Smart irrigation with crop recommendation using machine learning approach

Anitha Palakshappa[1], Sowmya Kyathanahalli Nanjappa[2], Punitha Mahadevappa[2], Sinchana[2]
[1]Department of ISE, Ramaiah Institute of Technology, Visvesvaraya Technological University, Karnataka, India
[2]Department of ISE, JSS Academy of Technical Education, Visvesvaraya Technological University, Karnataka, India

Article Info

Article history:

Received Feb 28, 2023
Revised Nov 11, 2023
Accepted Dec 6, 2023

Keywords:

Automated agriculture
Machine learning
Random forest
Smart agriculture
Smart irrigation
Soil prediction

ABSTRACT

Increasing crop yield with sustainable growth is the primary requirement for farmers with a growing population. Effective management and conservation of depleting natural resources is a priority task. Decrease in manpower due to migrating population has forced automation in agriculture. In this work, an automatic water irrigation and an effective crop recommendation system is proposed. Gypsum blocks based soil sensor is used to measure dielectric permittivity associated with the tested soil. The water-potential present in soil, along with potassium (K), nitrogen (N), phosphorus (P), potential of hydrogen (pH) helps to quantify the soil nutrients available and the suitable crop that can be considered for harvesting in a specified demography and environment. Sensory data indicating soil quality obtained is used to recommend crops by utilizing machine learning approaches. Telegram application is linked to the recommendation model to assist decision making and to ensure farmer-friendliness by sending notifications periodically.

Corresponding Author:

Anitha Palakshappa
Department of ISE, Ramaiah Institute of Technology, Visvesvaraya Technological University
Belgaum-590018, Karnataka, India
Email: anitha.palakshappa@gmail.com

1. INTRODUCTION

Crops are the lifeline for a growing population and for the economy of any country across the globe, agriculture being its pillar. Agriculture uses 70% of the accessible fresh water globally. The quality of any crop depends on the water the farmer irrigates at the right time. Crops should not be damaged due to overwatering or underwater, and there should be a need to conduct regular checks at regular intervals. Water utilization can be optimized with the help of drip irrigation, sprinkler irrigation and center pivot irrigation using various sensors. In India, agriculture has its history. As per the statistics survey, India's gross domestic product (GDP) growth for agriculture is 6.1% for allied sectors, and about 50% of the workforce depends on farming. The contribution of agriculture to India's GDP is steadily decreasing with the country's because of migration of rural youth, less attention on farmers by governments. Still, agriculture is the broadest sector and plays a remarkable role in the overall social fabric of India.

Growing crops is of utmost importance for mankind. Using standard technology increases efficiency and lessens the workload of the farmers. An automated or semi-automated irrigation system must be able to understand the unique requirements of each crop in the agricultural field. The most captivating part of automation is the internet of things (IoT) components that connect with one another and provide relevant information. Smart irrigation uses soil moisture sensors and soil pH sensors that collect real-time information about soil in the field. The current work focuses on recommending the crops based on the real-time values sensed by the sensors. All of these characteristics make the automatic system a practical alternative for improving farming and irrigation effectiveness.

Smart farming enables us to monitor environmental conditions and control irrigation systems with the help of IoT. A combination of software and hardware tools are essential for developing the IoT for agricultural activities. Two types of microcontrollers: the Arduino Mega and the Raspberry Pi 3 were chosen based on processing capability, cost, and simplicity of availability [1]. The changeable parameters will be constantly checked with the use of several sensors, and irrigation appropriate for and particular to the kind of crop will be completed. Placing the wireless sensor network field, in which every node is interconnected by wires, is the first step in implementing a Keen irrigation system for farm mechanisms [2]. A programmed watering structure is created using sensors connected to a microcontroller. The heat and humidity sensor (DHT11 sensor), as well as the soil moisture sensor (VH400), were used in the study. The DHT11 sensor detects the temperature and humidity of a specific plant’s root zone [3]. Using the above-gathered parameters, a machine learning (ML) representation is employed to estimate the growth of the shoot length and aid the farmer [4]. The goal is to create a wireless three-level regulated smart irrigation system that will provide autonomous irrigation for plants while saving water and money [4]. The objective of the learning was to employ a smart irrigation structure to govern the quantity of liquid that is given to crops. The system accomplishes this by establishing an internet connection between the irrigation system and the operator’s Smartphone and automating the irrigation process through computer programming and microcomputing [5].

PC-based laboratory virtual instrument engineering workbench (Lab VIEW) systems are used to display the moistness of soil present during dry and wet conditions, compute the relevant relative humidity, and irrigate it according to its nature. Database aids to track soil moisture, temperature, and rainfall for backup purposes. This backup is used for weather forecasting and instructs farmers on which crops to plant in the future [6]. Water resources of good quality, minimizes the cost of water handling for industrial and drinking reasons while also increasing agricultural production rates. Water claim is gradually increasing as a result of population growth, industrial activity, intensive agriculture, and urbanization. Predictions of water quality are required to assess its suitability for a certain purpose, as well as to establish suitable treatments or precautions if it is unhealthy [7]. ML is a critical decision-making tool for predicting crop yield, as well as for determining which crops can be grown and what should be done during the crop prediction [8].

Precision management of plant growth circumstances has become a topic of research in recent years, with the goal of assuring food safety, increasing food output, and reducing the labor load on agricultural farmers. In the agricultural sector, various types of sensors are employed, but some of these sensors are inadequate for the precision control necessary [9]. The objective of this work is to create an automatic irrigation system that employs ML to autonomously water agricultural land by sensing the humidity content in the soil and a variety of other factors. The prototype implemented can measure the wind speed, rain status, water level, soil moisture and humidity [10]. The proposed approach in this research intends to assist farmers in managing their agricultural farms wisely while utilizing limited resources [11]. In this study, the author surveyed many data mining approaches that can be used in projects including modern data science. The knowledge discovery in database (KDD), which has been used as a methodology for working on this research, is one of the most widespread concepts [12]. The author suggested that the prediction of crop yield helps farmers in selecting better crops for the future [13]. The author implemented and validated an IoT framework to raise the yield of chili with a case study [14]. ML with IoT can help in reducing water usage with minimal intervention of farmers [15]. Multilayer perceptron (MLP) classifier for the crop prediction system is proposed by the author, where the random forest (RF) algorithm has been implemented [16], [17].

Kumari *et al.* [18] implemented a recommender system using a relevant vector analysis algorithm to suggest the variety of crops in a smart irrigation system. Decision tree (DT) algorithms can also help in crop recommendation systems [19]. The naïve Bayes (NB) algorithm is implemented by the author to detect the unwanted plants in the farm, which gives 89% accuracy compared to regression algorithms [20]. The author used expert systems, which collect data in real time to take actions in minimizing agricultural loss due to crop diseases [21]. The cloud-based ML model for a crop recommendation system is proposed by the author to assist farmers in harvesting the crops [22]. Five prediction algorithms are compared to identify an efficient algorithm for a recommendation system [22]. ACRIS module is another crop recommender system implemented [23]. Sundaresan *et al.* [24] considered some crops like bananas, oranges, cotton, coffee, and many more for the recommendation system. Thangavel *et al.* [25] identified agriculture machinery usage by districts around South Tamil Nadu to predict suitable machinery for that area. ML algorithms with IoT address many problems related to agriculture [26], [27]. Clustering helps in the segmentation and detection of crop diseases [28]. In the subsequent sections the proposed methodology adopted is described followed by the inference.

2. METHOD

In order to take advantage of the smart world technology by enriching farmer expectations, the following key factors are identified: i) creating a simple irrigation structure by planning and installing IoT components; ii) power saving and licenses for the utilization of automatic irrigation systems in a range of other applications; iii) reduce the quantity of water used; iv) automation of the process; v) reduction in operating costs; and vi) farmer-friendly system.

The proposed system primarily monitors water level for smart irrigation. This reduces the water wastage, and improves agricultural production. This irrigation technology is beneficial in areas where water is scarce and upsurges the sustainability of the region. In the second stage, a multi-sensor irrigation system is adopted to monitor moisture's level in soil and also to identify soil's fertility in a given area to determine the suitable crop that can be grown in the given soil. ML algorithms are used in the proposed approach to provide the prediction result and have been trained using the standard dataset [29]. Further, the work can also be extended to meet the needs of diverse crops.

Figure 1 shows the outline of the proposed system, which includes integrated modules, each of which completes a specific task. The low cost user friendly Arduino is connected to multiple components like power supply, pH sensor, moisture sensor, liquid-crystal display (LCD) display and Telegram app, and relay. The first step toward establishing a smart irrigation and crop recommendation system is collecting data through the moisture, pH, and NPK sensors deployed in the farm. The real-time moisture, pH, and NPK values are displayed in the LCD which is associated with the Arduino board, and with the assistance of Arduino board and WIFI module the data will also be displayed in the user's Telegram App. Telegram app makes the farmers know better about their field condition in virtual mode. The data collected from sensor devices will assist water irrigation as follows: i) if the soil is dry, then the water pump will be automatically turned on with the assistance of a relay and ii) if the soil is wet, then the water pump will be automatically turned off with the assistance of a relay. The soil chosen for the experiment is varied and is selected from diverse location and the sample images of the soil selected are shown in Figure 2.

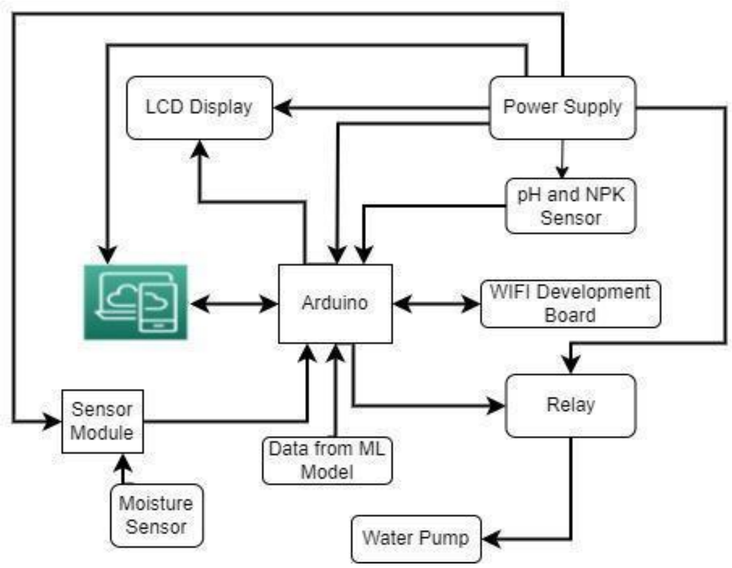

Figure 1. Proposed smart irrigation and crop recommendation system

Figure 2. Red and black soil samples considered for the proposed work

2.1. Hardware components used

The components used in the experiment are as follows:

- Sensors: a soil moisture sensor is a type of hygrometer that detects the humidity of the soil. As a result, it is ideal for creating an autonomous watering system or monitoring plant soil moisture. A temperature sensor is a device that computes the temperature of the surrounding environment. There are three pins on this sensor: a positive, a ground, and a flag. A three-way soil meter is a device to check the soil conditions for the growth of flowers, fruits, shrubs, vegetables, and many more. It is helpful for farmers who do mixed cultivation involving fruits, vegetables, plant timber and grass. The device is simply inserted into the soil and the value is read on the scale.
- Relay driver: a relay module is an electrical plug-in switch. When the controller sends the low signal to the relay, it turns on. It is a switch that is attached to the pump and used to start irrigation via a controller. The two-channel relay module used is shown in Figure 3. A relay is an electromagnetic device that connects two circuits magnetically isolating them electrically.

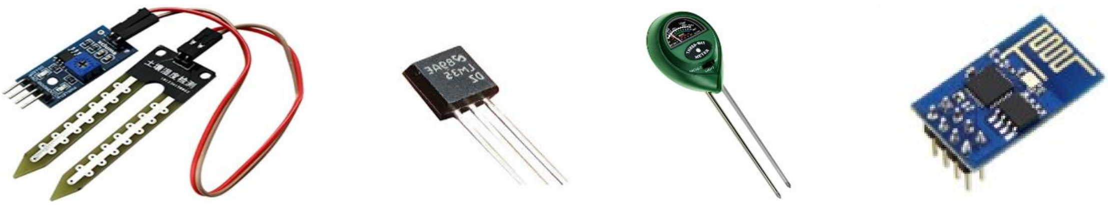

Figure 3. Soil moisture sensor, temperature sensor, three-way soil meter, and relay driver

- Water pump: the water pump is used to provide water as per the soil requirement. It is made functional by electronic means by connecting it to the microcontroller. It can be turned 'off' and 'on' by transmitting the appropriate signals. The process of providing water artificially is known as Pumping. Pumps are available in a range of shapes and sizes. The idea makes use of a small water pump in this prototype that is connected to an H Bridge.
- The microcontroller, ESP8266-01 Wi-Fi module and the water pump used for the experiment is shown in Figure 4.

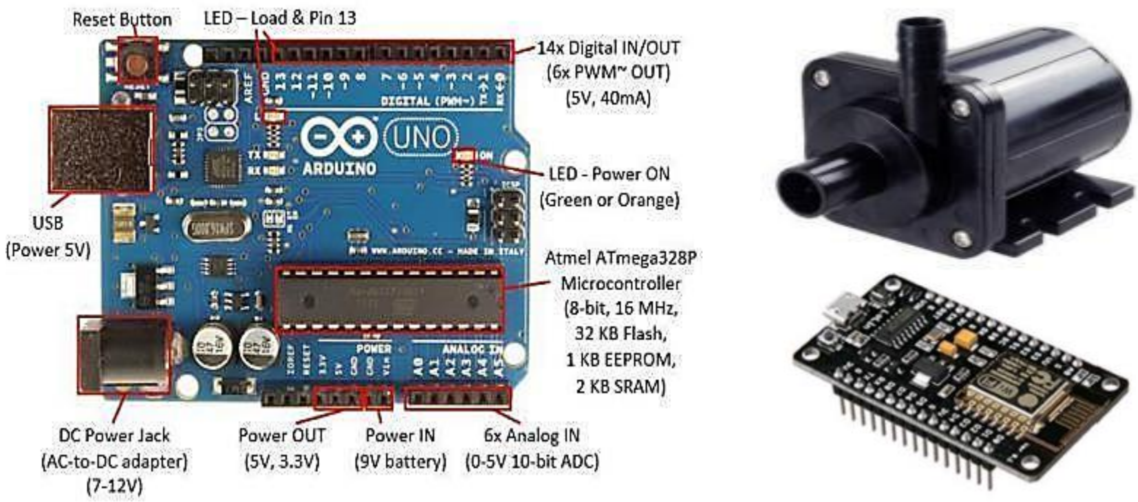

Figure 4. Arduino Uno microcontroller, water pump, and WiFi module

- Wi-Fi module: the Wi-Fi module enables the Arduino board to connect to the internet. It is used to transmit sensor data to the cloud. It has eight pins and runs on 3.3 V power. The proposed approach helps to gain advantage of water utilization, reduction of water loss due to evaporation.

Using the moisture, NPK, pH, rainfall, and temperature data, the farmer is assisted with the type of crop that can be grown in the field resulting in an increase of yield production rate. The implementation process is depicted in Figure 5.

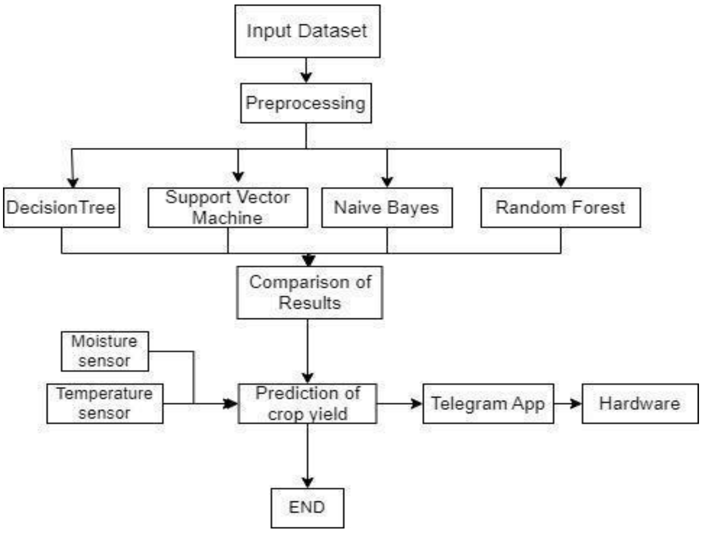

Figure 5. Data flow representation for crop recommendation

3. IMPLEMENTATION AND RESULTS

The proposed smart irrigation system is implemented as shown in Figure 6. The data generated from the sensors is fed to the ML recommendation system for crop prediction. The framework is engineered to gather, transmit and process the physical parameters (soil dampness, air temperature, mugginess, and water level) of the farming area to deal with the water system process proficiently. The sensors are connected with Arduino to collect the required data like soil moisture, N, P, K, pH, humidity, rainfall, and temperature from the field and are transmitted to telegram applications using the NCU WiFi module. After comparing the received data with the actual required in real time the water pump is controlled for time-to-time irrigation depending on the prerequisites of the crop. In the second stage crop recommendation is made by utilising machine learning algorithms. Among the machine learning algorithms considered, the RF algorithm was best suited providing the most accurate data enabling it to provide water for the plants at a low cost. The prediction process adopted for the data received through sensors is shown in Figure 7.

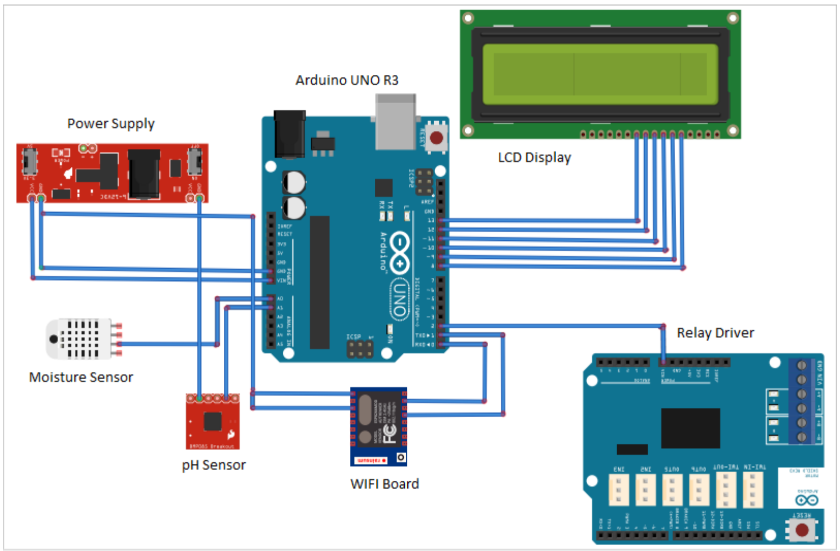

Figure 6. Circuit connection/hardware configuration for crop recommendation system

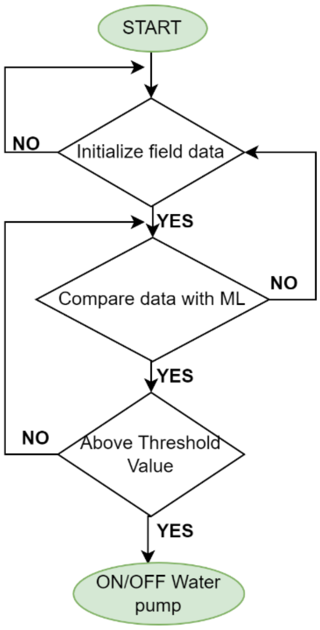

Figure 7. Data flow scenario for crop prediction using machine learning algorithms

Crop recommendation dataset taken from kaggle website [29] is initially considered for training purposes. Table 1 gives the description of the dataset. The dataset includes data related to NPK, rainfall, temperature, pH of about 22 types of crops.

Table 1. Data set description

Sl No	Attribute	Type	Description of attribute
1	N	Numeric	Value of nitrogen present in the soil
2	P	Numeric	Value of phosphorus in soil
3	K	Numeric	Potassium content in soil
4	Humidity	Numeric	Humidity in %
5	Temperature	Numeric	Temperature in degree celsius
6	pH	Numeric	Soil quality which defines whether soil is acidic, basic or not
7	Rainfall	Numeric	Rainfall in mm
8	Label	Nominal	Name of the crop

The model uses 30% of the data for training and 70% for testing. The existing dataset is enriched by adding sample inputs from various soil sources considered to the existing repository. The proposed ML training model compares four algorithms: DT, support vector machine (SVM), Naive Bayes (NB), and RF. Among these four, RF achieves 98% accuracy. Table 2 displays the results obtained with different algorithms for the selected dataset.

Table 2. Comparison of ML algorithm to determine best model for crop recommendation

ML algorithm	Accuracy (%)
DT	89
SVM	93
NB	96
RF	98

Users will be notified through telegram messenger about the soil condition in their field. If the soil is dry, then the pump will turn on automatically. If the soil is wet, then the pump will turn off automatically. The recommendation of a crop using real-time data is collected and stored periodically from the sensors to assist crop recommendation. Figure 8 shows the prototype for the crop recommendation system used. The instructions are then written to the Arduino Uno board as per the interface designed for the proposed system.

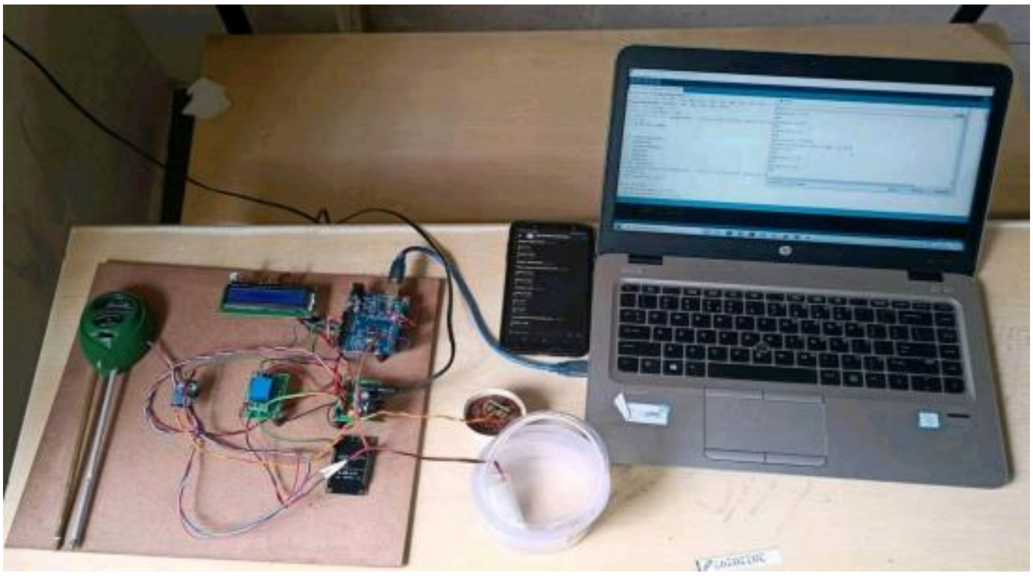

Figure 8. Proposed system connecting with software and hardware components

4. CONCLUSION

The smart irrigation system developed is practical and cost-effective in terms of maximizing agricultural productivity with the required amount of water. It meets the SDG goal 12 by ensuring sustainable consumption and production patterns. Soil moisture sensors are used in this work to evaluate soil moisture levels and arrange irrigation accordingly. It will regulate the amount of water used to irrigate the field, preventing water waste while also assisting in maintaining productivity and improving production. The accuracy of the predictions is enhanced by comparing ML algorithms. Farmers will be able to learn more about their field soil and maximize crop yields. The research aims to create a system that can forecast soil pH and crop type. Farmers will be able to learn more about their field soil and maximize crop yield. ML algorithms are implemented and compared to get better results for prediction. As per the experiment RF is giving better accuracy compared to other algorithms. The work can be further extended to improve the crop yield by analyzing farm images or videos.

REFERENCES

[1] D. Thakur, Y. Kumar, and S. Vijendra, "Smart irrigation and intrusions detection in agricultural fields using I.o.T.," *Procedia Computer Science*, vol. 167, pp. 154–162, 2020, doi: 10.1016/j.procs.2020.03.193.

[2] A. Vij, S. Vijendra, A. Jain, S. Bajaj, A. Bassi, and A. Sharma, "IoT and machine learning approaches for automation of farm irrigation system," *Procedia Computer Science*, vol. 167, pp. 1250–1257, 2020, doi: 10.1016/j.procs.2020.03.440.

[3] R. Udathu and V. B. Hency, "Implementation of an automated irrigation system," in *IEEE Sponsored 2 nd International Conference on Innovations in Information, Embedded and Communication systems (ICIIECS),* 2015.

[4] Y. Aringale, "Smart irrigation system using ML," *International Journal of Progressive Research in Science and Engineering*, vol. 2, no. 10, pp. 93–98, 2021.

[5] O. K. A, "A mobile phone controllable smart irrigation system," *International Journal of Advanced Trends in Computer Science and Engineering*, vol. 9, no. 1, pp. 279–284, Feb. 2020, doi: 10.30534/ijatcse/2020/42912020.

[6] M. D. Josephine, S. Gurunathan, V. Krishna, G. Nath, and S. Ramasamy, "Smart irrigation system," in *IEMECON 2021-10th International Conference on Internet of Everything, Microwave Engineering, Communication and Networks*, 2021, doi: 10.1109/IEMECON53809.2021.9689158.

[7] A. El Bilali and A. Taleb, "Prediction of irrigation water quality parameters using machine learning models in a semi-arid environment," *Journal of the Saudi Society of Agricultural Sciences*, vol. 19, no. 7, pp. 439–451, Oct. 2020, doi: 10.1016/j.jssas.2020.08.001.

[8] T. van Klompenburg, A. Kassahun, and C. Catal, "Crop yield prediction using machine learning: A systematic literature review," *Computers and Electronics in Agriculture*, vol. 177, Oct. 2020, doi: 10.1016/j.compag.2020.105709.

[9] M. Futagawa, T. Iwasaki, H. Murata, M. Ishida, and K. Sawada, "A miniature integrated multimodal sensor for measuring pH, EC and temperature for precision agriculture," *Sensors*, vol. 12, no. 6, pp. 8338–8354, Jun. 2012, doi: 10.3390/s120608338.

[10] A. Kaur, D. P. Bhatt, and L. Raja, "Developing a Hybrid Irrigation System for Smart Agriculture Using IoT Sensors and Machine Learning in Sri Ganganagar, Rajasthan," *Journal of Sensors*, vol. 2024, pp 1-15, 2024, doi: 10.1155/2024/6676907.

[11] S. Ramya, A. M. Swetha, and M. Doraipandian, "IoT framework for smart irrigation using machine learning technique," *Journal of Computer Science*, vol. 16, no. 3, pp. 355–363, Mar. 2020, doi: 10.3844/jcssp.2020.355.363.

[12] A. H. Blasi, M. A. Abbadi, and R. Al-Huweimel, "Machine learning approach for an automatic irrigation system in Southern Jordan Valley," *Engineering, Technology and Applied Science Research*, vol. 11, no. 1, pp. 6609–6613, Feb. 2021, doi: 10.48084/etasr.3944.

[13] G. S. Manoj, G. S. Prajwal, U. R. Ashoka, P. Krishna, and P. Anitha, "Prediction and analysis of crop yield using machine learning techniques," *International Journal of Engineering Research and Technology (Ijert)*, vol. 8, no. 15, pp. 19–23, 2020.
[14] R. Prabha, E. Sinitambirivoutin, F. Passelaigue, and M. V. Ramesh, "Design and development of an IoT based smart irrigation and fertilization system for chilli farming," in *2018 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, Mar. 2018, pp. 1–7, doi: 10.1109/WiSPNET.2018.8538568.
[15] A. Bhoi *et al.*, "IoT-IIRS: Internet of things based intelligent-irrigation recommendation system using machine learning approach for efficient water usage," *PeerJ Computer Science*, vol. 7, pp. 1–15, 2021, doi: 10.7717/PEERJ-CS.578.
[16] K. Bakthavatchalam *et al.*, "IoT framework for measurement and precision agriculture: predicting the crop using machine learning algorithms," *Technologies*, vol. 10, no. 1, Jan. 2022, doi: 10.3390/technologies10010013.
[17] M. Jagadeeswari, C. S. Manikandababu, K. S, P. R, and M. S, "Artificial intelligence based crop recommendation system," in *2022 4th International Conference on Inventive Research in Computing Applications (ICIRCA)*, Sep. 2022, pp. 1127–1133, doi: 10.1109/ICIRCA54612.2022.9985645.
[18] N. M. J. Kumari, N. T. Rao, and D. Bhattacharyya, "Smart irrigation and cultivation recommendation system for precision agriculture driven by IoT," in *Machine Intelligence, Big Data Analytics, and IoT in Image Processing*, Wiley, 2023, pp. 123–149.
[19] R. Reshma, V. Sathiyavathi, T. Sindhu, K. Selvakumar, and L. SaiRamesh, "IoT based classification techniques for soil content analysis and crop yield prediction," in *2020 Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC)*, Oct. 2020, pp. 156–160, doi: 10.1109/I-SMAC49090.2020.9243600.
[20] I. Dasgupta, J. Saha, P. Venkatasubbu, and P. Ramasubramanian, "AI crop predictor and weed detector using wireless technologies: a smart application for farmers," *Arabian Journal for Science and Engineering*, vol. 45, no. 12, pp. 11115–11127, Dec. 2020, doi: 10.1007/s13369-020-04928-2.
[21] R. Shahzadi, J. Ferzund, M. Tausif, and M. Asif, "Internet of things based expert system for smart agriculture," *International Journal of Advanced Computer Science and Applications*, vol. 7, no. 9, 2016, doi: 10.14569/ijacsa.2016.070947.
[22] N. N. Thilakarathne, M. S. A. Bakar, P. E. Abas, and H. Yassin, "A cloud enabled crop recommendation platform for machine learning-driven precision farming," *Sensors*, vol. 22, no. 16, p. 6299, Aug. 2022, doi: 10.3390/s22166299.
[23] V. E. Jesi, A. Kumar, B. Hosen, and S. D. D., "IoT enabled smart irrigation and cultivation recommendation system for precision agriculture," *ECS Transactions*, vol. 107, no. 1, pp. 5953–5967, Apr. 2022, doi: 10.1149/10701.5953ecst.
[24] S. Sundaresan, S. D. Johnson, V. M. Bharathy, P. M. P. Kumar, and M. Surendar, "Machine learning and IoT-based smart farming for enhancing the crop yield," *Journal of Physics: Conference Series*, vol. 2466, no. 1, Mar. 2023, doi: 10.1088/1742-6596/2466/1/012028.
[25] C. Thangavel *et al.*, "A study on agricultural engineering equipment in South Tamilnadu using linear regression," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 3, pp. 1480–1488, Jun. 2022, doi: 10.11591/eei.v11i3.3325.
[26] M. G. Kibria and M. T. A. Seman, "Internet of things based automated agriculture system for irrigating soil," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 3, pp. 1752–1764, Jun. 2022, doi: 10.11591/eei.v11i3.3554.
[27] A. A. S. Aliar, J. Yesudhasan, M. Alagarsamy, K. Anbalagan, J. Sakkarai, and K. Suriyan, "A comprehensive analysis on IoT based smart farming solutions using machine learning algorithms," *Bulletin of Electrical Engineering and Informatics*, vol. 11, no. 3, pp. 1550–1557, 2022, doi: 10.11591/eei.v11i3.3310.
[28] T. G. M. Thimmegowda and C. Jayaramaiah, "Cluster-based segmentation for tobacco plant detection and classification," *Bulletin of Electrical Engineering and Informatics*, vol. 12, no. 1, pp. 75–85, Feb. 2023, doi: 10.11591/eei.v12i1.4388.
[29] A. Ingle, "Crop recommendation dataset," *Kaggle*. https://www.kaggle.com/datasets/atharvaingle/crop-recommendation-dataset.

BIOGRAPHIES OF AUTHORS

Anitha Palakshappa received her Ph.D in Faculty Computer and Information Sciences from Visvesvaraya Technological University in the area of Data Analytics in 2023. Currently working as an Assistant Professor in the Department of Information Science and Engineering at Ramaiah Institute of Technology Bengaluru. Her research areas of interest are data mining and analytics, supply chain analytics, IoT, machine learning, and artificial intelligence. She can be contacted at email: anitha.palakshappa@gmail.com.

Sowmya Kyathanahalli Nanjappa received her Ph.D. in Faculty of Computer and Information Sciences from Visvesvaraya Technological University for her work in the area of Video Forensics in 2020. Currently, she is an Associate Professor in the Department of Information Science and Engineering, JSS Academy of Technical Education, Bengaluru. Her research areas of interest are image and video forensics, cyber security, pattern recognition, machine learning, deep learning, and computer vision. She can be contacted at email: kn_sowmya@rediffmail.com.

Punitha Mahadevappa is a Research Scholar from the Department of Computer Science and Engineering working in JSS Academy of Technical Education, Bangalore, India. She has 4 years of teaching experience. Currently she is pursuing her research in the area of internet of things and cloud computing. She can be contacted at email: punithamahadevappa92@gmail.com.

Sinchana completed her Bachelors of Engineering degree in Information Science and Engineering in JSS Academy of Technical Education, Bengaluru. Her areas of interest include IoT and machine learning. Currently she is working in Stratogent Technology services as a system analyst. She can be contacted at email: sinchrs19@gmail.com.