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A Modified Web-Based Agro-Climatic Remote Monitoring System Via Wireless Sensor Network

James Agajo, Jonathan G. Kolo, Godfrey Jonas, Abdulkareem Ridwan Opeyemi
Department of Computer Engineering
Federal University of Technology Minna
Niger State
Nigeria
james.agajo@futminna.edu.ng,
jgkolo@futminna.edu.ng,
godfreyjtech2020@gmail.com,
ridwanabdulkareem@gmail.com

Nosiri Onyebuchi Chikeze
Department of Electrical/Electronics
Federal University of Technology Owerri
Imo State
buchinosiri@gmail.com

Okeke Benjamin Chukwujekwu
Department of information Technology
Federal University of Technology Owerri
Imo State
benokeke2001@yahoo.com

Abstract: Weather and climatic monitoring plays a significant role in agriculture, so the collection of information about the temporal dynamics of weather or climatic changes is very important. This does intend to advance our previous work by modifying it and focus on Web based Remote monitoring and data acquisition of Agro-climatic parameters using wireless sensor system. The system which has been designed to operate remotely consists of the temperature/humidity sensor, soil moisture sensor interfaced to the ATMEGA 2560 Microcontroller, a local display and the CC3000 Wi-Fi shield also interfaced to it. When the system is active, the sensors sense these physical parameters and then, the LCD displays the current conditions sensed locally. Furthermore, a connection is established between the CC3000 Wi-Fi shield and the access point in order to transmit the sensed parameters to the web application via the web address for remote monitoring and data acquisition. The entire system is capable of sensing parameters, display them locally and transmit the same parameters to the web where they can be remotely monitored, acquired and analyzed. The result obtained from this developed system in comparison with an existing system capable of measuring temperature and humidity respectively shows that, the percentage error for temperature and humidity from the existing system was evaluated as 7.91% and 9.52% respectively and the percentage error for temperature and humidity from the developed system was evaluated as 8.21% and 9.45% respectively. Based on the result obtained, the accuracy of the different sensors used is assumed to be responsible for this variation. Therefore the percentage error of the system is a function of the accuracy of the sensors that were used. The developed system prototype could be deployed in areas like agriculture so as to boost farm and climate monitoring and data acquisition.

I INTRODUCTION

A Background of Study

The productivity of crops in agriculture is highly affected by the conditions such as temperature, humidity, and soil moisture level, and light intensity level, amount of carbon dioxide and microbial activities. These environmental and climatic factors determine the quality and better productivity of the plant growth. Continuous monitoring of these factors gives relevant information pertaining to the individual effects of the various factors towards obtaining maximum crop production [1]

Agriculture can be defined as the science, art or practice of cultivating the soil, producing crop and rearing of livestock for the sustenance of human life. Agriculture is an essential component of societal well-being. Agricultural production influences, and is influenced by, health, water quality and quantity, ecosystem, biodiversity, the economy, and energy use and supply[2] The seasonality and ubiquity of agriculture make agricultural practices and production amenable to efficient synoptic monitoring[2] Remotely monitoring of environmental parameters is important in various applications and industrial processes most especially in agriculture.

Temperature, a measure of quantity of heat energy possessed by a body is caused by heat transfer[12]. Soil temperature is degree of hotness or coldness of a particular soil which is influence by Rainfall, Irrigation and Soil physical properties[3,12] Soil Temperature plays an importance role in seed germination and growth as optimum temperature is required for proper germination, effective growth and development because planting before optimum temperature can result to poor germination, limited growth or total death of the seed[4]. The optimum temperature for all crops ranges from 15 to 40 degree Celsius. Microbial activities that increase soil fertility survive at the maximum range[12]. When the temperature is above optimum value, this activity get reduce as bacteria and other micro-organism that add nutrient to soil are being exposed to unfavorable condition. The loss nutrient can

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be regained through Mulching, Shading and appropriate tillage operation.

Soil moisture is importance to plant growth as it is source of water for plant use. It is the amount of water available in the soil either in liquid or vapour phase Soil water significantly affect several agricultural processes such Photosynthesis, Turgidity, Nutrient uptake in aqueous medium, Translocation of Food, Microbial Action that increase soil fertility. Dry soil hinders microbial activity by making them less active. Since the growth of crops is affected when there is shortage of water in the soil, there is a need for frequent rainfall or irrigation to provide for water loss. The ability of soil to hold water against force of gravity is a factor that determines how good the soil is, for planting. A good soil allows 50% pure space and 50% solid practices. The optimum moisture level of soil ranges from 0.1 to 1 bar is considered best for planting [5] . The Soil moisture for the plant medium (soil) must be kept evenly moist i.e. it must not be too dry or water logged.

Another climatological factor that affects the growth of plant is relative humidity. It is the percentage ratio of actual water vapor content to the saturated water vapor content at a given temperature and pressure. This plays a major roles in plant growth as it affect agricultural processes such as leaf growth, photosynthesis and Pollination. For instance, at high temperature and low humidity, transpiration process increases causing plant to lose much water. The loss in water cause partial or fully closure of the stomata and increase mesophyll resistance blocking the entry of carbon dioxide. The optimum relative humidity for healthy plant growth is 50% with plus or minus 10%.

Monitoring these parameters remotely in a localized area and acquiring of the data for further processing, has led to the development and deployment of more sophisticated systems and of which their short comings cannot be over emphasized. For instance a smart farm, In smart farm development which is the process of deploying several techniques to optimize the yield per unit farming land by adopting sophisticated technologies to achieve best in terms of quality, quantity and financial returns of farm product. Technologies such as GPS services, WSN are used to optimize and monitor plant requirement for climate factor like rainfall, relative humidity, soil moisture content, temperature and other factor like plant nutrients and fertilizer application[11] . These technologies are able to acquire data from the field for effective water management, weather event control and heavy rainfall. With smart farming, several barriers such as low plant growth, limited availability of arable land, climate change have been tackled.

B Problem Statement

Most climatic Monitoring systems have existed as standalone. These systems are only capable of sensing their environment and displaying the parameters within its deployed area, thereby making data acquisition and remote monitoring difficult and tedious.

C Motivation and Objectives

The aim of this research wprk is to develop a web based remote monitoring system for agro-climatological parameters and data acquisition using wireless sensor system.

The objectives are:

i. To develop a wireless sensing system that monitor agricultural parameters
ii. To develop a web application or dashboard for data acquisition
iii. To implement the designed system on a farmland.
iv. To evaluate the performance of the system based on Accuracy.

D Monitoring Techniques

Over the years, several techniques have been carried out both locally and internationally to monitor plants and livestock in agriculture. Certain traditional techniques have been employed ranging from the manual methods of travelling a long mile to a remote field to carry out monitoring, maintenance and even data acquisition. Some of the agricultural monitoring techniques employed include basically; the traditional technique and the satellite based technique as discussed in section E and F

E. Traditional Technique

The traditional techniques have employed manual monitoring and data acquisition of the climatic parameters from the field. These parameters are manually analyzed and estimated inappropriately to make conclusions. This method has led to the following drawbacks and they include: difficulties in comparing statistics and validating data collected on different fields, which apply different methodologies for monitoring and measuring their agricultural production. More so, the traditional technique was time consuming and the expensive nature of frequent field trips.

F. Satellite Based Monitoring

Remote sensing technique is been carried out with the use of satellite. The satellite plays a very significant role in remote sensing by taking images of large areas and monitoring them. These method improved agricultural monitoring and data acquisition most especially in large scale agricultural production. Satellite Monitoring assisted greatly in increasing the availability of accurate prediction several months before harvesting crops. One basic limitation of the satellite based monitoring is that it covers a very large area and most times some specific climatic parameters that are used in agriculture may not be monitored correctly as parameters such as temperature and humidity vary in different geographical locations and also the difficulty of acquiring data by private individuals is high and it's not cost effective as setting up this could be very expensive.

Fig 1 is a classification of existing Agricultural Monitoring and control systems.

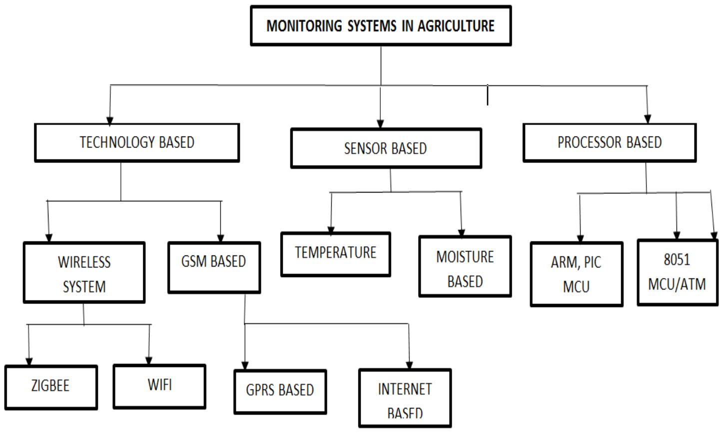

Fig 1 Classification of existing Agricultural Monitoring and control systems (Bansal, 2014)

II. Agro-Climatology

Agro Climatology, as the name implies is a cross breeding of two disciplines which includes climatology and agriculture. Therefore agro-climatology implies the use of climatological data in ensuring practical and effective management of agriculture.

Climatology on the other hand is a study that is fundamentally concerned with the weather and climate of any given area. Environmental scientists are interested in the process which takes place in the atmosphere, because the process affects the various component of the environment. Climatology has made enormous contribution towards ensuring that a good understanding and control of the processes is achieved [6]. Climate is the synthesis of the weather of a place over period of time. Also the study of climate is based on three approaches namely: the regional Climatology; this deals with the study of climate over a selected area on the earth surface, the Synoptic Climatology; this relates atmospheric condition to weather and climate and the physical climatology; emphasizes on global energy and water balance regimes of the earth and atmosphere.

Agro Climatology is majorly concerned with the interaction between the atmospheric environment, the plants and livestock while Meteorology is the science of the physical, chemical and dynamic state of the atmosphere. Meteorology deals with the study of the weather.

Weather and climate being the focal point of climatology consists of parameters such as rainfall, temperature, humidity, sunshine or light intensity, wind, amongst others. These parameters vary at different geographical locations. Therefore measurement of the various parameters is done using specialize equipment and sensors deployed to the field. When these equipment are deployed, the parameters within that region of deployment are being monitored and are properly maintained

Climate determines the type of crop to be grown in an area and also timing of agricultural operation as well as farming system. Unlike, tropical region where temperature is relatively higher than other parts of the world. The warm climates have peculiar implications for agriculture particularly as it affects crops, livestock, irrigation, pests and diseases [6]. Monitoring of agro-climatologic parameters is of great importance as it could help reduce the problem of food security.

A. Food Security

The recent global food crisis brought food security issues to the forefront of the world's consciousness and the impacts of the crisis have been felt most seriously in third world countries. According to the International Monetary Fund, food prices increased 43 percent between March 2007 and March 2008. While developed countries are often able to mitigate impacts of such crises, developing countries are most affected and take much longer to recover [7]

In addition to market-driven impacts on food security, many of those at risk rely upon adequate weather conditions for subsistence agricultural activities. Subsistence agriculture, a form of farming where nearly all commodities produced are consumed by farmers and their families, persists in many parts of the world and is especially widespread in sub-Saharan Africa]6]. The combination of high food prices and poor growing season conditions can be devastating for this segment of the world's population. Therefore, there is a profound need to accurately monitor growing season conditions that impact food security in the developing world such as Nigeria.

B Agro-climatological Parameters

Agricultural activities are very sensitive to climate and weather conditions. An agricultural decision-maker can either be at the mercy of these natural factors or try to benefit from them. The only way to profit from natural factors is to take them into account and learn to know them as well as possible. In practice mainly climatological parameters are essential in planning agricultural production. Environmental conditions have always been a challenge to most farmers since it is a major factor that determines the growth of plant. For effective growth and development of plants, moderate climatic factors such as Temperature, Sunlight, Relative Humidity, Soil moisture, Rainfall etc. is require. These parameters do not only affect the photosynthesis, proper germination and effective growth and development of crop but also has adverse effects on plants if it is below or above the normal condition. For example, most plants germinate at temperature value ranging from 40F to 104F.

C. Temperature

Temperature is one of the most commonly measured physical parameters which plays important role in the life of human and plant. Soil Temperature is degree of hotness or coldness of soil which is influence by rainfall, irrigation and soil physical properties [7] . Temperature is measured in degree Celsius, Fahrenheit and Kelvin respectively. Soil Temperature plays an importance role in seed germination and growth as optimum temperature is required for proper germination and effective growth and development. This is because planting before optimum temperature can result to poor germination, limited growth or total death of the seed [4]. The optimum temperature for most crops ranges from 15 to 40 degree Celsius. Microbial activities that increase soil fertility survive at the maximum range. When the temperature is above optimum value, this activity get reduce as bacteria and other micro-organism that add nutrient to soil are being exposed to unfavorable condition. The lost nutrient can be regain through Mulching, Shading and appropriate tillage operation.

D Soil Moisture

Soil moisture content is importance to plant growth as it is a source of water for plant use. Soil moisture sensor measures the volumetric water in the soil . Soil water significantly affect several agricultural processes such as photosynthesis, turgidity, nutrient uptake in aqueous medium, translocation of food, microbial action that increase soil fertility. Dry soil hinders microbial activity by making them less active. A good soil allows 50% pure space and 50% solid practices. The optimum moisture level of soil ranges from 0.1 to 1 bar which is considered best for planting [4]. The Soil moisture for the plant medium (soil) must be kept evenly moist that is, it must not be too dry or water logged.

E. Humidity

Humidity is the amount of moisture content in the atmosphere. There are three main measurement of humidity and they include: absolute humidity, relative humidity and specific humidity respectively. The absolute humidity describes the moisture content in air at a given temperature expressed in gram per cubic meter. Relative humidity is expressed as a percent measures of the current absolute humidity relative to the maximum (highest point) for that temperature. Specific humidity is a ratio of the water vapor content of the mixture to the total air content on a mass basis. This climatic parameter helps in farm irrigation and can be said to be the major parameter in which rainfall depends on.

F. Overview of Wireless Sensor System

Wireless Sensor Systems is aimed at the growing field of wireless sensor networks and distributed systems, which has been expanding rapidly in recent years and is evolving into a multi-billion dollar industry[12]. Wireless Sensor Network are spatially distributed network of sensors aimed at remotely acquiring data, the system is made up of Sensing , Conditioning, Processing and data transmission stage respectfully. .

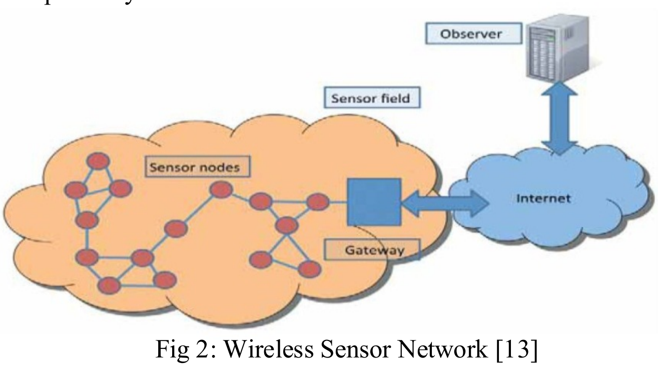

Fig 2: Wireless Sensor Network [13]

Some of the features or rather component of the wireless sensor networks includes: Sensor node, Actuator nodes, Gateways, Clients or observer, and the sensor field as shown in Fig 2.

G Data Acquisition System

This is a device that detect and convert physical variable such as temperature, humidity, soil moisture, pressure amongst others into electrical signal as output. The sensor consists of transducers that play significant role in converting physical variables into electrical signals and transmit these signals to a signal conditioning device or directly to the analog to digital converter where possible. This is explained in fig 3

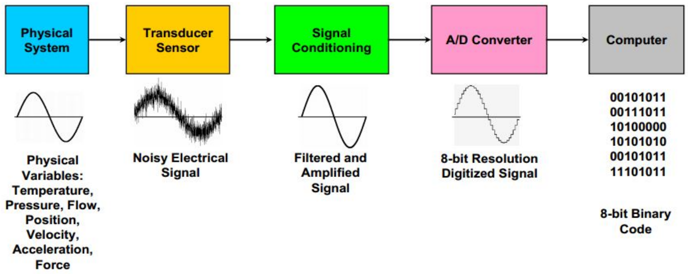

Fig 3 Data acquisition system[4]

H Internet of Things (IoT)

With the advances in technological development WSNs is becoming the technology for IOT (internet of things). The idea for internet of things was developed in parallel to wireless sensor sensing. It refers to the uniquely identifiable objects and their virtual representation in an internet like structure. These objects could be anything from large buildings, industrial plants, planes, cars, machines, any kind of goods, specific parts of a larger system to human beings, animals and plants and even specific body parts of them. Integration of these objects into IoT has been a major evolution of WSNs.

I. Wi-Fi Shield

The WI-FI is a local area wireless computer network technology that allows electronic devices to network mainly using the 2.4GHz (12cm) and 5GHz (6cm) radio bands. The Wi-Fi alliance defines Wi-Fi as any wireless local area network (WLAN) product based on the IEEE 802.11 standards. Devices that uses Wi-Fi includes personal computer, video game console, smart phones, digital camera, tablets computer and so on.

The Wi-Fi is based on the institute of electrical and electronics engineers standard IEEE 802.11. This standard is a set of media access control (MAC) and physical layer (PHY) specifications for implementing WLAN computer communication in the 2.4GHz, 3.6GHz, 5GHz and 60GHz frequency bands. The Wi-Fi 802.11g and 802.11b uses 2.4GHz frequency band.

J Zigbee Based

Zigbee is a wireless communication standard based on IEEE 802.15.4 protocol. It was established by Zigbee Alliance that is supported by numerous numbers of companies. Owning to its low cost, low power consumption, it is widely used in several technological applications such as Food Industries, Weather Station, Aviation Home automation and control etc.. Features of IEEE 802.15.4 devices include:

- 868MHz band, 1 channel, 20 kbps;
- 915MHz ISM band, 10 channels, 40 kbps;
- 2.4 GHz ISM band, 16 channels, 250 kbps;
- connecting up to 255 devices per network;
- full protocol for transfer reliability;
- Power management to ensure low power consumption. These connection enables data transmission within larger range distances compared to the Bluetooth technology..

K Bluetooth Technology Based

Bluetooth was established and standardized by the IEEE as Wireless Personal Area Network (WPAN) in 1998 with IEEE 802.15 as its specification. It is a short range Radio Frequency (RF) wireless communication technology used in establishing communication between electronic devices, data synchronization and with the internet. It uses the 2.4 GHz, 915 and 868MHz radio bands to communicate at 1 Mbit between up to eight devices. The Bluetooth is considered a cable replacement for mobile devices. Bluetooth supported devices like phones, laptop, printers, keyboard amongst others and one major limitations is that it can only transmit data within a short range.

L. Arduino IDE

The source code is written in C/C++ respectively, compiled and uploaded on the Atmega 2560 microcontroller directly. The arduino is an open source integrated environment for debugging and creating the arduino code.

M. Web Application Development Process

This is an application that runs or is executed on the web browser process illustrated in fig 4. In other words a web application is a client–server software in which the client or user interface runs on a web browser. Common web applications include: webmail, online auctions, and online retails

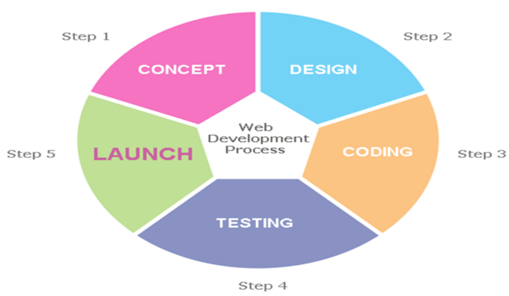

Fig 4 Web development process

M Launching and Hosting

This is the art of making the website public. This can only be achieved by hosting it on a known server on the web. This marks the final stage of the web development process.

N. Web Server

This project shall improve on the various limitations by developing a very robust web-based system for monitoring both locally and remotely agro-climatological parameters and data acquisition using wireless sensor system.

III. Method And System

This section describes the method used in carrying out the design and implementation of a Wireless Sensing and Data Acquisition system, which will include system overview, scope of the system, system objective, components used in the design, hardware and software consideration of the system to achieve the project work objectives.

A System Overview

The system is a collection of sensor node which consists of the temperature, humidity and soil moisture sensor. The local display and Wi-Fi shield interfaced with it, this is mainly for transmission purposes and also the web server for getting and acquiring data transmitted to its database in order to enhance remote monitoring in figure 5 and 6.

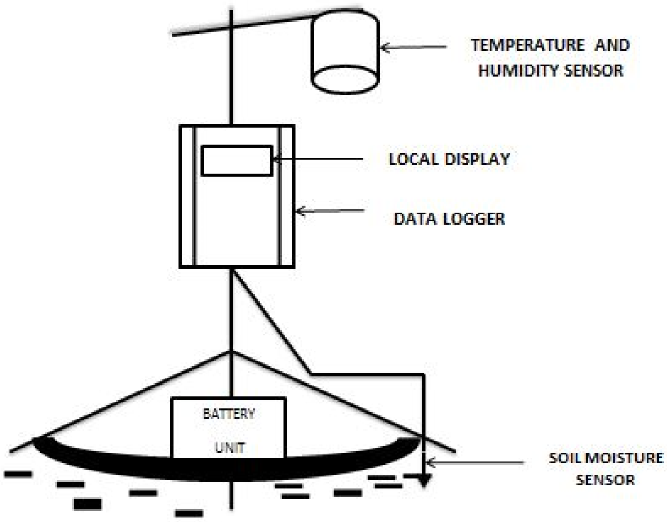

Fig 5 Weather station stand

B Method and Material

The method employed to realize the objectives of this project is the sensor system. The wireless sensor system is a multiple sensor nodes, comprising a signal processor, a controller, a data acquisition system and a display

C System Block Diagram

The Block Diagram of the system is shown Fig 6

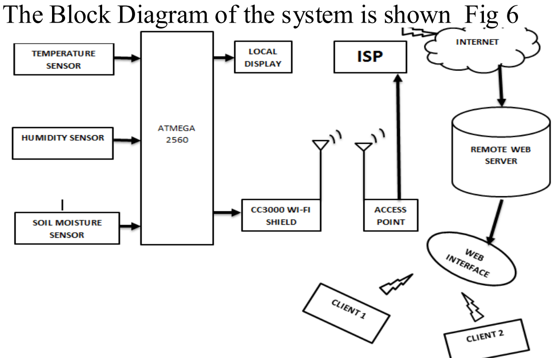

Fig 6 Overall System Block Diagram

Ohms law statesV=IR and Power = IV

Table 1

COMPONENT	VOLTAGE	CURRENT	POWER
DHT11 Sensor	5V	100uA-150uA	500-750uW
Moisture Sensor	5V	35mA	175mW
LCD	5V	150mA	750mW
CC3000 Wi-Fi	5V	190mA	950mW
Arduino Board	9V externally	500mA	4500mW

D Power Supply Unit Testing

The power supply unit was designed to obtain +9V D.C which was used to power the system. The CC3000 Wi-Fi shield, LCD, DHT11 sensor and the Soil moisture sensor were interfaced with the Arduino MEGA2560 board that is capable of receiving external Voltage ranging from 5V to 12V D.C supply. A regulator was used to regulate the 12V rechargeable battery to an output of 9V. In this case a multi-meter was used to measure the output voltage regulated.

Power Unit Test Result

Input Voltage	Voltage Regulator	Expected Voltage	Average Measured Voltage	Fluctuation Error
12V	9V	9V	8.91V	0.09V

Meanwhile, other test such as polarity test and continuity test were also conducted in order to avoid any form of short circuit.

E. ATMEGA 2560 Micro controller

The microcontroller is the brain of the entire sensor node, where control operations are carried out. The microcontroller is used for the design and development of the system generally. The microcontroller is embedded on a board called Arduino-Mega development board. This board is integrated with several input and output pins. All major components are connected to this board.

F. Temperature and Humidity Sensor (DHT11)

The temperature in Fig 7 and humidity were sensed using the DHT11 sensor. The sensor consists of three usable pin outs the supply voltage pin (VCC), the Data Pin and the ground (GND). The data pin was connected to the PIN 8 of the arduino board the VCC pin to the 5V supply and ground to the GND.

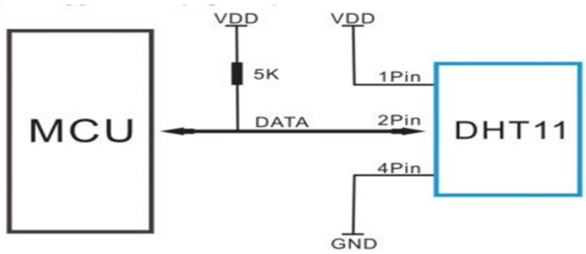

Fig 7: Operation of the DHT11 sensor

DHT11's power supply is 3-5.5V DC. When power is supplied to the sensor, do not send any instruction to the sensor in within one second in order to pass the unstable status. One capacitor valued 100nF can be added between VDD and GND for power filtering.

G. Communication Process

Serial Interface (Single-Wire Two-Way) Single-bus data format is used for communication and synchronization between MCU and DHT11 sensor. One communication process is about 4ms. Data consists of decimal and integral parts. A complete data transmission is 40 bit, and the sensor sends higher data bit first. Data format:

8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data + 8bit check sum. If the data transmission is right, the check-sum should be the last 8bit of "8bit integral RH data + 8bit decimal RH data + 8bit integral T data + 8bit decimal T data".

When MCU sends a start signal, DHT11 changes from the low-power-consumption mode to the running-mode, waiting for MCU completing the start signal. Once it is completed, DHT11 sends a response signal of 40-bit data that include the relative humidity and temperature information to MCU. Without the start signal from MCU, DHT11 will not give the response signal to MCU. Once data is collected, DHT11 will change to the low power-consumption mode until it receives a start signal from MCU again.

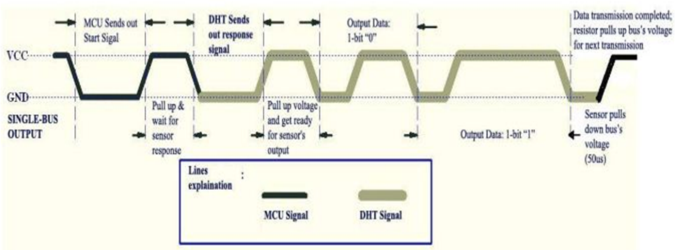

Fig 8 Communication Pattern

MCU Sends out Start Signal to DHT (Figure 8 Data Single-bus free status is at high voltage level. When the communication between MCU and DHT11 begins, the program of MCU will set Data Single-bus voltage level from high to low and this process must take at least 18ms to ensure DHT's detection of MCU's signal, then MCU will pull up voltage and wait 20-40us for DHT's response. Once DHT detects the start signal, it will send out a low-voltage-level response signal, which lasts 80us. Then the program of DHT sets Data Single-bus voltage level from low to high and keeps it for 80us for DHT's preparation for sending data. When DATA Single-Bus is at the low voltage level, this means that DHT is sending the response signal. Once DHT sent out the response signal, it pulls up voltage and keeps it for 80us and prepares for data transmission. When DHT is sending data to MCU, every bit of data begins with the 50us low-voltage-level and the length of the following high-voltage-level signal determines whether data bit is "0" or "1" If the response signal from DHT is always at high-voltage-level, it suggests that DHT is not responding properly and please check the connection. When the last bit data is transmitted, DHT11 pulls down the voltage level and keeps it for 50us. Then the Single-Bus voltage will be pulled up by the resistor to set it back to the free status. The LCD prints the values sensed at a particular time before transmission of the sensed parameter.

H Grove Moisture Sensor

The soil moisture sensor consists of three usable pins that include the VCC, GND and the Data pin. The data pin was connected to the analog pin of the MCU (A0). The sensor is inserted to the ground or soil and it senses the moisture at different level and then displays the sensed equivalent value on the LCD.

I. CC3000 WIFI SHIELD INTERFACING

This shield consists of seven functional pins that includes. These pins consists of both the SPI pins (MOSI, MISO and SFE), the INT, EN, CS and the power supply which includes the VCC, +3.3V supply and the ground (GND). The CC3000 shield were interfaced to the arduino using this pins as shown in the table below.

After interfacing the shield with the arduino board, the following test were performed on the CC3000 Wi-Fi shield at a baud rate of 115200 and their results were recorded accordingly:

- Board test
- Scan test
- Connection test
- Ping test
- Web client test

J Board Test

The board test was carried out purposely to show that the CC3000 Wi-Fi shield was functional. That is to test its workability. The test result is shown in Fig 9.

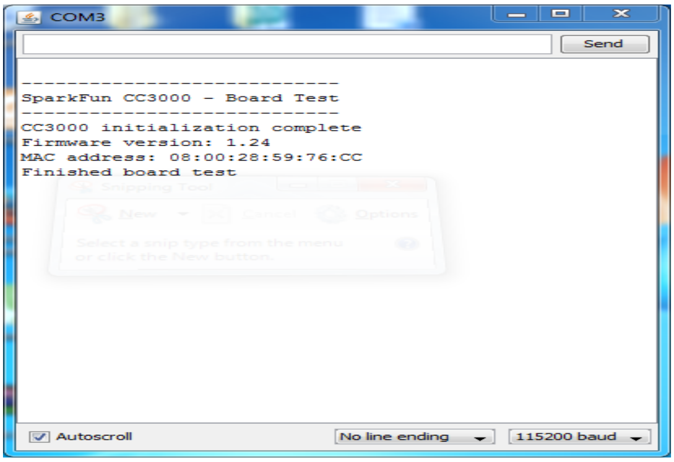

Fig 9 Board test of CC3000 Wi-Fi shield

In Fig 9 the board test carried out displays of the inherent properties of the shield which includes the firmware version of the shield and its MAC address only.

K. Scan test

The CC3000 WIFI shield in figure 10 scans it environment for available networks irrespective of the security levels and display on the serial monitor the properties of the network which includes the name or SSID of the network, The MAC address of the network, the RSSI port number and the wi-fi security mode either WPA2, WPA or unsecured network.

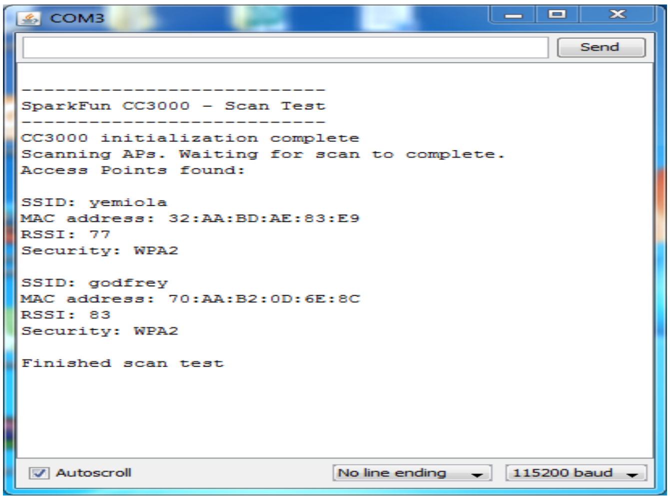

Fig 10 CC3000 Scan test Result

L. Connect Test

This test shows the Wi-Fi shield is capable of connecting to a network in figure 11.

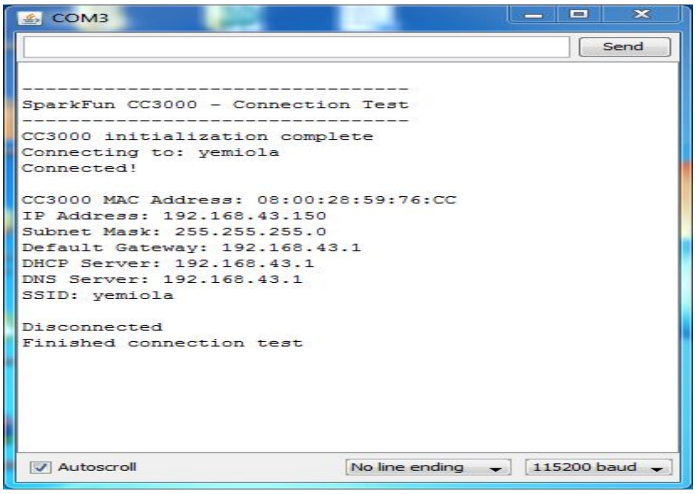

Fig 11: CC3000 shield Connection test

The credentials required for this connection includes the network's service set identification name (SSID) and the Password access only if the network is a secured network (WPA2) cases but for an unsecured network such as (WEP), only the SSID is needed and also static address can be used. The information include the MAC Address of the chip, assigned IP address, IP address of the DHCP Server, DNS Server, Default Gateway and the SSID of the network connected to. The result of the test is shown in fig

M Ping Test

Ping is a network troubleshooting tools in Fig 12 used to verify communication between two different hosts in the same network (intranet) or outside the network (Internet). It send an echo message to check if the host is reacheable or not. This test is very important as it assurance wifi shield can communicate with a server from a diiferent network.

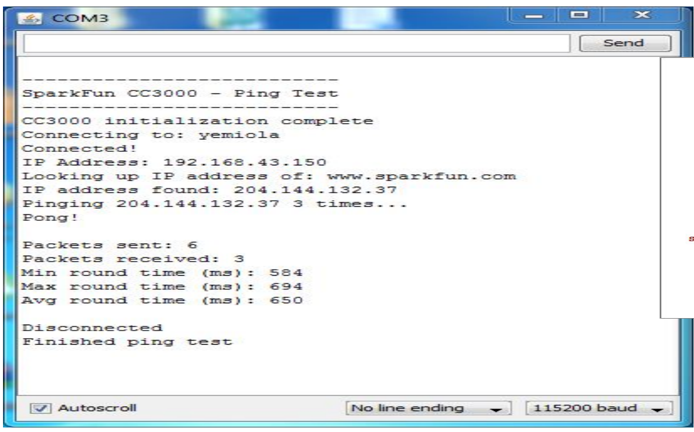

Fig 12 Result of CC3000 Shield Ping Test

After a connection is established, the CC3000 through the access point can ping an IP address or web server and as well as transmit packets and receive packets too.

N. Web Client Test

Having established a connection the wi-fi shield is capable of pinging a web address and retrieving information about the web address. The web address in this case is example.com.
After establishing a connection, a GET request is performed on a web address. The GET request is performed in order to obtain and view the source code of the web address shown in fig 13.

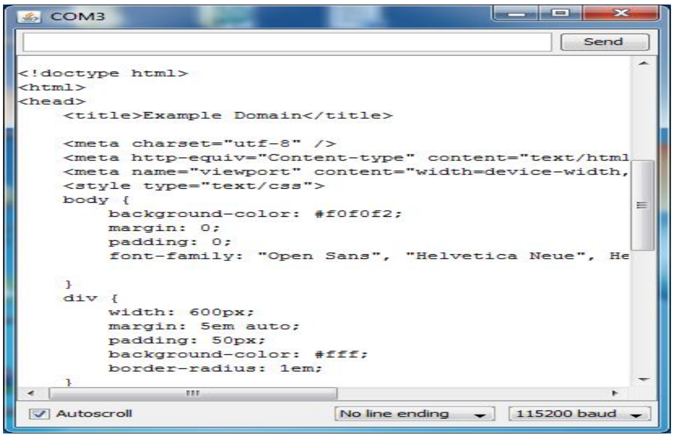

Fig 13 Results of CC3000 shield Web client Test

Connection of the Wi-Fi shield

CC3000 Wi-Fi shield Pin	Arduino Board Pin
EN	7
INT	2
CS	10
MOSI	50
MISO	51
SCK	52
VCC	+5V
3.3V	Arduino +3.3 supply

Interfacing the Arduino Mega Microcontroller, Display Unit and Sensor Unit

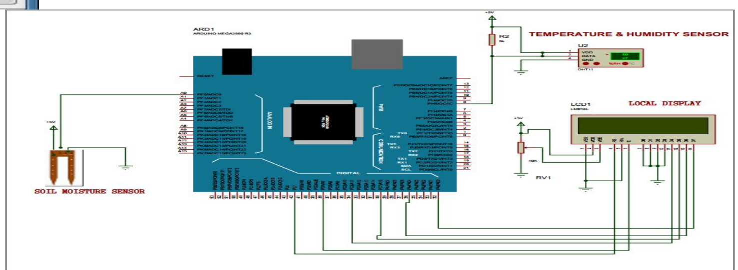

Fig 14 Proteus ISIS circuit design model

O. Mathematical Modeling of the system

Modelling is simply an abstract representation of a system so as to know its behaviour and possibly control it. A model simply represents the relationship of the system interms of its input and output using any form of a modelling technique. In this case a model was developed to define the behaviour of the entire system in terms of sensing. Factors that determines sensing and the data acquisition of these devices. This is illustrated in fig 15

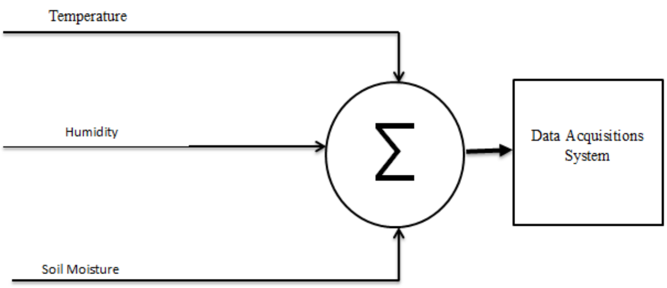

Fig 15: Setup for data acquisition

The acquired data (A_d) from the sensor (O) is a composite sum of the temperature (P), humidity (E) and soil moisture (I).

$$A_d = P + E + I \quad (1)$$

$$Ø = f(P,E,I) \quad (2)$$

Since P and E vary at different locations therefore

$$P = P1 + P2 + P3 + P4 + \quad + Pn\text{-}1 + Pn \quad (3)$$

$$E = E1 + E2 + E3 + E4 + + En\text{-}1 + En \quad (4)$$

$$n = 12\ 3\ 4$$

$$r = 1\ 2\ 3\ 4$$

The sensor is therefore to sense the number of operational points (n), the environmental reading (r) and the time of usage

$$F(P) = \sum_{i=1}^{n} \sum_{j=1}^{t} P_i \quad (5)$$

and

$$F(E) = \sum_{i=1}^{n} \sum_{j=1}^{t} E_{ij} \quad (6)$$

Recall that,

$$Ø = f(P,E,I)$$

$$Ø = f(P) + f(E) + f(I) \quad (7)$$

Therefore,

$$\mathbf{Ø = \sum_{i=1}^{n} \sum_{j=1}^{t} P_{ij} + \sum_{i=1}^{n} \sum_{j=1}^{t} E_{ij} + f(I)} \quad (8)$$

IV. Hardware Implementation

The circuit was designed and simulated using the and the proteus ISIS. The coding was written in C programming language and compiled using the arduino integrated development environment. The arduino mega board was interfaced to the entire component of the circuit and each code were uploaded to the arduino board via the universal serial bus for testing. The various unit were then soldered on different vero board and then integrated and interfaced to the arduino microcontroller board.

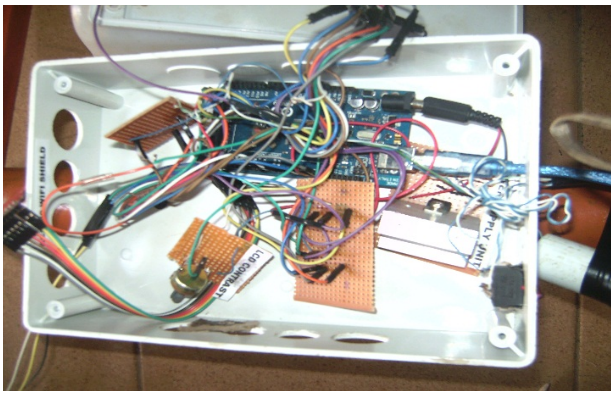

Fig 16 Vero Board Implementation and Packaging

A. System Testing and Coupling

The multi-meter was used to test the polarities of all the components used in the project which includes the passive components such as the resistors, capacitors regulator, battery voltage and the continuity in the circuit. The entire units were then integrated together to form the sensor system. The central module is shown in fig 16

B. Software Consideration and implementation

A web application was developed using two major scripting languages such as PHP and Java Script so as to enable data acquisition and graphical display.

C. Server Side Scripting

In server side scripting the code were written in such a way that they could only be executed and interpreted by the web server. This is not viewable or accessible by any visitor or general public. The PHP combines with the MySQL database and was used to implement the server side scripting.

D. Client Side Scripting

Since client side scripting is the type of code that is executed or interpreted by web browsers thereby making them visible by any visitor to the site. The source file can be viewed as well. Java Script, Cascading Style Sheet and Hypertext Markup languages were used to implement the client side so as to create an interactive interface.

3.9.3 Software Tools

During the design and development of this project, the following tools were used and they include:

- Sublime text editor
- Extended Apache MySQL and PHP local host (XAMPP)
- Proteus ISIS
- Arduino IDE version 1.6.0

The sublime text editor was used to format the web application source code and to debug it as well. The XAMPP on the other hand was used as a local host before making the web application public, this interface was used majorly for testing the functionality of the web app. The developed system was interfaced with the web application and was locally tested and the results were obtained.

The Proteus ISIS was used in the design of the circuit and simulated accordingly. The Arduino IDE was installed on the PC and was incorporated with different libraries for DHT11 sensor, Soil Moisture sensor, and CC3000 Wi-Fi shield libraries respectively. Also the source codes were developed, verified and uploaded to the ATMEGA 2560 microcontroller via the Universal serial bus, for testing.

E. Software and Hardware Integration

The hardware component were assembled together to form the sensor node or transmitting station as shown in the fig 17.

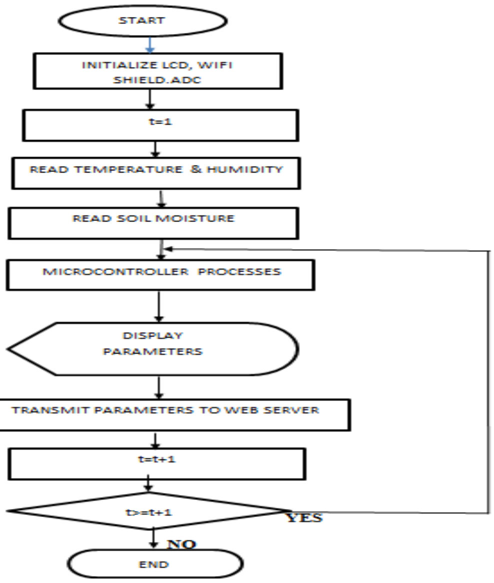

Fig 17 Flow Chart of system flow

F RESULT AND DISCUSSION

1 Sensor node and Web application Integration

The hardware component which consist majorly of the temperature/humidity sensor, soil moisture sensor, the local display (LCD), the CC3000 Wi-Fi shield and the Wireless Access Point were successfully assembled to make up the Hardware system as shown in figure 19.

G. Web Application Interface

The web interface was designed to be a user friendly interface. The parameters acquired from the remote system deployed are posted here. The interface consists of a graph plotter that acquires the recent five value received from the system and plots a dynamic graph at different time stamps assigned by the server during transmission. Also the results are also displayed in rows and column for easy readability. Fig 18 is a site were the system was deployed and tested

Fig 18 Deployed Sensor node (Hardware Component)

H. System Implementation Testing

The development of web based remote monitoring system was achieved. The system was deployed to the farmland and when activated, it senses temperature, Humidity and soil moisture of the immediate environment where it was deployed, the monitored parameters are then displayed locally on the LCD and posted to the web server via the CC3000 Wi-Fi shield. At the other end the parameters are collected and displayed in a user friendly manner for easy readability and acquisition. It was found out that the value displayed on the web application was the same value that was displayed on the local display (LCD).

I. Result

After deploying the developed system to the field, Measurement were taken between the developed system and existing system respectively. This was done in order to evaluate the performance of the developed system based on accuracy of the system with a standard existing system. Temperature, Humidity and soil moisture reading were acquired after subjecting the system to intensive performance testing. Fig. 20 ,21 are capture climatic parameters.

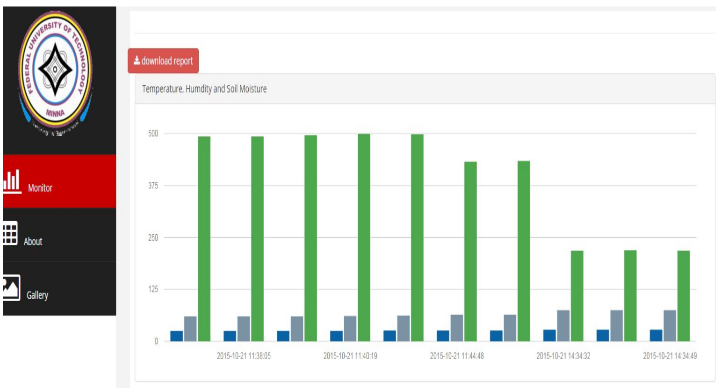

Fig 20 Temperature Humidity and Soil Moisture Reading in Bar chart format from Website.

Temperature	Relative humidity	Soil moisture
28	75	218
28	75	219
28	75	218
26	64	434
26	64	432
26	62	498
25	61	499
25	60	496
25	60	493
25	60	493

Fig 21 Temperature Humidity and Soil Moisture Reading

Table 1 Day 1 Reading for the Developed System

S/N	Time (min)	Temperature (°C)	Humidity (%)	Soil Moisture (cm³/cm³)
1	15.00	30.00	77.00	0
2	15.01	30.00	77.00	0
3	15.02	30.00	76.00	0
4	15.03	31.00	76.00	299
5	15.04	31.00	76.00	314
6	15.05	30.00	77.00	306
7	15.06	28.00	78.00	801
8	15.07	28.00	78.00	743
9	15.08	28.00	78.00	742
10	15.09	25.00	58.00	464

Table 2 Day 1 Reading for the Existing System

S/N	Time (min)	Temperature (°C)	Humidity (%)
1	15.00	30.10	77.20
2	15.10	30.00	77.20
3	15.20	30.05	76.00
4	15.30	31.00	76.50
5	15.40	31.20	76.40
6	15.50	30.10	77.50

Table 3 Day 2 Reading for the Developed System

S/N	Time (min)	Temperature (°C)	Humidity (%)	Soil Moisture (cm³/cm³)
1	15.00	30.00	77.00	0
2	15.01	30.00	77.00	0
3	15.02	30.00	76.00	0
4	15.03	31.00	76.00	299
5	15.04	31.00	76.00	314
6	15.05	30.00	77.00	306
7	15.06	28.00	78.00	801
8	15.07	28.00	78.00	743
9	15.08	28.00	78.00	742
10	15.09	25.00	58.00	464

Table 4 Day 2 Reading for the Existing System

S/N	Time (min)	Temperature (°C)	Humidity (%)
1	14.00	28.10	75.50
2	14.10	28.00	75.00
3	14.20	28.00	75.40
4	14.30	26.30	64.30
5	14.40	26.40	64.20
6	14.50	26.40	62.10
7	14.60	25.20	61.20

Table 4.5 Perfomance Evaluation Result

	DAY 1		DAY 2	
	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)
Developed system	29.10	75.10	26.71	68.00
Existing System	29.22	75.42	26.91	68.24

The percentage error of temperature and humidity for the two days was calculated for both developed and the existing system using the equation:

$$\frac{Initial\ Value - Final\ value}{Initial\ value} \times 100\% \qquad (9)$$

The percentage error for temperature and humidity from the developed system was gotten to be 8.21% and 9.45% respectively.
The percentage error for temperature and humidity from the existing system was gotten to be 7.91% and 9.52%

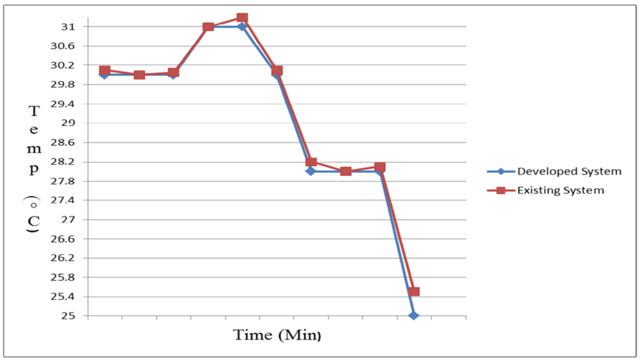

Fig 22: Graph of Temperature for Day 1

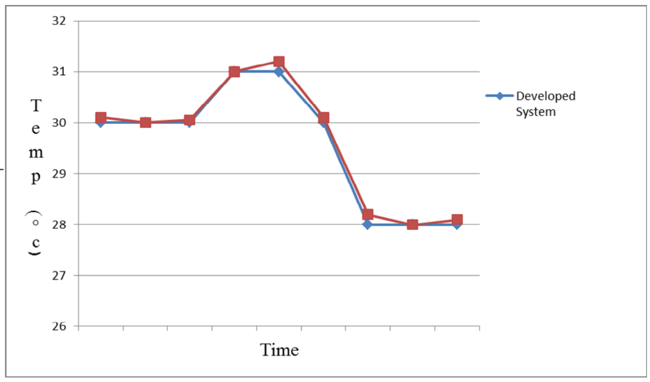

Fig 23: Graph of Temperature for Day 2

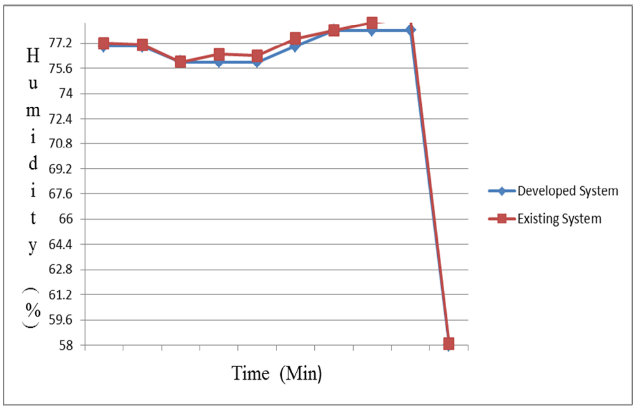

Fig 24: Graph of Humidity for Day 1

V. DISCUSSION OF RESULT

The graph of all the reading were plotted for both Temperature and Humidity as the measurement were taken for two consecutive days. The output of the graph were shown in Fig 22 to 24 . The percentage error of the existing system was calculated for both temperature and humidity

Table 2 shows the result obtained for the performance evaluation. The percentage error obtained from both system as reported above shows that the result of the temperature of the existing give a better reading compared to the developed system by a factor of 0.30, this variation is due to differences in the accuracy of the sensors used for both system.

The percentage error calculated from both system for humidity values shows that the developed system is more accurate than the existing system by a factor of 0.07, the accuracy of the different sensors used is assumed to be responsible for this variation.

VI. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The project has successfully been developed and evaluated. The transmitting station which consists majorly of the sensor node has been designed and developed. The parameters which include temperature, humidity and soil moisture value are sensed respectively, displayed locally on the LCD and transmitted in real time to the web application dashboard for remote monitoring and global access to monitored parameters. This is of immense benefit to the farmer and agro-climatological researchers as these parameters can be downloaded for analysis and necessary evaluations. The integration of the hardware and software component makes this project a unique one as it helps to improve food security in the agricultural sector and in monitoring the climate as in climatology of a specific place.

The system design schematic and overview of the system design are found in fig 5 and fig 6 respectively. The transmission station design was achieved and shown in the figure 5 where the sensor node which consists of the sensors, power supply, ATMEGA 2560 microcontroller, CC3000 Wi-Fi shield and other passive electronic components was developed and deployed to sense, display and transmit the parameters. The web based application or dashboard designed to receive and view the data was developed successfully, adhering to all the steps involved in web development process . The transmitting station and the web dashboard were successfully integrated together in order to establish communication.

Finally, the performance of the system was evaluated based on its sensor sensitivity level, accuracy in transmission and response time.

B Recommendation and Future work

The system can be improved upon in the future by the following:

- **Portable Power Optimization**
  The wireless sensing system is one major system that consists of electronic components whose power rating is high thereby reducing the lifespan and availability of the system. Therefore to increase and maintain workability the power supply must be optimized.

- **Distributed Sensing**
  In order to achieve large scale monitoring multiple sensor nodes should be deployed to the area of interest to form a wireless sensor network.

- **Multiple Sensor Integration**
  Other sensors such as light sensor, soil temperature sensor, atmospheric pressure sensor, and devices such as wind vane, anemometer and rain gauge can be integrated in order to attain high rate of environmental monitoring.

- **Stable Internet Access**
  Networking Devices such as wireless access point and routers can be incorporated to the system so as to provide stable internet access.

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