2020 IEEE Students Conference on Engineering & Systems (SCES)
July 10-12, 2020
Prayagraj, India

Monitoring of Soil Parameters and Controlling of Soil Moisture through IoT based Smart Agriculture

Abhishek Srivastava
Department of EEE
National Institute of Technology
Nagaland, Nagaland - 797103
Email: abhishek91026@gmail.com

Dushmanta Kumar Das
Department of EEE
National Institute of Technology
Nagaland, Nagaland - 797103
Email: dushmantakumardas29@gmail.com

Ravi Kumar
Department of EEE
National Institute of Technology
Nagaland, Nagaland - 797103
Email: rkumar.ravi222@gmail.com

***Abstract*—Agriculture plays a vital role in the economical growth and development of any nation. Changing climatic condition have badly affected the production ofagriculture products. Therefore, to improve the quality and quantity of agriculture products, many new technologies are being developed to practice smart agriculture which can adapt to the changing climatic condition. In this paper, one such method is proposed. The developed method is a new and simple internet of thing based approach to practice smart agriculture. In this proposed approach, a hardware and software setup is used to monitor important soil parameters from a remote location and automatic control of soil moisture content. The proposed approach helps in remote monitoring and water conservation process.**

***Index Terms*—Smart Agriculture, Internet of Things (IoT), Smart Irrigation, Wireless sensor network**

I. Introduction

Agriculture has a major role in the development of any nation. Agriculture supports the livelihood and helps in increasing the economic growth of a nation [1]–[3]. According to [4], sixty percent of the population in India is dependent on agriculture for their livelihood.

Changing environmental conditions have directly or indirectly affected the diversity of agriculture production system [5]–[8]. According to an analysis presented in [9], climate change in India has affected agriculture soil by degrading process which includes 93.7 by water erosion, 9.5 by wind erosion, 5.9 by salinity and alkalinity, etc. With the advancement in the field of engineering, new agriculture technologies are being developed, known as Smart Agriculture. These new technologies can adapt to climate changes and help in improving the quality and quantity of production of crops.

Different studies, literature, and hardware setups have been proposed to practice agriculture in a smart and conservative environment. In [10], an energy-efficient simultaneous wireless information and power transfer for wireless sensor networks are proposed for smart agriculture. Climate-smart agriculture as an alternative to the conventional methods to grow rice and wheat is presented in [11]. In [12], smart agriculture with organic farming and the use of biofertilizer to improve the yielding is presented. In [13], an IoT based smart agriculture model with real-time data analysis is presented which can help to increase the productivity of crops. In [14], a comparative study on the conventional and smart farming methods have been presented. In [15], a comprehensive review has been done on the methods developed to so IoT based smart farming with the use of unmanned aerial vehicles (UAV). To effectively utilization of water resources with simplified irrigation across different agricultural farms a smart irrigation system based on cloud and Internet of things is discussed in [16]. In [17], an automatic irrigation system with an idea of the Internet of Things (IoT) has been presented in which controlling and remote access of data is done using Arduino micro-controller. All the data of sensors are even communicated to the farmer through mobile communication. In [18], an automatic irrigation system that can optimize the water used for agriculture is discussed. The communication channel used between the sensor and the control unit is wireless. Some algorithms are developed for the micro-controller. The system is tested for 136 days and has saved 90% of the water in comparison to traditional irrigation practice. In [19], a new device based on a wireless network, global system mobile (GSM), and radio communication is discussed. The developed device is divided into the three-unit control platform, controller, and action units. The developed device is tested and installed in some of the farms in northwest China. In [20], new irrigation technology has been discussed. The new methodology provides wireless solutions for intelligent field irrigation systems. The wireless solution is based on Zigbee technology. This solution has proved to have high performance, reliability, and practicability. In [21], anautomated irrigation system that can remotely monitor and control parameters of the agriculture field has been described. The automated system uses Bluetooth wireless radio communication to interface sensor and control unit. To have stable remote access, graphic user interface (GUI) based software has also been discussed in [21].

In this paper, a new approach and simple internet of things (IoT) based approach to practice smart agriculture are proposed. The main focus in the development of this approach is to develop a simple and cost-effective product for the framers. Using this approach, farmers can monitor soil parameters from a remote location and automatically control the moisture content of the soil. The hardware setup includes a different sensor that is used to sense an important parameter of the soil. All sensor data are processed by a controller which is sent to a central controller unit at a remote location.

For data transmission, a wireless communication network is developed using Zigbee modules. At the central control unit, all the data are further processed which helps in taking the necessary control actions. Finally, all the data is savedon a cloud server which can be accessed from any remote location. The proposed method can be used to practice smart agriculture which can also help in the conservation of water required for irrigation of the field. The complete setup for smart agriculture is represented as a block diagram in Fig. 3.

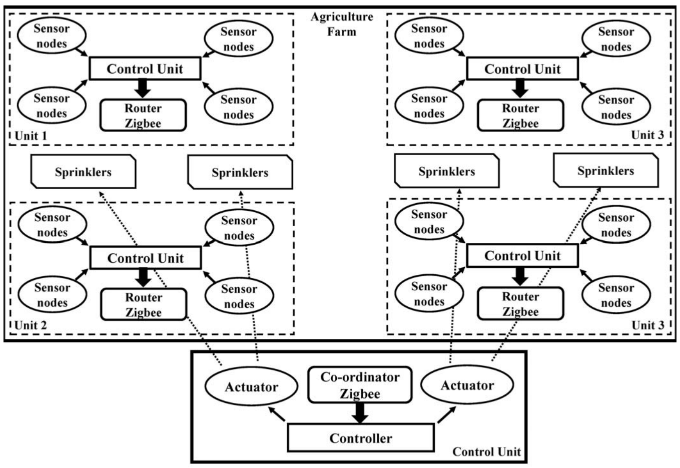

Fig. 1: Block diagram representation of proposed Smart Agriculture

II. Methodology

To remotely monitor soil parameters and automatically control the soil moisture level, IoT based hardware and software setup are proposed in this article. The process of measuring, controlling, and remotely monitoring of the vital soil parameter, five stages are followed. These stages are discussed briefly in this section. Further, to explain the complete work flow, flowchart is presented in Fig. 2.

A. Sensor's interfacing and its working

To implement smart agriculture in a field, sensors play a vital role. Crops health can directly or indirectly be affected by some vital parameters of the soil and the environment surrounding the farm [22]–[24], [24], [25]. These vital parameters include soil moisture, temperature, humidity, rainfall, pH, etc. Different sensors are therefore used to measure these parameters of the soil and surroundings.

In this proposed work, a soil moisture sensor is used to measure and monitor the soil content of the soil. This sensor uses two probes to measure the voltage difference. The voltage difference varies with the moisture content of the soil. For dry soil, the voltage difference is high and the same as the applied voltage to the sensor. In the case of wet soil, this potential difference is small and can be zero for fully moist soil. Similarly, a rainfall sensor is used to get alerts of rainfall. The working of this sensor is similar to a soil moisture sensor. This sensor also consists of a probe. The potential difference of the probe is high on a dry day, whereas on a rainy day this difference is low. A DHT-22 sensor is used to measure the temperature and humidity level of the environment surrounding the field. A DHT-22 sensor consists of two electrodes which act as a humidity sensing component and a variable resistance with a Negative Temperature Coefficient (NTC) which acts as a temperature sensing component. The change in resistance gives information about temperature and humidity.

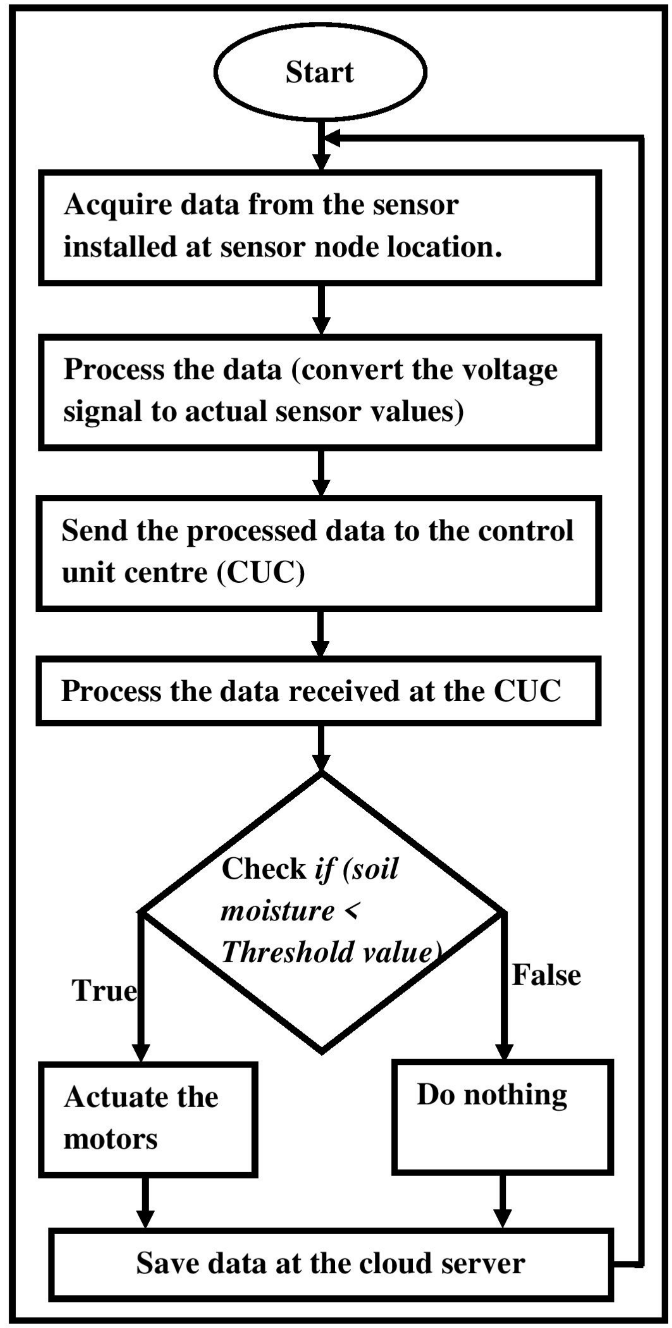

Fig. 2: Flowchart for the proposed work

These sensors are interfaced with the Arduino microcontroller. All the data received from the sensors are converted to analog values using this micro-controller. For rainfall and soil moisture sensors, the analog input received is converted to an equivalent percentage. This mathematically is represented as follows:

$$V_{actual} = D \times S, \quad (1)$$
$$Q = \frac{V_{max} - V_{actual}}{V_{max}}, \quad (2)$$

where V_{actual} is the actual voltage measured; D is the data received by the microcontroller from the sensor; S is the sensitivity factor and is equal to 0.00488281; V_{max} is the voltage at which sensor works and is equal to 5 volts; $Q\%$ represents the percentage of measure quantity i.e. soil moisture level and rainfall.

TABLE I: Specification of soil moisture and rainfall sensor

Sr.No.	Specifications	Range
1.	Input Voltage	3.3 5V
2.	Output Voltage	0 4.2V
3.	Input Current	35mA
4.	Working Teperature	10°C 30°C
5.	Output Signal	Both Analog and Digital

In the case of a DHT-22 sensor used for measurement of temperature and humidity. Arduino microcontroller provides *adafruit library* using which sensor data can directly be converted to equivalent analog temperature and humidity values.

TABLE II: Specification of Temperature and Humidity Sensor

Sr. No.	Specification	Range
1.	Power supply	3.3-5.5V DC
2.	Output signal	digital signal via 1-wire bus
3.	Sensing element	Polymer humidity capacitor
4.	Operating range	Humidity 0-100%
		Temperature -40∼80Celsius
5.	Accuracy	Humidity +-2%RH
		Temperature +-0.5Celsius

B. Wireless transmission of sensor data

Normally, agricultural lands are spread over a large area. Therefore, sensors have to be implanted at various locations of the agriculture land. Therefore, a number of sensor units are set upwith controllers in the field. All these controllers perform the same operation. The data received by the controller are further transmitted to a control unit center (CUC) locate at a remote location. At the CUC, the sensor data are further processed and used for further analysis. The transmission of sensor data from a field location to a CUC location is done using a wireless network developed using Zigbee modules.

Zigbee modules are low power devices and ideal for developing a wireless communication channel for the sensors and controllers. To set upa network, aminimum of two Zigbee modules required. One of these modules is configured as a router and other as co-ordination. A field can have multiple routers but only one coordinator. Therefore Zigbee located near the field location is configured as a router and is connected to the Arduino microcontroller. Whereas, Zigbee at the CUC location is configured as coordinator and is connected to a Raspberry-pi (R-pi). Fig. 3 represents the block diagram of the complete setup for the wireless communication network.

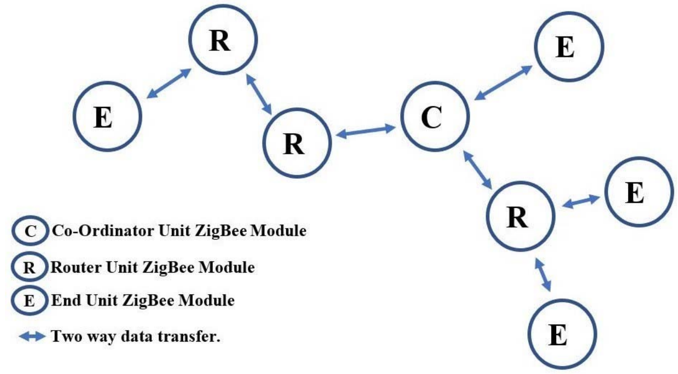

Fig. 3: Block diagram of wireless communication network using zigbee module

TABLE III: Specification of ZigBee Module.

Sr.No.	Specifications	Range
1.	Supply Voltage	3.3 V,
2.	Supply current	205 mA (Transmit) 47 mA (Receive)
3.	Operating Temperature	−40°C 85°C
4.	RF Data Rate	250,000 b/s
5.	operating Frequency	ISM 2.4GHz
6.	Range	300ft

TABLE IV: Specification of microcontroller

Microcontroller	Atmega2560
Operating Voltage	5V
Input Voltage (Recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54
Analog Input Pin	16
DC Current per I/O Pin	40mA
DC Current for 3.3V Pin	50mA
Flash Memory	256KB
SRAM	8KB
EEPROM	4KB
Clock Speed	16MHz

C. Controlling soil parameters

A coordinator Zigbee at the CUC location receives sensor data from a number of router ZigBee. To avoid overlapping of sensor data, the time delay is provided to each router Zigbee. Once a complete data is received, R-pi process these data further so that necessary control actions can be taken if necessary.

In a practical field, only soil moisture level can be controlled hence only moisture level is controlled in this proposed work. Other parameters such as temperature, humidity, and rainfall are only used for monitoring and further analytic. To control the moisture level, a simple control strategy is used i.e by comparing the measured sensor data to a threshold value. If sensed data is below the threshold level, a high trigger signal is passed which actuates the motors. As stated before, theagriculture field may be quite large, therefore, for a large agriculture field, an average moisture data is first computed then this average data is compared with the threshold value. This control strategy is programmatically represented as follow:

1) $M_{avg} = \frac{\sum_{n=1}^{m} M_n}{m}$
2) $if\ (M_{avg} < M_T)$
3) $\quad trigger = 1$
4) $else\ if\ (M_{avg} \geq M_T)$
5) $\quad trigger = 0$

where M_{avg} is the average moisture content of the field; M_n is the moisture content of soil measured by a n^{th} sensor node; m is the number of sensor nodes installed to measure the moisture content of the soil in the field; M_T is the threshold moisture level; $trigger$ is the signal which actuates the motor. It can be either 1 or 0.

D. Remote monitoring

For remote monitoring of the sensors data, all sensors data received at the CUC is saved on a cloud server provided by Thingspeak. Thingspeak is a free cloud server provider and it can easily be integrated with R-pi using a unique API key. Thingspeak provides a free android based mobile application and web service which can be used to monitor the data saved on the cloud server at any remote location. Apart from the present value of sensor data, Thingspeak also provides average sensor value, maximum sensor value, and minimum sensor value. All the data are present graphically which makes the interpretation and visualization of data easier.

Thingspeak provides a unique API key to every user when they sign up to Thingspeak. This helps to update data saved on a cloud server every 15 seconds. To access this data, first channels or fields (graphs) as to be set upusing the Thingspeak website. For each data one field has to setup. After this, all the plots can be viewed on a private view page in Thingspeak. Data plots can also be shared using the public view. On further information, please visit the Thingspeak website "https://thingspeak.com/".

E. Uninterrupted power supply

To provide an uninterrupted power supply to sensors, controller, Zigbee, pumps, etc, solar panels with battery backup are installed. During the day time, solar panels charge the batteries so that in the absence of sunlight, they can power all the equipments.

III. Hardware Setup and Results

The hardware setup for the smart agriculture includes sensors like soil moisture sensor, rainfall sensor, temperature sensor, and humidity sensor, Arduino microcontroller, Zigbee modules, Raspberry-pi, actuators, and pumps. For this project, we have developed two artificial fields. Both the field is equipped with sensors, micro-controller and Zigbee modules. The sensed data from the sensors are feed to the microcontrollers. The microcontroller decodes the received data to an actual analog value and sends them to the Zigbee modules. The ZigBee has installed in the fields acts as the routers and transmits the data to a remote coordinator Zigbee at a control unit center (CUC). CUC includes a Zigbee module, R-pi, actuators, and pumps. The date received by the coordination is transmitted to the R-pi which processes the data. The processed data is then saved on a cloud server provided by Thingspeak. While the CUC process data, if the soil moisture level is below a predefined value, CUC sends a high trigger signal to the actuator. As actuators are connected with the pumps, the pumps are started till a low trigger signal is received. By controlling the actuator, pumps are controlled, and thereby soil moisture level is controlled.

The setup of the field with the different sensors, microcontrollers and Zigbee is presented in Fig. 4. The setup for a CUC with R-pi, actuator, pumps Zigbee is presented in Fig. 5. For remote monitoring, the Thingspeak cloud server is used which provides a mobile application and web access. Fig. 7 shows the data plots of the different parameters visible on the Thingspeak web page. Whereas, Fig. 6 shows the data plots of different parameters on a Thingspeak mobile application. A user can directly access the field data from the sensor on any of the applications. From Fig. 6 and 7 it can be seen that the data being plotted are temperature, humidity, and moisture content of the field. Based on the values received the controller takes action on the actuation of motors.

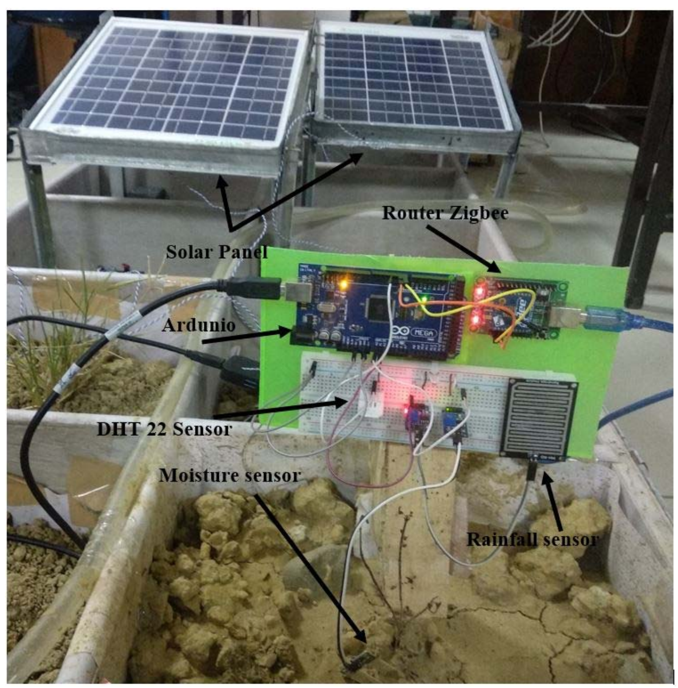

Fig. 4: Field setup

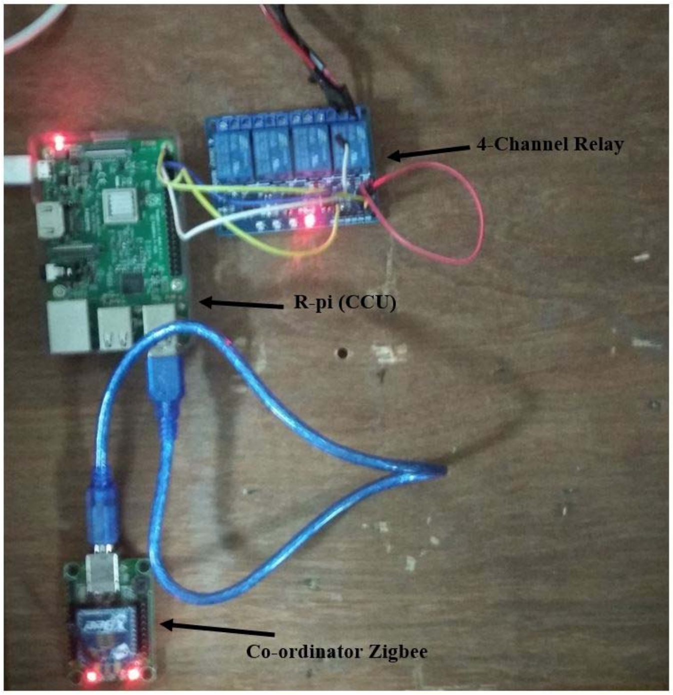

Fig. 5: Control unit center

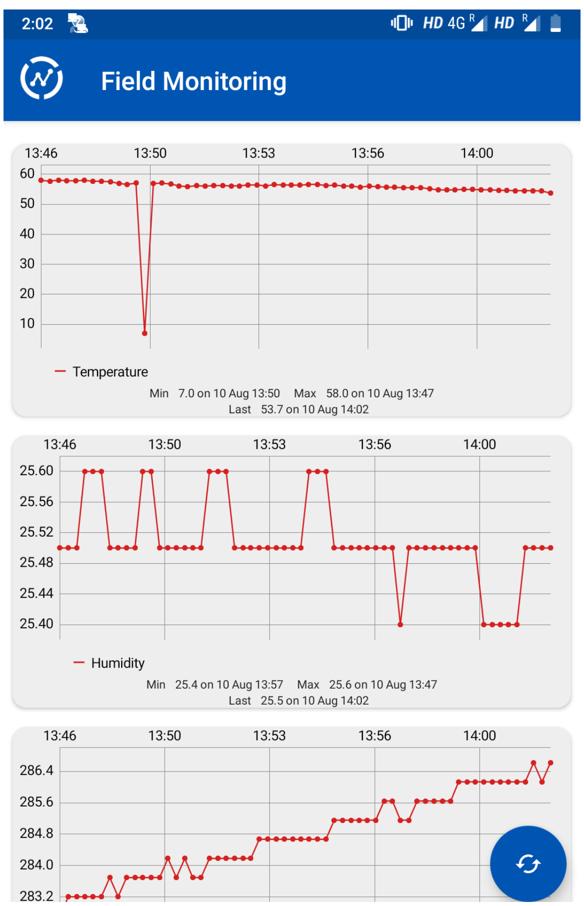

Fig. 6: Monitoring of sensor data on a Thingspeak mobile application

Fig. 7: Monitoring of sensor data on a Thingspeak server

IV. Conclusion

In this paper, a new methodology to practice smart agriculture based on IoT is proposed. The proposed approach uses different sensors to measure some of the important parameters of the soil. All the sensor data are initially processed by using an Arduino micro-controller and are transmitted to a control unit center. For transmission of the sensor data to a control center, a wireless communication network using Zigbee modules is developed. At the control center, all the sensor data are processed and necessary control signals are sent for actuation. In this project. only soil moisture content is controlled as other parameters are hard to control on an agriculture field. Also, for remote monitoring of the sensors, the Thingspeak cloud server is used. In this method, theoverall cost of equipment is tried tominimize. In the future, this methodology will be extended with the development of more advanced algorithms to monitor and control other soil parameters. Further, a mobile application will be developed to remotely monitor and manual controlling of the soil parameter. In this way both types of control options would be providedto the users.

V. Acknowledgement

The authors would like to acknowledge and thank “National Mission on Himalayan Studies (NMHS)” implemented by the Ministry of Environment, Forest and Climate Change (MoEF&CC) under the nodal and serving hub G.B. Pant National Institute of Himalayan Environment and Sustainable Development for their valuable support for providing the required funds for the project and carry out this research work. The author would also like to thank Thingspeak for the web service and free online cloud services.

References

[1] K. Lakhwani, H. Gianey, N. Agarwal, and S. Gupta, “Development of iot for smart agriculture a review,” in *Emerging Trends in Expert Applications and Security*. Springer, 2019, pp. 425–432.

[2] J. Li, W. Gu, and H. Yuan, “Research on iot technology applied to intelligent agriculture,” in *Proceedings of the 5th International Conference on Electrical Engineering and Automatic Control*. Springer, 2016, pp. 1217–1224.

[3] A. Collins, S. Anthony, J. Hawley, and T. Turner, "The potential impact of projected change in farming by 2015 on the importance of the agricultural sector as a sediment source in england and wales," *Catena*, vol. 79, no. 3, pp. 243–250, 2009.

[4] A. S. Mathur, S. Das, and S. Sircar, "Status of agriculture in india: trends and prospects," *Economic and political weekly*, pp. 5327–5336, 2006.

[5] D. J. Raiten, G. F. Combs *et al.*, "Nutritional ecology: Understanding the intersection of climate/environmental change, food systems and health," *Agriculture for Improved Nutrition: Seizing the Momentum*, p. 68, 2019.

[6] R. Cavicchioli, W. J. Ripple, K. N. Timmis, F. Azam, L. R. Bakken, M. Baylis, M. J. Behrenfeld, A. Boetius, P. W. Boyd, A. T. Classen *et al.*, "Scientists warning to humanity: microorganisms and climate change," *Nature Reviews Microbiology*, p. 1, 2019.

[7] N. T. L. Huong, Y. S. Bo, and S. Fahad, "Economic impact of climate change on agriculture using ricardian approach: A case of northwest vietnam," *Journal of the Saudi Society of Agricultural Sciences*, vol. 18, no. 4, pp. 449–457, 2019.

[8] J. M. Reilly, *Economic issues in global climate change: agriculture, forestry, and natural resources*. CRC Press, 2019.

[9] R. Lal, "Adaptation and mitigation of climate change by improving agriculture in india," in *Climate Change and Agriculture in India: Impact and Adaptation*. Springer, 2019, pp. 217–227.

[10] R. Prestele and P. H. Verburg, "The overlooked spatial dimension of climate-smart agriculture," *Global Change Biology*, vol. 26, no. 3, pp. 1045–1054, 2020.

[11] H. Jat, M. Choudhary, A. Datta, A. Yadav, M. Meena, R. Devi, M. Gathala, M. Jat, A. McDonald, and P. Sharma, "Temporal changes in soil microbial properties and nutrient dynamics under climate smart agriculture practices," *Soil and Tillage Research*, vol. 199, p. 104595, 2020.

[12] C. Agrimonti, M. Lauro, and G. Visioli, "Smart agriculture for food quality: facing climate change in the 21st century," *Critical Reviews in Food Science and Nutrition*, pp. 1–11, 2020.

[13] K. Sekaran, M. N. Meqdad, P. Kumar, S. Rajan, and S. Kadry, "Smart agriculture management system using internet of things," *Telkomnika*, vol. 18, no. 3, 2020.

[14] B. B. Sharma and N. Kumar, "Internet of things-based hardware and software for smart agriculture: A review," in *Proceedings of ICRIC 2019*. Springer, 2020, pp. 151–157.

[15] A. D. Boursianis, M. S. Papadopoulou, P. Diamantoulakis, A. Liopa-Tsakalidi, P. Barouchas, G. Salahas, G. Karagiannidis, S. Wan, and S. K. Goudos, "Internet of things (iot) and agricultural unmanned aerial vehicles (uavs) in smart farming: A comprehensive review," *Internet of Things*, p. 100187, 2020.

[16] S. Koduru, V. P. R. Padala, and P. Padala, "Smart irrigation system using cloud and internet of things," in *Proceedings of 2nd International Conference on Communication, Computing and Networking*. Springer, 2019, pp. 195–203.

[17] A. Premkumar, K. Thenmozhi, P. Praveenkumar, P. Monishaa, and R. Amirtharajan, "Iot assisted automatic irrigation system using wireless sensor nodes," in *2018 International Conference on Computer Communication and Informatics (ICCCI)*. IEEE, 2018, pp. 1–4.

[18] J. Gutiérrez, J. F. Villa-Medina, A. Nieto-Garibay, and M. Á. Porta-Gándara, "Automated irrigation system using a wireless sensor network and gprs module," *IEEE transactions on instrumentation and measurement*, vol. 63, no. 1, pp. 166–176, 2014.

[19] G. Yang, Y. Liu, L. Zhao, S. Cui, Q. Meng, and H. Chen, "Automatic irrigation system based on wireless network," in *Control and Automation (ICCA), 2010 8th IEEE International Conference on*. IEEE, 2010, pp. 2120–2125.

[20] Y. Zhou, X. Yang, L. Wang, and Y. Ying, "A wireless design of low-cost irrigation system using zigbee technology," in *Networks Security, Wireless Communications and Trusted Computing, 2009. NSWCTC'09. International Conference on*, vol. 1. IEEE, 2009, pp. 572–575.

[21] Y. Kim, R. G. Evans, and W. M. Iversen, "Remote sensing and control of an irrigation system using a distributed wireless sensor network," *IEEE transactions on instrumentation and measurement*, vol. 57, no. 7, pp. 1379–1387, 2008.

[22] S. H. Doerr and A. D. Thomas, "The role of soil moisture in controlling water repellency: new evidence from forest soils in portugal," *Journal of Hydrology*, vol. 231, pp. 134–147, 2000.

[23] T. Iizumi and N. Ramankutty, "How do weather and climate influence cropping area and intensity?" *Global Food Security*, vol. 4, pp. 46–50, 2015.

[24] B. R. Sharma, K. Rao, K. Vittal, Y. Ramakrishna, and U. Amarasinghe, "Estimating the potential of rainfed agriculture in india: Prospects for water productivity improvements," *Agricultural Water Management*, vol. 97, no. 1, pp. 23–30, 2010.

[25] Z. Rengel and C. Tang, "Role of plant cation/anion uptake ratio in soil acidification," in *Handbook of soil acidity*. CRC Press, 2003, pp. 71–96.