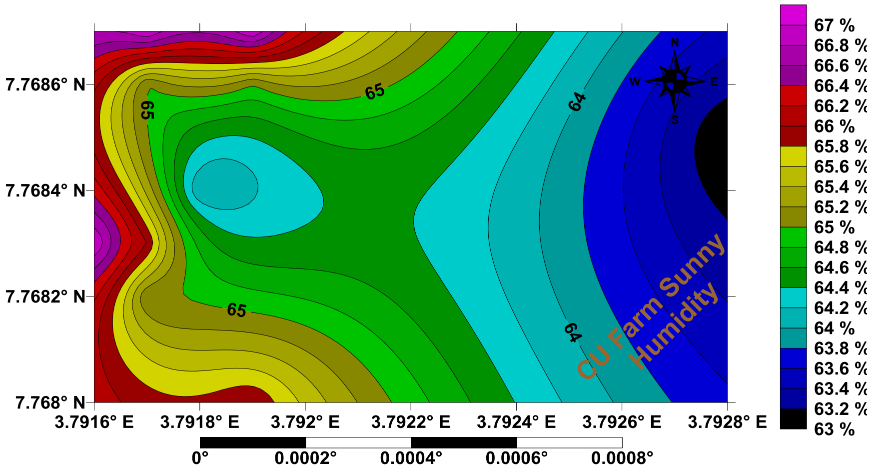

Fig. 6. Variation of humidity in CU farm during the sunny period.

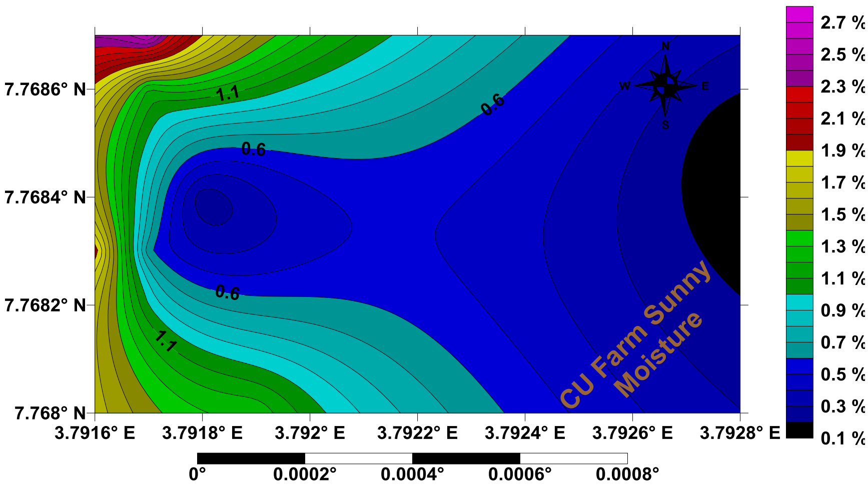

Fig. 7. Variation of soil moisture in CU farm during the sunny period.

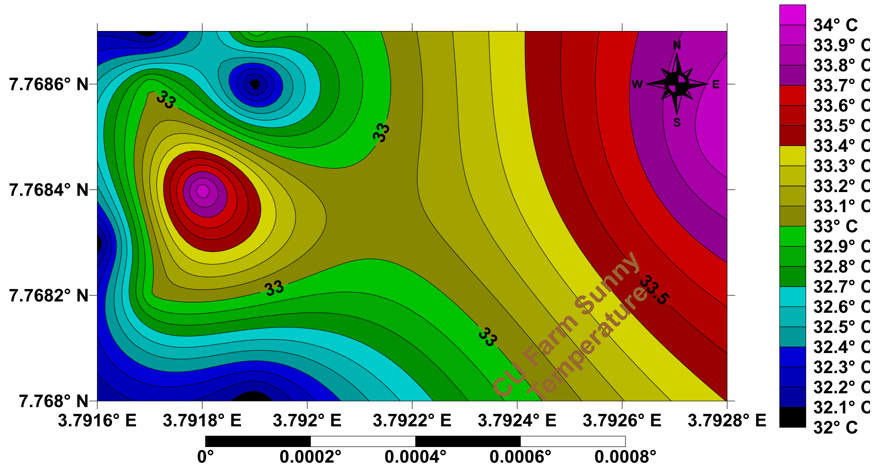

Fig. 8. Variation of temperature in CU farm during the sunny period.

4. Conclusion

In this study a smart device that is capable of measuring relative humidity, soil moisture content and temperature was constructed. The performance evaluation of the device was tested both in the laboratory and on the field. This device is capable to measure some basic parameters that could be used to predict crop growths and yield for sustainable agricultural practices especially in Nigeria. The device is portable, user friendly and quite easy to handle. It can be operated by any farmer. The moisture of the soil can be measured up to the root region of the crop. Remote access to the data through WIFI connection range is possible in this portable device, which would also assist the agricultural rural and extension workers to perform their role effectively in remote villages.

Acknowledgement

We appreciate the management of Covenant University, Nigeria for the publication support received from them.

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