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Monitoring and Control System for Precision Agriculture Using Wireless Sensor Network

Sabiha Kousar [a], Sidra Shahid [a], Sanaullah [b*], Asad Ullah [a], Adnan Ghafoor Tabsum [c] and Misbah Tubassam [a]

[a] Department of Computer Science, University of Agriculture, Faisalabad, Pakistan.
[b] Institute of Plant Protection, Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan.
[c] Department of Space Science, University of Punjab, Lahore, Pakistan.

Authors' contributions

This work was carried out in collaboration among all authors. Author SK executed research analysis in laboratory and author SS conceive the idea and supervised the work. Author Sanaullah has proof read the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Agriculture is an essential part of the Pakistani economy, and it is embedded into the country's antiquated financial framework. Intelligent systems can be developed through the usage of IoT-based technology. In hydroponics farming, precision is a challenge, particularly for some sensitive plants like bok choy and lettuce. These plants need a certain amount of fertilizer and water each time in order to grow as well as possible. The Internet of Things (IoT) enables routine monitoring of every element of a person's life. A remedy might be to periodically evaluate the plants' nutrient and water requirements. In this study, monitoring and control systems for hydroponic precision agriculture are developed using IoT and fuzzy logic. Fuzzy logic is utilized to control how much food and water the plants receive, and IoT is used to make it feasible to periodically assess the nutritional and water needs of plants.

**Corresponding author: E-mail: sanaullahjatoi74@gmail.com;*

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1. INTRODUCTION

Precision agriculture (PA) is an agricultural management concept focused on monitoring measuring and adapting to agricultural variation for both areas. To ensure that the crops obtain the exact amount of minerals, really needs optimal quality and development of precision agriculture system which utilizes information technology (IT). Because of this, stability, prosperity, and pollution prevention are all maintained. While managing crops, it considers variables such as soil type, location, weather, plant growth, and crop data. To maximize productivity, farming needs the proper WSN, soil moisture, temperature, humidity, and care.

Farmers have reported significant financial losses because of inaccurate weather forecasts and poor crop irrigation techniques. Now that WSN technology has advanced, it is conceivable to employ them for precision agriculture applications such as autonomous environmental monitoring and field parameter control [1,2]. The lack of understanding about soil type, composition, the type of fertilizers used, pattern of irrigation that should be used depending on the soil's porosity and capacity to retain water, are some of the primary issues that exist today. Analysis of soil is not widely employed in the current Pakistan context to boost crop yields, partly because it is expensive and difficult to find labs that have these testing facilities [3].

Wireless sensor networks (WSN) and radio-frequency identification (RFID) are recognized as the two main pillars of IoT sensing and communication technologies. Wireless sensor networks have numerous applications in the military, in agriculture, in sports, in medicine, and in business [4]. As a result, a lot of data is being produced. Monitoring the soil, the climate, and the plants is necessary to make the best use of agricultural resources.

Sensors collect data, and IoT modules, IoT cloud services, data processing application servers, and monitoring devices are utilized to transmit it. These are the primary components of agricultural monitoring. With the use of IoT, devices may be upgraded to become smarter, communicate, and exchange data. IoT has grown rapidly as it employs a variety of technologies and is employed by a wide range of applications. The number of IoT application domains and, as a result, connected devices is rapidly increasing [5]. Small- to medium-scale arable farming uses spatially enabled mobile sensing technology to provide accurate assessment of field conditions in the various soil layers, nutrient levels, and general ambient environmental conditions. Smart irrigation is also being used to enhance the irrigation cycle by accounting for the plants' evapotranspiration rate. Temperature and soil moisture sensors are routinely used to plan irrigation [6].

A wide range of applications can be solved by using Wireless Sensor Networks (WSNs). Examples of applications include tracking your health, tracking your agricultural, tracking the weather, tracking your air quality, and tracking landslides. WSN incorporates a number of technologies, including those related to sensors, networking, controls, information storage, and information processing.

Aim of this research is to introduce sensor-based model in Pakistan, which control related soil temperature, humidity: A large variety of climatic parameters are being observed in this investigation using the sensor nodes that are in place right now. Precision agriculture uses IoT and data analytics applications as smart systems.

In [7] investigated that agri-food industries have increased with the aim of improving productivity by at least 70%. Precision agriculture (PA) has greater potential and is made possible by new methods of data analysis that reveal patterns and trends as well as emerging technologies like the Internet of Things (IoT). One of these technologies, known as remote sensing (RS), is regarded as one of the most crucial for this application. RS has been used to monitor crops since its debut forty years ago, initially using photos from sensors on satellite platforms. When using these, the spatio-temporal, and spectral resolutions needed for many PA applications are constrained. In this study, [8] achieved the goal of precision farming to align agricultural methods with climatic conditions to maximize the accuracy of application. Farming acreage has slightly decreased during the past 40 years. However, the farmers have recently doubled in number. Sharma et al [9] achived the application of automated farming and autonomous tractors, farmers can use irrigation systems to practice modern farming. The frequent application of lags behind domestic food production already employing ML algorithms to analyses and evaluates the primary data in order to improve and control farming practices. Based on data from sensors, climatic records, and satellite images, Machine Learning algorithms are also used to predict the weather and amount of rainfall. Precision farming has become a global phenomenon due to advanced machine learning (ML), fast internet, and powerful computing hardware [10]. The Ecological Revolution or third agricultural revolution, which took place between 1960 and 1980, improved crop yield and food security, especially in developing nations, Precision farming is also referred as precision agriculture. It is the process of acting in the appropriate manner, at the appropriate time, and in the appropriate location [11], They went into great depth about how IoT is assisting precision agriculture by allowing fields to connect with one another. They proposed using IoT to increase agricultural yield to meet the needs of a large population by utilizing the limited available arable land for cultivation, fresh water for irrigation, and so on, by providing the precise and required quantities of fertilizers, insecticides, and water. WSN was utilized to design and implement an environment monitoring system for precision agriculture.

2. MATERIALS AND METHODS

To achieve the best results, farming necessitates a certain amount of micro-management and attention because it plays a significant social and economic role in the world. Such management might theoretically be done automatically, remotely, and without a lot of human involvement. A system for such management would be necessary to maintain and irrigate crops, watch over, evaluate weather predictions, spot fires or other threats on farmland, and analyze less productive crop irrigation systems. Furthermore, such a network must be controllable on both a micro and large scale. A structure of this kind can feasibly be realized through IoT-based architecture by implementing micro electromechanical scanning controllers, water level sensors, laser sensors, soil sensors, temperature sensors, humidity sensors, cameras, internet connections, and cross connectivity with other systems, such as mobile phones, etc [12].

The architecture of the system is comprised of five major modules: an ESP8266 microcontroller module, a pH sensor module, an electrical conductivity sensor module, a water level sensor linked to a relay and pumps, and a humidity sensor module design. In developing the application, the author also employs the C language, which is compiled using the esp-openSDK toolchain via the Arduino IDE to build programs on the Arduino Uno microcontroller, to be able to control each input from the sensor and output to be carried out. The Arduino Uno will receive sensor input and use fuzzy logic to make a decision. Each value given by the sensor will be read by the microcontroller, processed, and a decision will be made. To store measurement data, the microcontroller will connect to the server via an already-existing internet connection. As shown in Table.1, four sensors the pH sensor, EC sensor, water level sensor, and humidity sensor are used in this study. Fuzzy logic will be utilized to automatically control PH settings in accordance with a defined rule. The PH Up pump and PH Down pump should be turned on in this case in accordance with the PH value and water level conditions, according to the stated criteria. Examples of rules from a knowledge base that will be used are shown in Table 1 as follows: The valve's duration of PH up is moderate if the PH is extremely low and it is dry. If the water quality and PH condition are inadequate, the PH Up Faucet will activate in a medium period of time. The valve should remain open for a considerable amount of time if the PH is really low and there are numerous water sources. If there are various water conditions and the PH is extremely low, the PH up tap will be on for a long time.

$$Z = \frac{\sum Z_j \mu(Z_j)}{\sum \mu(Z_j)}$$

Table 1. Knowledge base for ph sensor (if the ph is very low and the V is waterless, then the duration of the valve ph up is moderate. if the ph level is low and the water quality is poor, the ph up faucet will activate for a short period of time. if (ph is very low and V water is plenty), then open the valve for a long period of time. if the ph is very low and the water conditions are numerous, the ph up tap will be turned on for an extended period of time. if (ph is high and v is dry), then turn the valve ph down for a short period of time. if the ph is high and the water conditions are poor, the tap will be switched on immediately)

Water Level	Pump On - pH Up		Off	Pump On - pH down	
	pH Very Low	**pH Low**	**Normal**	**pH High**	**pH Very High**
Low	medium	fast	stop	Fast	medium
Normal	medium	medium	stop	medium	medium
High	Long	medium	stop	medium	long

Table 2. Input and output fuzzing parameters (the output value of the aforementioned parameter is displayed as the amount of time it takes to open the tap in the duration grouping)

Output parameters	Duration
Fast	0 – 3 second
Medium	3 – 5 second
Long	5 – 8 second

The TDS pump will be active for a long time if there are numerous water conditions but few EC conditions. - The TDS pump will be turned on quickly if the EC condition is low and the water quality is poor. If the EC conditions and water conditions are both deficient, the TDS pump will activate quickly. In this work, fuzzy logic was created utilizing Mamdani rules and the Center of Area (COA) approach, and the universe's affirmation (defuzzification) was accomplished through the use of an equation.

2.1 Design Architecture

Hardware design is combination of two modules:

- Embedded module
- Ethernet communication module

The primary module consists of two microcontrollers that detect the parameters of the framework a water, temperature, humidity, and a fire sensor is used. Data is transmitted via the UDP protocol over Ethernet using Wi-Fi connects. It collects data, maintains records and displays viewpoint activity. It has two working modes.

- Automate mode and Manual mode.

If the system is operating in programmed mode, it would carry out the activity according to the sift hoad value and keep providing input via the GUI and IP. Devices are controlled via buttons in the GUI if the system is configured to operate manually. The sensor-based creature incubator includes a subsystem, soil sensors, temperature sensors, humidity sensors detector, IP cameras, an incubator, and a fire detection system.

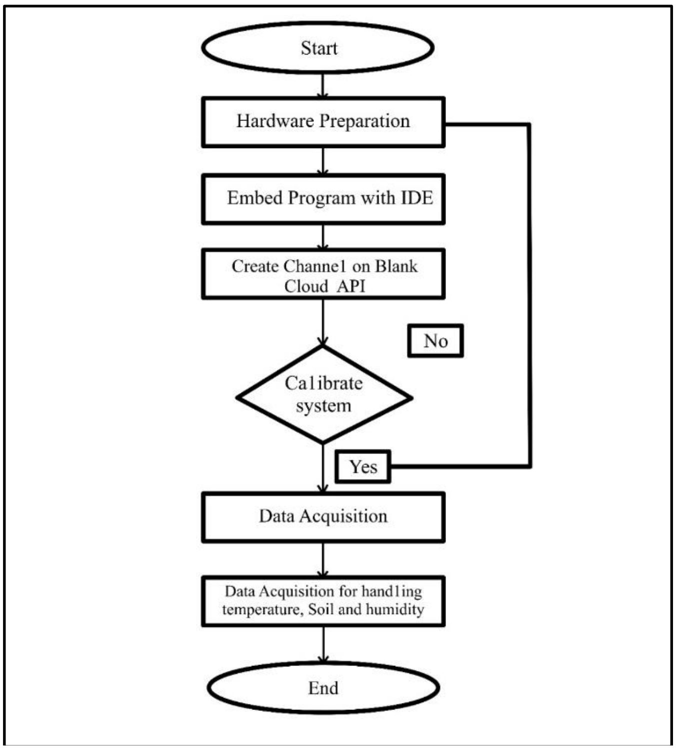


Fig. 1. Proposed Diagram (Work on the hardware first, according to the flow chart, during the designing process. Following that, both created modules were integrated into the software level. Following a successful integration, data collection begins, and all information gathered is displayed on the BlynkCloud API)

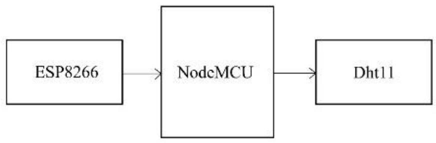


Fig. 2. The BlynkCloud API offers top-notch tools for building IoT sensors. Using the channels and web pages made available by the BlynkCloud API, we can manage the network over the Internet, and we can access the BlynkCloud API website to check on our data from any location

The first stage in creating a smart framework is to create a flow chart for the full mode l as shown in Fig.1. to describe the mode l's fundamental functionality and flow of work. If required, the flow chart is modified and adapted to meet user needs. Conforming to the flow chart, work on the hardware first in the designing mode. Afterwards merged both designed modules into the software level. Data collection begins after successful integration, and all obtained details are displayed on the BlynkCloud API.

2.2 Temperature and Humidity Sensors

Temperature and humidity are often monitored parameters in numerous places, including fields, nurseries. As shown in Fig. 2., For monitoring humidity and temperature and displaying data on the BlynkCloud API, Arduinos are used. This IoT project utilizes BlynkCloud API to remotely monitor humidity and temperature along with the BlynkCloud API server to broadcast real-time humidity and temperature data. Transmission of data between the Arduino, DHTll sensor module, and ESP8266 Wi-Fi module is used to achieve this. For real-time monitoring from anywhere in the world, Celsius and Percent Hygrometers transmit ambient humidity and temperature measurements to the BlynkCloud API server.

There seem to be four main phases to the IoT-based project. The humidity and temperature sensor DHTll, which monitors simultaneously humidity and temperature. In second phase, NodeMCU transforms the information from the DHTll sensor into the proper percentages and degrees Celsius when transferring it to the Wi-Fi module. Eventually, data is sent to BlynkCloud API servers using the Wi-Fi module ESP8266. The data is analyzed results by BlynkCloud API which displays it in graph format. BlynkCloud API provides great tools for IoT development that use sensors. manage the network via the internet by using the channels and web pages supplied by BlynkCloud API and are able monitor our data from everywhere by utilizing the BlynkCloud API website. Data collected by sensors is "collected" by BlynkCloud API, which further evaluates and stylizes "data" and "behavior."

3. RESULTS AND DISCUSSION

The farm's revenue and expenditures are what determine its profit and loss. Plans and goals must be developed first for proper management. Agricultural goods, account water level sensors, laser sensors, soil sensors, temperature sensors, humidity sensors, cameras, internet connection, and artificial insemination procedures are only a few of the required records that must be maintained. Developing the organization provides the most efficient way to keep track of farm activities related to the environment and other management tasks [13]. This information can be processed and analyses to help with important decisions and identify areas that require improvement. The farmers are not required to participate in the services by themselves. It can control all activities using a GUI on a computer or smartphone.

Crops that provide a relatively higher yield are more sensitive to temperature. The increase temperature result increase in agricultural yield or production if the indicator is positive. Each plant exhibits a substantial negative correlation, which indicates that crops with relatively high yields are more susceptible to heat and may produce less when the temperature rises.

The relationship between crop production constants, soil temperature monitoring, and moisture coefficients is shown in Fig. 3. The integrating platform for collecting, analyzing, and delivering data is the BlynkCloud API. It offers further MATLAB analysis functionality for data that has been obtained.

Fig. 3. Graph pertaining to sensors for soil, temperature, and humidity This graphic illustrates the connection between soil temperature measurements, moisture coefficients, and crop production constants

Fig. 4. Humidity condition within field (Relative humidity is the measurement of the amount of water in the air in relation to the highest amount of water vapor (moisture). The air's capacity to hold water vapor rises as temperature does)

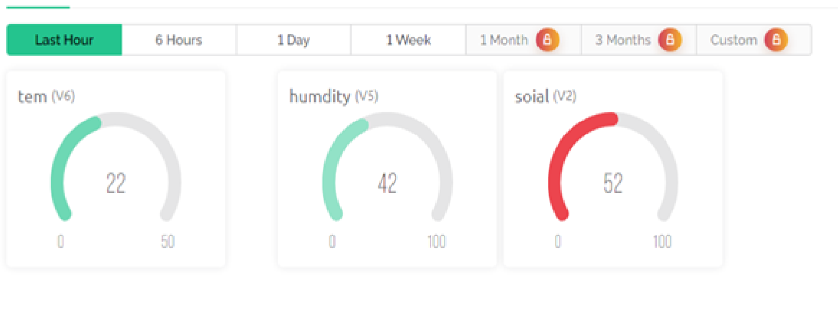


Fig. 5. Soil temperature (Calculations must be made using the soil temperature for the majority of below-ground ecosystem processes, including root growth and respiration, decomposition, and others soil temperature)

Temperatures ranging from 30 to 40% should be monitored in the field to produce appropriate crop conditions. To attain optimal circumstances, the humidity on the field should be set to 35-70%. Relative humidity is defined as the amount of water in the air in ratio to the highest amount of water vapor (moisture) as shown in Fig. 4. The higher the temperature, the more water vapor the air can transport.

According to Fig. 5. the crop needs to be kept at a temperature of between 30 and 40 degrees Celsius. Knowing the soil temperature is necessary to calculate ecological processes that occur underground, such as root growth and respiration, decomposition, and soil temperature. Because soil temperature responds to the net effect of the daily surface energy balance, it is possible to estimate soil temperature using a running average of air temperature, with longer integration times as soil depth increases. The temperatures of the soil, water, and air can all be monitored simultaneously via soil temperature sensors.

3.1 Evaluation of Plan Growth

After a series of tests on the sensor and the smart controlling system as a complete chunk in accordance with the needed scenario, the researcher begins conducting studies on directly applying this smart controlling system on plants. In this experiment, the researchers contrasted two installations. The initial installation required manual control every three days and employed hydroponic planting. The proposed technique was utilized to control the second installation. Lettuce and Bok choy were planted in these two installations. Every three days, the system's performance was evaluated. In both installations, the researchers measured the plant's leaf length and width. To simplify measurement, the researcher simply measured the leaf length and width of each installation pot. The graph displaying the results of the measurements from both installations makes it simple to compare the increase in plant growth at each location.

3.2 Data Splitting

Because the leaves are growing longer but not much wider, the results demonstrate that lettuce plant growth is not doing very well. In bok choy plants, the results of smart control systems show better leaf breadth and length as well as plant height. When planted conventionally, bok choy plants grow more slowly.

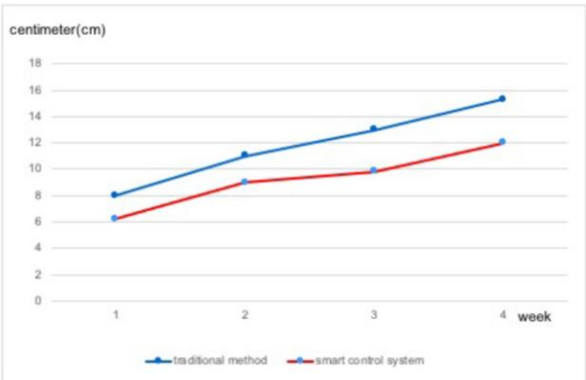
3.3 Leaf Length Comparison

The results are shown by the growth of leaf length and width (see Fig. 6.). These results from the smart control systems clearly show that plant development is improved compared to the traditional methods.

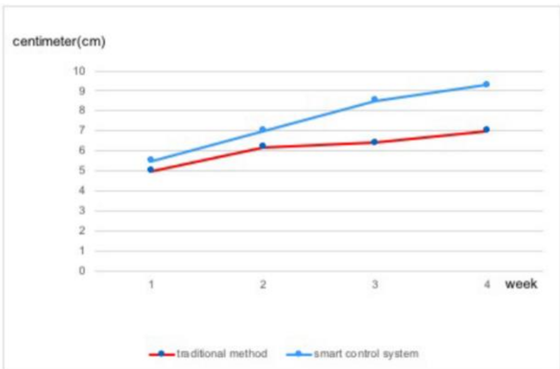
Every three days, the pH and nutritional value of the plant installation are assessed for planting done using the standard method. If the measurement results are outside the prescribed range, the plant's nutritional value and pH are both within it. Manually determining the pH and nutrient content of soil does not always result in the best results because it must be done regularly every three days and is occasionally forgotten.

3.4 Leaf Width Comparison

Additionally, because a number of factors, like the weather, can cause a number to change rapidly in a short period of time, this method does not guarantee that the pH and nutrient levels in the installation are within the permissible range. According to the period given in (Fig. 6. and 7), the smart regulating system will automatically measure the pH and nutrient content values, and it will then change the values so that they are always within the appropriate range.

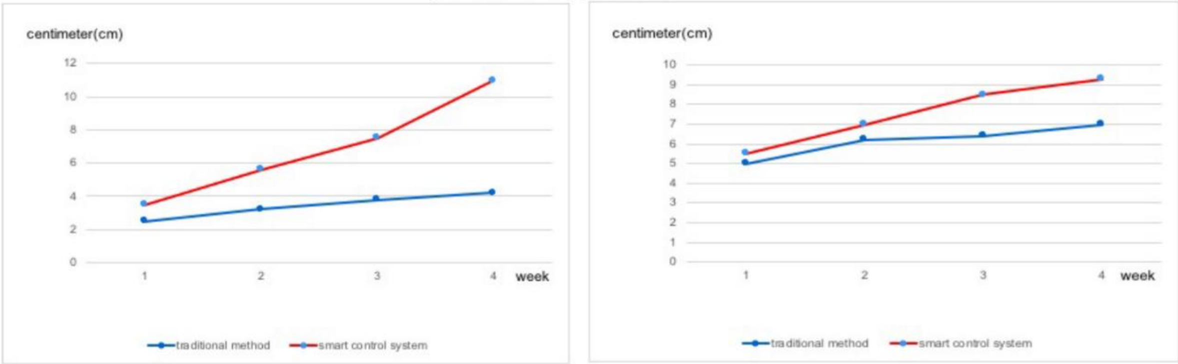


Lettuce plants (A)



Bok choy plants (B)

Fig. 6. The results of the graphs in (A) and (B) show a comparison of traditional approaches with a smart regulating system. The outcomes of smart controlling research better growth in lettuce plants is shown through systems. The outcomes can as evidenced by the expansion of leaf length and breadth



Lettuce plants (C) Bok choy PLANTS (D)

Fig. 7. This result(C) and (D) differs from the normal approach in that the lettuce plant growth leaves are longer, but they are not wide, indicating that lettuce plant development is inadequate. Smart regulating mechanisms in bok choy plants result in increased leaf breadth and length, as well as plant height. Traditional methods cause bok choy plants to grow more slowly

4. CONCLUSION

In this study, an IoT approach is proposed that considers the needs of a crop yield for the climatic conditions of Pakistan. The WSN in farming is a cutting-edge device for gathering and processing information in sugarcane fields. Compared to conventional agriculture methods, it is better. This study organized the precision agricultural monitoring system using wireless sensor nodes and a base station to store sensor node data. With this low-cost solution, captured data is sent by SMS over a GSM network to a remote site. The adoption of IoT devices will reduce water use by only watering the crops when necessary and with the appropriate amount of water. Therefore, based on their Internet connection, region, type of crops, etc., farmers can choose from a wide selection of platforms that will help them improve their work. The objective of this study is to compare the most widely used farm platforms while highlighting a variety of various aspects, such as knowledge base, monitoring modules, efficiency, etc. The proposed system is designed to monitor the factors important to crop. To build precision agriculture systems, the wireless sensor network infrastructure offers data collection, processing, and recording at the node level. This is a low-cost technique that improves the effectiveness of resource utilization, potentially increasing productivity. Applying the right amount of nutrients and water is possible. The very adaptable and user-friendly GUI on a smartphone can be used to remotely control the entire system. The system is quick and responsive, and farmers will be informed if there are any errors. Labor costs are decreasing. In this work, a monitoring and control system for hydroponic plants based on the Internet of Things and fuzzy logic has been suggested. The precise flow of water and nutrients is controlled by fuzzy logic, and the Internet of Things is used to monitor the plants' need for both. The outcomes of the experiment with lettuce and bok choy plants show that the hydroponics produced in accordance with the suggested method outperforms the hydroponics grown in accordance with the traditional manual method.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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