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Smart Agriculture: Automated Controlled Monitoring System using Internet of Things

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***Abstract:** This paper proposesan efficient monitoring unit for Controlled Environment Agriculture (CEA) system based on hydroponics environment using various IoTsensor nodes, which is mainly useful toanalyse the habitat conditions. This proposed work makes use of data logging mechanism, which provides detailed overview of the climatic conditions periodically to obtain better quality control along with reduced cost and effort. In particular, we analysed the habitat conditions for various seasonal regions of India and has been proved to be more reliable for these conditions of Indian agriculture.*

***Keywords**—Hydroponics, Controlled Environment Agriculture (CEA), Sensor Nodes, IOT.*

I. INTRODUCTION

Farming in India is done using the routine ways. The fact that most of our farmers lack proper knowledge makes it even more erratic. A large portion of farming and agricultural activities are based on the predictions, which at times fail. Farmers have to bear huge losses and at times they end up committing suicide. Against the challenges such as extreme weather conditions and rising climate change, and environmental impact resulting from intensive farming practices, the demand for more food has to be met.
The global population is set to touch 9.6 billion by 2050. So, to feed this much population, the farming industry must embrace Internet of Things (IoT). As, IoT has the capability to transform the world we live in; more-efficient industries, connected cars, and smarter cities are all components of the IoT equation. However, the application of technology like IoT in agriculture could have the greatest impact. Since we know the benefits of proper soil moisture and its quality, air quality and irrigation, in the growth of crops, such parameters cannot be ignored. Hydroponics is the one of the predominant soilless plantation techniques in agriculture.hydroponics with IoT technology would escalate the yield profoundly.

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The application of modern technology in the field of agriculture to raise productivity and profitability has gradually evolved. Automated Collection of sporadic data of targeted factors like temperature, humidity, water level, light detection can be achieved by employing sensor tools[2].
This helps in avoiding the need to employ manpower in perilous plights. In addition, manual collection of data can be tedious and can cause complications such as incorrect measurement. With increased awareness of utilizing technology, remote measurement of environmental characteristics is possible; this is where Internet of Things comes into play.

Internet of Things (IoT) refers to intelligently connected devices over internet to exchange and consume data gathered by embedded sensors and other physical objects with minimal human intervention. Along with IOT, several technical developments taken together are required to reduce gap between physical and virtual world. In the coming years, due to advance in IOT technology both producers and consumers will be benefitted. In this paper, we proposed

Controlledenvironment agriculture (CEA)*using IOT[5], which is a technology-based approach towards sustainable food production and distribution. Therefore, the local food production in large volumes, in urban and exurban environments becomes feasible. This proposed work makes use of data logging mechanism, which provides detailed overview of the climatic conditions periodically to obtain better quality control along with reduced cost and effort. Moreover, this work gives some of the merits, namely; reduces the need of chemical fertilizers and harmful pesticides, significant reduction in the use of resources such as water, nutrients with observation, which achieves optimal growth environment.

The paper is structured as follows: Section II gives the related work and literature survey requires for this proposed work. Section III gives the design and modelling of CEA. The results and experimental analysis of CEA are presented in Section-IV . Section V concludes the paper with future scope of this research work.

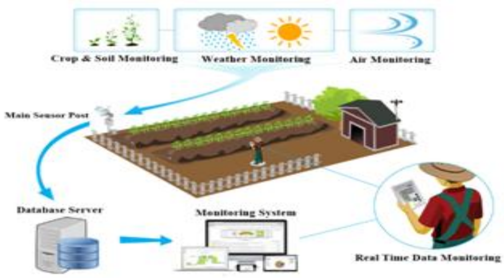

Figure-1 Controlled Environment Agriculture (CEA) using IOT

II.LITERATURE SURVEY

This subsection presents the state of art contributions that were produced by various researchers. BoSun.et.al put forth *Crop Monitoring System Based on Wireless Sensor for Agriculture Using Wi-Fi Network*ing which he coupled wireless technologies with the sensor based devices to monitor many of the important constraints of the Indian agriculture like moisture, humidity and temperature. The points of interest of their thoughts are having a remote sensor that interfaces through Wi-Fi towards one of Central Monitoring Node using a General Packet Radio Station [2]. He also adds that it additionally associates with GPS to send back rub to the focal checking station. Moreover, they had external sensors such as soil moisture, pH and leaf moisture. Basing on the data readings like that of soil moisture, which they obtain from the various sensors, and take necessary actions like turning on or off the water sprinklers.

Albright.et.al presented A Scoping Study on CEA in which he has done a very intensive study on the various concepts and paradigms of the Controlled Environment Agriculture. In the paper, the author explicitly specifies that there should be a use of hydroponics instead of traditional soil. Hydroponics [3] is the methodology of agriculture, where the plants are grown in the water and all the required nutrients are directly introduced into the water, instead of through soil. It is considered a diverse option to the agriculture. The author discusses the foundational and functional concepts of CEA. Based on the climatic conditions, weather shifts, ecological footprint etc. there are many constraints that are to be considered.

Junyan.et.al orchestrated Connecting Agriculture through IOT using sensors in which he mentions that networks of Sensors can connect the space between the world and cyberspace, and thus the key to connect the agriculture to IOT is the design of the device. Further, those associations sets uplinks around agronomists, farms, and products in any case from claiming their geological differences, What's more along these lines enhances the creation of Agricola items. Previously, future work, they would be arranging will re-design the requisition once highest priority on 6LoWPAN architecture, which he accepts will enhance the bury vivo trust - operability is more simplicity for modifying to sensor networks at interfacing of the IOT.

JiChun.et.al detailed The Application and study of IOT technology in the Agriculture, which explained the importance of IOT, and its usage in the agriculture field. He supports RFID technology, to support the connectivity between the sensors that are used. RFID technology uses the radio waves in order to recognize items and was assumed to be one of the major users of the Internet of Things. The IOT technology has been integrated with control networks and information networks to study the actual scenario of agricultural production. The idea of remote monitoring system using internet and wireless communications is proposed. They concluded that there is a scope to build greenhouse monitor system that should stay online logging all the data, that is operated online.

Lakshmi.et.al proposed Smart Precision based Agriculture using sensors in which wireless sensor based networks can be used to monitor the agricultural environment. Raspberry pi and ZigBee based monitoring system for the agriculture is identified as an efficient and reliable method for monitoring agricultural parameters. It not only allows the users to view the data, but also helps them to see through the accurate changes in the various constraints. Further, author focusses on developing the tools for monitoring, display and alarm the users about the various conditions using the advantages of wireless sensor network system.

Li Li.et.al detailed The Applications in Internet of Things and Smart Grid about Wi-Fi-based Wireless Sensor Network, which supported that the use of the Internet of Things and smart grid are of most importance towards guiding the evolution of agriculture. He argues that there is a need of uncommon prerequisites from claiming a few applications, taking off the existing engineering unsatisfactory. He proves that the Wireless Sensors Networks (WSN) have advantage over the ZigBee, as they show higher bandwidth and rate, non-line transmission ability, large scale storage & data collection, also highly cost effective. It also has the capability for also monitoring the video feed. This paper proposes about the application of W. S. N over Wi-Fi based smart agriculture, smart grid, intelligent environment protection and various other applications.

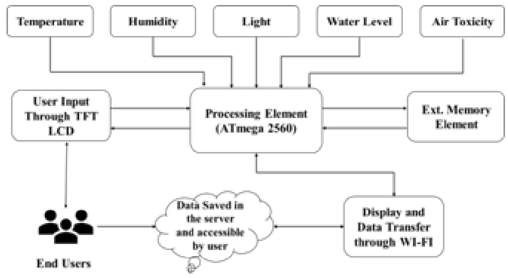

Figure-2 Proposed Monitoring and Control Unit of CEA System

III.PROPOSED AUTOMATED MONITORING AND CONTROLLED ENVIRONMENT AGRICULTURE SYSTEM

In this section, we proposed to design the CEA system, which provides automated monitoring and control unit for effective and accurate data of environmental constraints. The rest of the section presents the functional, non-functional requirements, system architecture, hardware and software design.

3.1 Functional Requirement.

The following are the requirements for proposed framework, which describes the behaviour of the various sensors used within the system- Sensor nodes are used to sense the Temperature, Air Toxicity, Water Level, The Light and the Humidity. LCD Screen is used to display the sensor readings, User Interface for the optimal values

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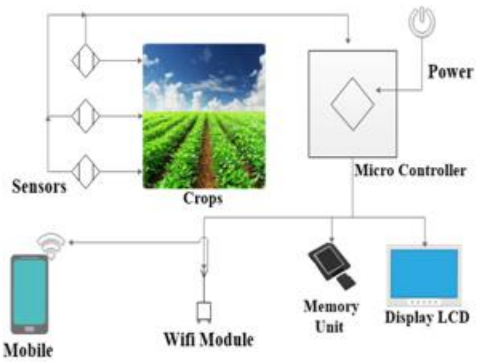

Figure-3 System Architecture of Controlled Environment Agriculture

3.2 Non-Functional Requirement

The various metricsof non-functional requirements of this proposed systemare better Maintainability,Reliability, Availability and Easy to use.

3.3 System Architecture

This subsection presents the system architecture of the proposed system, which is modelled using AMD (Arduino Mega Development)kit that is connected with various sensor nodes like *light sensor* for measuring the luminance, *Temperature/Humidity Sensor* for sensing the temperature and humidity of the surroundings, *Soil Moisture Sensor* is used for measuring the water level within the soil, *Air Toxicity Sensor* is used for sensing the carbon monoxide and oxygen levels in the open air of the surroundings.

Initially, all the sensors nodes (Temperature, Humidity, Light, Water Level and Air Toxicity) are connected to Processing Unit(PU), ATMEGA 2560, which is micro-controller that takes the input data from the all the above sensors and display on the TFT LCD monitor which function as output. This output data is transferred to the end user through Wi-Fi module, which is integrated in PU. In addition, the PU also maintains the logged data stored in External SD card for any further information required by the end users. Moreover, we also designed a User Interface (UI) that provides the flexibility to the user to set the threshold values through the TFT LCD monitor. This interface will be useful to alert the end user, when the sensor data exceeds the user defined threshold value of each sensor node.

3.4 Software System Design:

This subsection presents the implementation of working model of proposed system using Arduino Genuine (IDE) environment that integrates both the hardware and software, which is depicted in the figure-5. The Arduino board contain a WIFI module with unique IP address that passes the sensor data from the Arduino board, in turn passes to the server that has a public IP, forwards the data to the end user through the web page and notifies the end user through browser notifications. In addition, we also designed an End User Interface (UI) that provides the

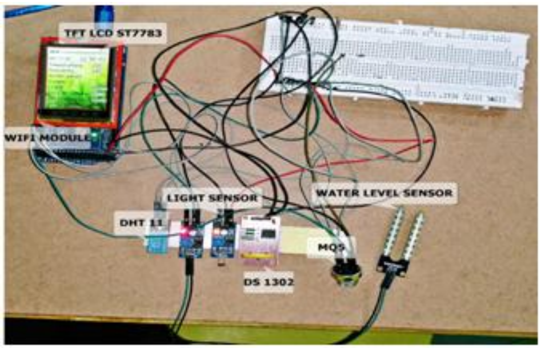

Figure4 Hardware Model of Controlled Environment Agriculture

flexibility to the user to set the threshold values using either Touch screen LCD monitor or through the web interface. When the threshold value from sensor data exceeds the user defined threshold value, a notification will be sent to the user as a browser notification, so that the end user can monitor the sensor data at any time, any place and on any device. The proposed system also maintains the backup data in the form of log data stored in External SD card for any other further information required by the end users, which is shown in the figure-6. The following algorithm-1 shows the algorithm of the proposed system.

Connection/Data Transfer Process:

The node (Arduino Board) contain a Wi-Fi module, which also gets a IP address that is connected to the router. In order to assign the set of static IP addresses to the nodes, we binded the MAC address and IP address to the router that reserves the specific IP addresses to the node.

Monitoring Process:

The plants are grown using hydroponics mechanism that comprises with various sensor nodes. These nodes are attached to the plant pot. The liquid level sensor is dipped into the water, which displays the readings and alerts the end user if there is a need of water source. Other sensors such as the temperature, humidity, and LDR Luminance, monitor the enclosed area where the plant is grown. Figure 1 and Figure 2 shows the future scope of CEA, which can be achieved with the proposed model. Figure 4 shows the prototype of monitoring device with sensors, which is tested on a tomato plant and the results are relatively close to real world scenario. The pot is kept in a room close to a window, maintaining the required conditions at all times and displaying the results in real time. Since it is a prototype, no control devices are used yet, but rather the temperature of the room and water level are adjusted manually. The sensors, which are incorporated with the device, will sense the information and process the data to the Arduino board and process the information to the server. Those values will be stored in the device in the form of log file, which is stored on device's memory card and as well as the server's database. The following table-1 shows the algorithm of the proposed system.

Algorithm: Software implementation of CEA	
1.	**BEGIN**
2.	Include the headers dht.h, tftlcd.h, sd.h, rtclib.h
3.	**If**(touchCalibrate() is *true*)
4.	bgImg = getImageFromSD( )
5.	drawBackground(bgImg)

```
initVar = initVariables( ) // returns Boolean value
While( powerSupply is true ) do
If ( initVar is true )
   data = displaySensorReadings( )
            // returns JSON object
sendToMainNode( data )
            // Server Recieves and Stores the data in DB
   If button pressed == LOG
clearScreen()
logData=  getDataFromSD ( )
displayLog( logData )
   End if
   If button pressed == SETTINGS
      clearScreen( )
      defValues = getDataFromUser( )
      setDataToSD( defValues )
   End if
   If button pressed == HOME
      clearScreen()
      displaySensorReadings( )
   End if
End if
Else
clearScreen( )
defValues = getDataFromUser( )
setDataToSD( defValues )
End else
End While
End
```

VI. EXPERIMENTAL ANALYSIS AND RESULTS

The section gives the experimental analysis and results of proposed CEA system that exemplifies the testing phase of the system. Specifically, this proposed system is tested on a tomato plants under controlled environment in green house at SVIET, Krishna District, Andhra Pradesh, India, during all seasons of the year. In addition, this system continuously monitors various environmental constraints like Temperature, Humidity, Light, Water Level and Air Toxicity etc. The sensed data of these constraints are logged for every one-hour, which stores in the SD card.

The settings option, as shown in figure-6 &7,of the device helps us to enter conditions, such as; we can set temperature range, humidity range and other parameters, which are displayed on the device. Therefore, whenever there are fluctuations in the environment, the device compares the values of the surrounding environment with assigned values and activates the control devices, if the values deviate from the given range. The code is written such that, certain digital pins are activated for which the control devices are connected. If the values cross the threshold values, then end user gets notified and the control devices are activated.

Figure-5 Display screen of the system

Figure-6 Log data screen of the System.

Figure-7 Settings screen requesting for optimal Temperature value

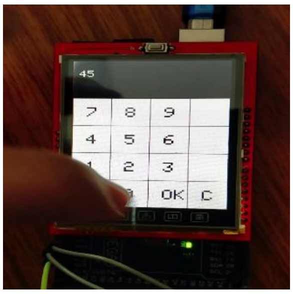

Figure-8 User entering the data in Settings screen

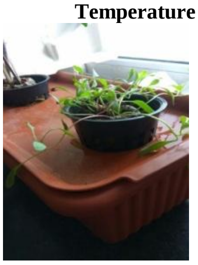

Figure- 9a Tomato sapling at budding stage

Figure-9b Root part after 1 month of growth in water

Figure- 9c Side view of root part

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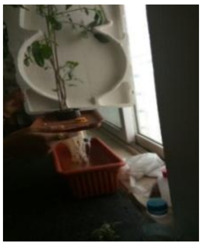

Figure-9d Plant growth after 2 months in controlled environment

Figure-9e Healthy plant after 3 months of growth in water

Figure-9f Tomato Fruit rippen from plant

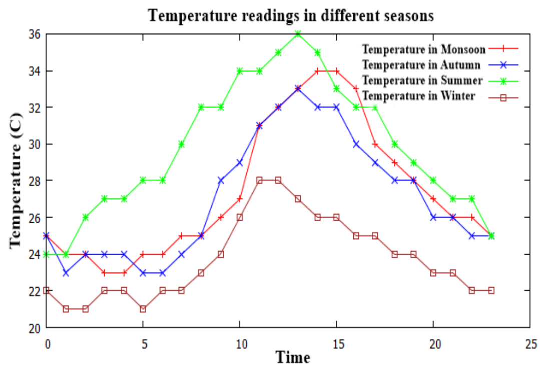

Figure-8 Temperature vs Time across all seasons

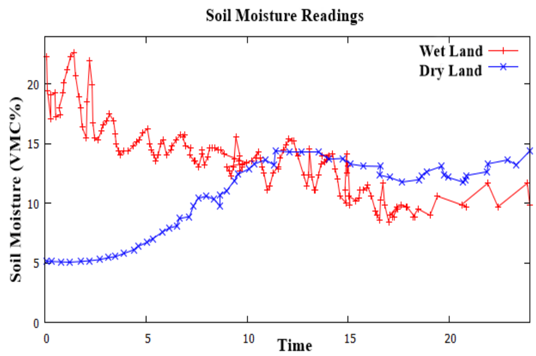

Figure-11 Soil Moisture vs Time

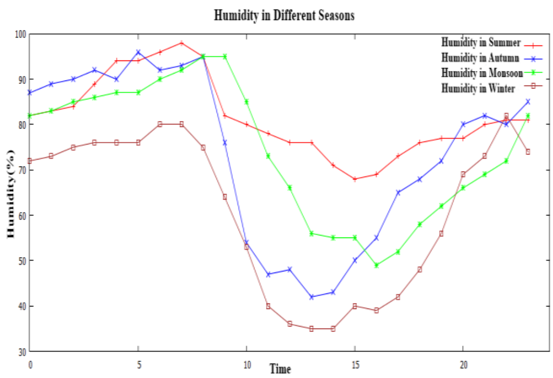

Figure-9 Humidity vs Time across all seasons

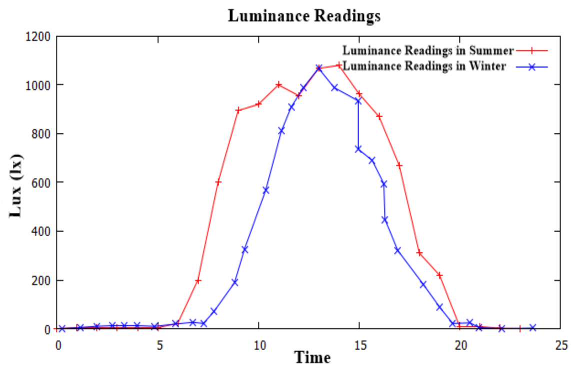

Figure-12 Luminance vs time

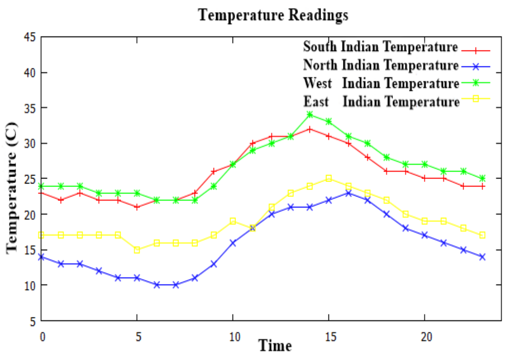

Figure-10 Temperature vs Time from different locations

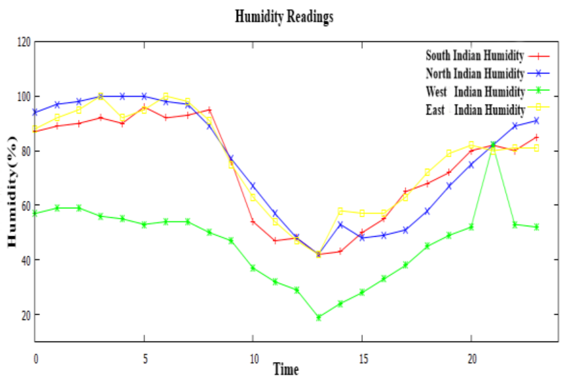

Figure-13 Humidity vs Time from different locations

The Figure-8 shows temperature values taken from DHT11 (Temperature/Humidity) sensor over different seasons in a year with varying time instances. Usually the time is measured in hours and temperature is measured in Celsius. It is observed from the figure-8 that during summer season, the temperatures are increasing steadily, as the time progress; it reaches a peak temperature of 36oC. While, it is recorded that the temperature falls to 25 o C at the end of the day. During the monsoon and the autumn, there is a substantial decrease of 5o – 10o C. Hence, with these result, the system can effectively monitor the water levels and alert the end user.

The Figure-9 shows humidity values taken from DHT11 (Temperature/Humidity) sensor node over different seasons in a year with varying time instances. The Humidity is measured in percentage with varying time. It is observed from the figure-9 that during winter season, the humidity percent gradually increasing steadily up to 08.00 hours. However, as the time progress humidity decreases to 35% at 01:00 hours and afterwards it gradually increases. While, in winter season, humidity reaches to the maximum up to 80% due to low temperatures in the season. Next, monsoon and autumn season the humidity are relatively close. Hence, with these humidity readings from the system, the end user can monitor the sensor data and take necessary precautions to increase or decrease the air conditioning appropriately.

The Figure-10 shows Soil Moisture sensor values taken from different terrains with varying time instances. The time is measured in hours against the moisture, which is measured in volumetric moisture content. It is observed from the figure-10 that the soil moisture in dry land is comparatively less than wet land. It is clearly seen from the figure-10 that the Soil moisture changes randomly for every hour; however, there is some inference in the dry land during noon and gradually increases in the night. While, the wet lands show consistent variation in the moisture throughout the day. Hence, with these results from the system, the end user can control the water flow of the plants root system.

The Figure-11 shows lux values taken from LDR Light Sensor node with varying time instances. Usually, the luminance is measured in lux. It is observed from the figure-11 that during summer season, the luminous intensity ascends to maximum of 1100 lux at 15:00 hours and it steeply descends to 2 lux at 20:00 hours. While, in winter season, the luminous intensity ascends to a maximum of 1000 lux at 13:00 hours and descends steeply to 5 lux at 18:30 hours. Hence, from these observations, the luminance values are comparatively higher in summer season than in the winter season. Based on these observations, farmer has ability to control the light intensity artificially

The Figure-12 shows temperature values taken from DHT11(Temperature/ Humidity) sensor over different regions in India over a year with varying time instances. It is observed from the figure-12 that at the time of summer season, the temperatures are increasing steadily, as the time progress in south and west India. During the month of December, the temperatures are varying from 20o C to 35 o C. On the contrary, the temperatures in north and east are very low ranging from 10o C to the maximum of 20 o C.

The Figure-13 shows humidity values taken from DHT11 (Temperature/Humidity) sensor node over different regions in India in a year with varying time instances. From the figure-13, it is observed that the humidity declines rapidly in western India from 59 % to 20% which results in very high temperatures. Likewise, the humidity range in other regions like north, south and east India are identical in nature

V. CONCLUSION

In this paper, we implemented and tested an efficient monitoring unit for Controlled Environment Agriculture (CEA) system based on hydroponics environment using various sensor nodes, which is mainly useful to analyse the habitat conditions. This work makes use of data logging mechanism, which provides detailed overview of the climatic conditions periodically to obtain better quality control along with reduced cost and effort. In particular, we analysed the habitat conditions for various seasonal regions of India and has been proved to be more reliable for these conditions of Indian agriculture. There is a need to extend this work further on protective casing of nodes under extreme weather conditions, Power supply from renewable sources. In addition, the system need to be tested on other level of water purity and small other area of soiled plantation.

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