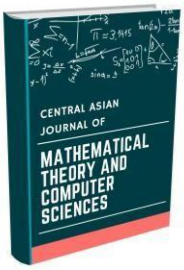

CENTRAL ASIAN JOURNAL OF MATHEMATICAL THEORY AND COMPUTER SCIENCES
https://cajmtcs.centralasianstudies.org/index.php/CAJMTCS
Volume: 07 Issue: 02 | April 2026 ISSN: 2660-5309

CENTRAL ASIAN STUDIES

Article

Intelligent Crop Prediction and Smart Irrigation System Using IoT, K-Means Clustering, and Random Forest Algorithms

S. Ramesh Kumar[1], M. Sree Rajeswari[2], M. Mohamed Thariq[3], A. Mohamed Fahadhu[4]

1,2 Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India
3,4 Department of Computer Science and Engineering, Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India
* Correspondence: rameshkuma@gmail.com

Citation: Kumar S. R., Rajeswari M. S., Thariq M. M., Fahadhu A. M. Intelligent Crop Prediction and Smart Irrigation System Using IoT, K-Means Clustering, and Random Forest Algorithms. Central Asian Journal of Mathematical Theory and Computer Sciences 2026, 7(2), 133-146.

Received: 10th Dec 2025
Revised: 12th Jan 2026
Accepted: 25th Feb 2026
Published: 03rd Mar 2026

Abstract: Agriculture covers more than 60.43% of the land in India. But we can't meet the country's growing needs if we keep using old farming methods. We need to sustainably and efficiently harvest most of the available farmland. The goal of this project is to set up a cost-effective system that uses high-tech sensors and the Internet of Things to make crop harvesting easier. The most important parts of the system are that it is a module that can be controlled by a mobile app and uses a set of sensors (electromagnetic, NPK, optical, and electrochemical) to measure the soil's texture and nutritional content. Advanced K-Means Clustering, Random Forest, and Decision Tree algorithms are used to analyse it and guess which crop can be grown. It uses infrared and laser sensors to figure out the best way to plant seeds so that they grow the most. It also keeps an eye on how wet the soil is and sets up irrigation systems like drip irrigation. A built-in weather forecasting system will predict rain and change the irrigation cycle to lower the risk of over- or under-irrigation. The module alerts the farmer when the crop needs something during the growth phase. It also has a flexible infrared motion sensor to detect movement and an alarm system to keep predators away, which is another way to keep it safe. Mobile apps control all the functions, while Machine Learning algorithms manage and oversee them. High-tech sensors and actuators, along with microcontrollers and Raspberry Pi, carry out the tasks.

Keywords: K-Means Clustering, Random Forest, Decision Tree, RaspberryPi, Information and Communication Technology, Internet of Things.

1. Introduction

People have recently thought of agriculture as a major strength of the world economy. Farming is one of the most important jobs in the world and the main way to get a lot of different crops [50]. Agriculture is having problems lately that could put its future at risk, like drought, problems with the quality and productivity of crops, and problems with predicting yields. The world's population is growing by about 3 people every second, or 250,000 people every day [58]. By 2025, it will reach 8 billion. The Food and Agriculture Organization (FAO) of the United Nations says that by 2050, the world's population will be about 9.6 billion [60]. Farmers need to grow more food while protecting the environment and using natural resources wisely to keep up with this steady rise, but they can't do it alone [48]. They can't do that with the usual farming methods [63]. So, modern technologies are very important for meeting the world's growing food needs [54]. The way farmers collect and use data to make smart decisions about farming is changing a lot [56].

Smart farming is the use of modern Information and Communication Technology (ICT), like machine learning algorithms, in agriculture and the smart use of natural resources, as a capital-based system, to improve technology in food farming in ways that are clean and sustainable [66].

Most people around the world are getting help from new technologies in a variety of ways [52]. Right now, the Internet of Things (IoT) and data analysis, like big data analytics and data science, are becoming more important in people's daily lives. They help people adapt to their surroundings [46]. In general, the agro-industrial and environmental sectors use IoTs and data analysis to diagnose and control smart farming systems [57]. This gives farmers, consumers, and the public important information about the basis and properties of agro-products and systems.The main problem is that farmers in most parts of the world don't know what causes their crops to fail and often don't get any help [49]. This project helps farmers by keeping an eye on and controlling all parts of farming [65]. The goal of the project is to use machine learning algorithms to make an IoT device and an interface that can keep an eye on and control farming practices [61]. The field of the project is Machine Learning. It has been hard for complex sensors to keep up with the progress of machine learning techniques [53]. In the IoT environment, all of the sensors are connected in one place. The goal of the project is to use a sensor-based monitoring system powered by machine learning to automate and keep an eye on the farming process [64]. This will save money.

It uses high-quality sensors to measure the testing matrix's parameters. Microcontrollers and computers process and store the data in the cloud in real time [51]. The model processes the data in real time and makes output. The results are measured against past metrics [62]. The methodology employed in this model involves the initial deployment of primary sensors, including NPK and soil sensors, to gather preliminary static and demographic data regarding the environment and to notify users of the status [59]. To save power and other resources, the sensors will switch between sleep and active states in the next stages. The moisture sensor checks the moisture level in the soil [67]. It also uses the OpenWeatherAPI to keep an eye on rainfall and change the flow of water to control irrigation [47]. The data from the sensors is cleaned up to get rid of null values and make it better, and then it is fed to a well-trained machine learning model to make predictions about what will happen [55].

2. Literature Review

Smart agriculture monitoring systems that use the Internet of Things (IoT) combine GPS-enabled remote supervision with environmental sensing technologies to make farms safer and more productive [11]. Most of the time, these systems have sensors for soil moisture and temperature, a way to detect wet leaves, automated irrigation control, and ways to detect intruders [37]. Farmers can keep an eye on field conditions in real time using mobile or web apps by combining microcontrollers with wireless communication modules. Security features like motion detection and devices that scare off intruders help protect crops [4]. Combining environmental sensing with automated irrigation makes sure that water is used in the best way possible, which cuts down on waste and boosts yield. Current research emphasises the significance of real-time data acquisition and remote accessibility in improving decision-making efficacy [28]. Still, there are problems with scalability, network reliability, and long-term maintenance of distributed sensor networks in rural farming areas [18]. Computer vision techniques are being used more and more in machine learning applications in precision agriculture to classify crops, find diseases, and estimate yields [42]. Machine learning models can tell different types of plants apart, check their growth stages, and find problems that affect quality by looking at large sets of crop images.

Deep learning architectures and convolutional neural networks are commonly used to automatically extract features and classify them correctly. These methods cut down on the amount of time needed for manual inspections and make it possible to act quickly to stop crop loss [14]. The literature stresses that transfer learning and data augmentation can make predictions more accurate [36]. But how well it works depends a lot on how different the datasets are and how good the images are [27]. Combining ML-driven image analytics with IoT-based monitoring systems makes precision farming better and helps farmers make decisions based on data. IoT-driven precision agriculture systems are built on wireless sensor networks and machine learning methods [7]. These networks gather information about the environment, like temperature, humidity, soil moisture, and nutrient levels, and send it to central platforms for analysis [32]. Smart farm prototypes that use data combine food, energy, and water management into one system. Machine learning algorithms use data from sensors to improve watering schedules, fertilisation, and energy use [21]. Research shows that predictive analytics can help with sustainability and making operations run more smoothly. But there are some problems, such as the limited energy of sensor nodes, communication delays, and worries about data security [43].

Ongoing improvements are centred on low-power communication protocols and edge computing solutions to improve reliability and scalability in agricultural settings [35]. IoT, crewless aerial vehicles, augmented reality, and machine learning are all parts of advanced precision agriculture frameworks that work together to make intelligent decision-support systems [2]. Drones take high-resolution aerial photos of crops, and IoT sensors collect data about the environment at ground level. Machine learning models look at this combined dataset to make suggestions for pest control, fertilisation, and irrigation [24]. Farmers can also use augmented reality tools to see how their fields are doing and get predictions about what will happen in the future. According to literature, integrating multiple technologies like this improves situational awareness and resource use [16]. Even though it has a lot of potential, putting it into action is hard because of high costs, technical difficulties, and farmers' lack of digital literacy [33]. Future research should focus on making smart farming technologies easier to use and cheaper so that more people can use them. Smart farming uses IoT and agricultural UAVs based on the ideas of intelligent sensing and automated monitoring [8]. IoT devices gather data about the environment and soil all the time, while UAVs do large-scale spatial analysis of crop conditions [44]. These technologies work together to find patterns of stress, nutrient shortages, and the need for irrigation [23]. When ground sensors and aerial imaging work together, they improve coverage accuracy and the ability to find things early.

Studies show that automation can help with better yield forecasting and less reliance on workers. Still, technical problems like battery life, complicated data integration, and reliance on weather affect how UAVs work [19]. Researchers are still looking into adaptive flight planning and sensor networks that use less energy to make operations more sustainable [31]. Comprehensive surveys on IoT-based smart agriculture highlight the swift advancement of sensing technologies, cloud computing, and data analytics [45]. New technologies like edge computing, AI, and 5G connectivity are changing traditional farming into data-driven operations [6]. These reviews describe how IoT ecosystems are built, including the layers for sensing, communication, data processing, and applications. The literature shows that productivity, water conservation, and crop health monitoring have all gotten a lot better [38]. Interoperability, cybersecurity, and standardisation are still big problems, though. For sustainable implementation, there needs to be strong infrastructure and training programs for farmers [41]. Future perspectives emphasise scalable architectures and the incorporation of predictive analytics to develop resilient, climate-smart agricultural systems [12]. Combining blockchain and the Internet of Things (IoT) in precision agriculture makes data more secure, easier to track, and more open. IoT devices gather real-time data about farming, and blockchain makes sure that transaction records are safe and can't be changed [25]. This combination helps with quality control, supply chain traceability, and building trust among stakeholders.

Research shows ways to cut down on fraud, make food safer, and improve logistics. But using blockchain raises worries about extra computing power, scalability, and energy use [26]. To work well, you need to find a balance between the benefits of decentralisation and the efficiency of the system. Research indicates that hybrid architectures integrating cloud platforms with blockchain networks can enhance performance [34]. When these technologies come together, they make smart agricultural ecosystems more trustworthy [1]. The CropDeep dataset is a big help to deep learning research in precision agriculture because it has a lot of labelled images that can be used for species classification and detection [17]. The dataset has more than 31,000 images and 49,000 labelled examples from different classes. It can be used to train and test computer vision models [29]. Deep learning architectures, like convolutional neural networks, can improve classification accuracy by using a wide range of labelled data. The dataset makes it easier to study automated weed detection, crop health monitoring, and yield estimation [10]. Maintaining dataset diversity and reducing annotation bias, on the other hand, are still problems that need to be solved. Standardised datasets make it easier to come up with new ideas for AI-driven agricultural applications and help researchers repeat their work.

The Reversible Automatic Selection Normalisation (RASN) deep network is a new way to build predictive models for smart agriculture systems [20]. RASN improves the stability of training and the accuracy of predictions by adding normalisation and renormalisation layers. This method solves problems with deep learning models that have too many features and don't scale them properly [5]. When used with agricultural data, RASN works better at predicting how crops will grow and how the weather will affect them. According to the literature, normalisation techniques have a big effect on how fast models converge and how well they generalise [13]. However, computational complexity and adjusting parameters are still very important things to think about. Continued research into adaptive normalisation methods could make deep learning applications in precision farming even better [39].

The Big Data and AI revolution in precision agriculture is about using big datasets to make better decisions and be more environmentally friendly [22]. Advanced analytics use sensor readings, satellite images, and weather data to make predictions. AI models make it possible to predict yields, find diseases, and use resources more efficiently [3]. Surveys show that data-driven farming has the power to change things for the better by increasing productivity and lowering the impact on the environment [30]. Still, social and financial problems, such as high costs of implementation and worries about data privacy, make it hard for everyone to use [9]. To make sure that everyone can use digital technologies and infrastructure, it is important to make sure that everyone can benefit from agricultural change [40]. Future research seeks to harmonise technological innovation with economic viability and social sustainability [15].

3. Project Description

The current system works in a tightly controlled space [80]. This system uses high-level machines to keep the environment under control, but it's not cost-effective, so most people can't afford it. There is no automation; most systems need to be run by hand [86]. The proposed system is a mix of hardware and software support. It can be used outside. It gathers information with semiconductor sensors that use less power and are cheap [68]. It also helps by using machine learning algorithms that make sure things are done correctly and guess what will happen. The user can see the model through a GUI. The analysis of Twitter data for sentiment is a new field that needs a lot more work. An architecture diagram is a picture that shows how a software system will be built in the real world [76].

It shows how the software system is put together and how its parts are connected, limited, and separated from each other (Figure 1).

Figure 1. Main Steps in the Proposed Architecture based on IA Techniques.

A data flow diagram (DFD) is a picture that shows how a business works by showing how data moves around [73]. It uses a standard set of symbols and notation. They are often parts of a formal method, like the Structured Systems Analysis and Design Method (SSADM) [85]. DFDs may look like flowcharts or the Unified Modelling Language (UML) on the surface, but they are not meant to show how software works in detail (Figure 2).

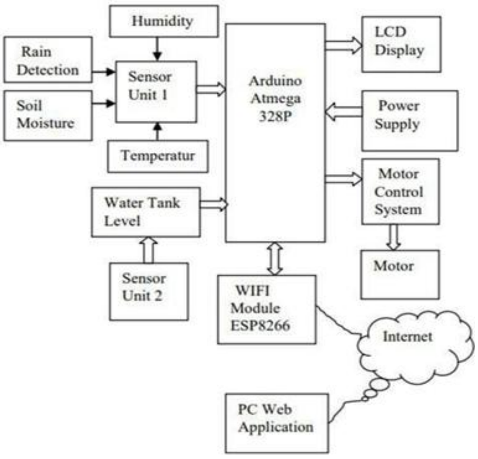

Figure 2. UML Diagram.

A UML diagram is a diagram that uses the Unified Modelling Language (UML) to show a system and its main actors, roles, actions, artefacts, or classes in a way that makes it easier to understand, change, maintain, or document the system [72]. A use case diagram shows how a system changes over time. It brings together use cases, actors, and their relationships to show how the system works [84]. It shows how a system or subsystem of an application should perform tasks, services, and functions [79]. It shows the main features of a system and how the user interacts with it.

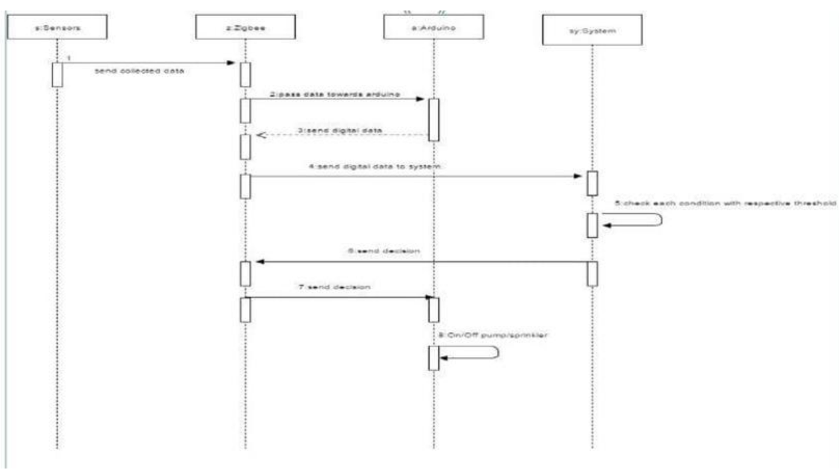

Figure 3. Sequence Diagram.

Figure 3 shows a sequence diagram in the Unified Modelling Language (UML) that shows how messages are sent between objects in an interaction [77]. A sequence diagram shows a group of objects with lifelines and the messages they send and receive during the interaction. It shows a timeline that starts at the top and goes down slowly to show the order of interactions [69]. There is a column for each object, and arrows show the messages that were sent between them (Figure 4).

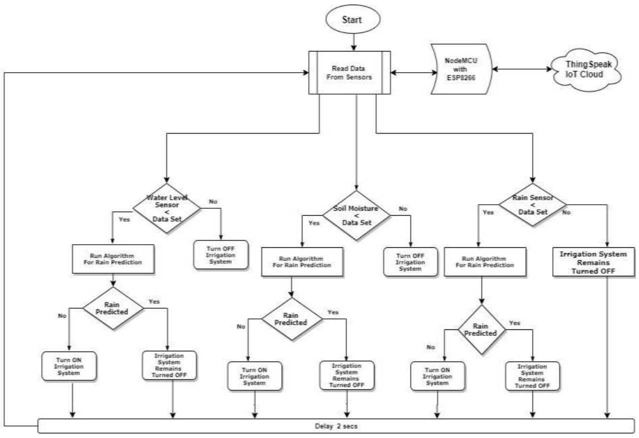

Figure 4. Flow Diagram.

A flow diagram is a picture that shows the order of steps or processes that make up a system, operation, or procedure. It shows how information, materials, or tasks move logically from one point to another in a system [74]. Flow diagrams usually use arrows and standardised symbols to show each step or process. The arrows show the order and direction of the process [87]. This lets the diagram show how a system works and how its parts work together. The DS18B20 temperature sensor can measure temperatures in Celsius from 9 to 12 bits and has an alarm function with user-programmable upper and lower trigger points that don't go away [81]. The DS18B20 has a 64-bit serial code that lets more than one DS18B20 work on the same 1-wire bus. Details about the technology: One-of-a-kind 1-Wire Interface; Measures Temperature range: -55 °C to +125 °C; Changes the temperature into a 12-bit digital word in 750 milliseconds (Figure 5).

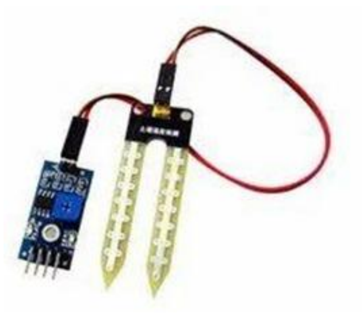

Figure 5. Soil Moisture Sensor-FC 28**.**

A Soil Moisture Sensor is used to check the moisture content of soil and other materials. There are two big exposed pads on the sensor that work as probes [71]. Together, they act like a variable resistor. This sensor tells how wet the soil is [88]. The analogue voltage will be low when the soil water level is low, and it will go up as the conductivity of the soil between the electrodes changes [82]. You can use this sensor to water a flower plant or any other plants that need to be automated (Figure 6).

Figure 6. Rechargeable Battery.

The SLA 12V, 9Ah rechargeable battery has a 5-hour (0.2C) discharge rate and a 20-hour (0.05C) discharge rate [75]. Longer discharge times give higher capacity readings because there are fewer losses. Lead-acid works well when there are a lot of current loads [83]. This battery powers the whole circuit from the inside (Figure 7).

Figure 7. External Ac Adapter.

A 12V AC adapter can also be thought of as part of the circuit's external power supply [70]. It lets the circuit be turned on when the battery is almost dead. The adapter can change AC to DC and send pure DC to the circuit from the outside [78].

4. Experimental Resources

NodeMCU is an open-source platform for developing Internet of Things (IoT) devices [97]. It comes with a firmware system development board that runs on the ESP8266 Wi-Fi SoC. It has a USB-UART interface and its own voltage regulator module. The pin rules make it very easy to develop. Wiring is also a big plus for the breadboard [91]. GPIO, PWM, I2C, 1-Wire, and ADC are all built into the NodeMCU development board. It has advanced hardware interfaces that make it easier for application developers to work with hardware without having to deal with complicated configurations and register operations [94]. NodeMCU can be developed in more than just Lua. It can also be developed in C++, Python (MicroPython), and Java (Smart.js). As you can see below, we use the CP2102 version of the board here (Figure 8).

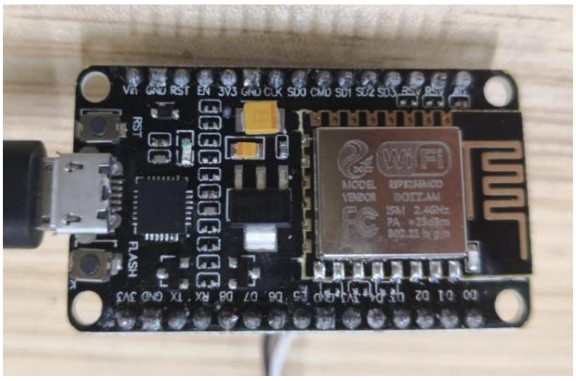

Figure 8. The Appearance of the NodeMCU based on the ESP8266 Development Board.

The DHT11 is a digital temperature and humidity sensor that combines several sensors into one [93]. It has a calibrated digital signal output that is very stable and reliable. An 8-bit microcontroller connects the NTC temperature-sensing element and the resistive sensing element in the DHT11. The OTP (one-time programmable) memory, which can't be erased, stores the calibration coefficients as a program. During the processing of the detection signal, these calibration coefficients are called from inside the program [89]. It has a single-wire serial interface that makes it easy and quick to connect to other systems. The DHT11 is small, doesn't use much power, and comes in a 4-pin single-row package that makes it easy to connect [96].

4.1. Soil moisture sensor

You can use a Soil Moisture Sensor to check the moisture content of soil and other materials. The sensor has two big, open pads that act as probes and work together as a variable resistor. This sensor measures how wet the ground is [92]. The analogue voltage will be low when the soil water level is low, and it will keep rising as the soil conductivity between the electrodes changes [95]. You can use this sensor to water a flowering plant or other plants that need automation. It has a technical specification of 3.3V to 5V, an analogue output, and an external VCC of 3.3V to 5V. The water level sensor is a cheap and easy-to-use sensor that can tell when the water level is high or low [98]. It does this by measuring droplets or water volume with a series of parallel wires with exposed traces. It's easy to convert water to an analogue signal, and an Arduino development board can read the analogue output values directly to set off an alarm when the water level rises. This is one kind of switch that can tell when it rains [90]. It works like a switch, and the way this sensor works is that the switch is usually closed when it rains (Figure 9).

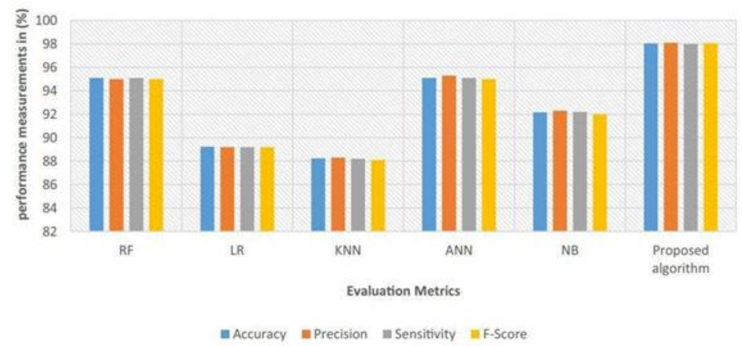

Figure 9. Output.

5. Results and Discussion

The model suggested in this study improves the features of the current system [101]. It uses machine learning to make IoT devices change over time, which makes the results more accurate and precise. It uses a hybrid, multimodal, and integrated mechanism to get real-time analysis and output. It is used in a centralised IoT network to improve performance and speed [99]. Organic farmers usually can't use synthetic fertilisers on their plants to fix the problems caused by nutrient deficiencies, so the main way to fix the problem is to grow green manure crops and use organic fertilisers. This long-term study sought to compare two distinct production systems, one with livestock and the other without, in the context of organic farming. Additionally, a control variant devoid of fertilisation was incorporated (treatment 1).

The production system that didn't include animal husbandry used renewable outside resources like compost or digestate (treatment 2) and the same fertiliser with extra substances (AS) (treatment 3). The production system that included animal husbandry used only farm-made fertilisers (fermented urine or manure) (treatment 4) and also used

AS (treatment 5). There were three copies of each treatment [102]. This study delineates the mean yields derived from four experimental years and five experimental sites. The first four years of this long-term study used winter wheat, potatoes, winter wheat spelt and a mix of legumes and cereals with maize as model crops [100]. Treatments 2 (7.1 t/ha grain, 33.9 t/ha tubers) and 3 (7.0 t/ha grain, 34.1 t/ha tubers) had the highest average yields of winter wheat grain and potato tubers during the first two years of the experiment (Figure 10).

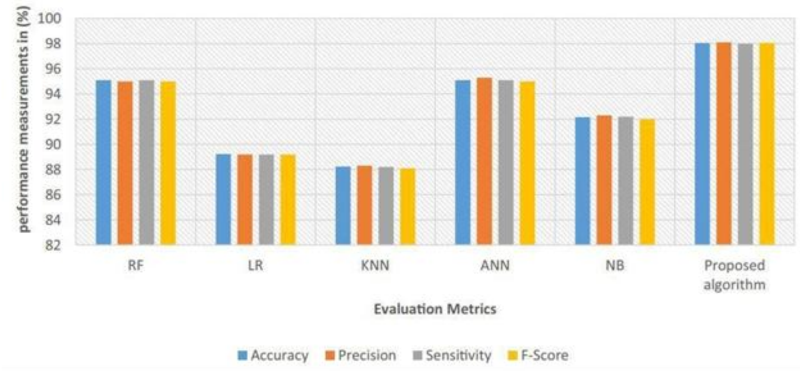

Figure 10. Performance Comparison of Machine Learning Algorithms.

6. Conclusion

The IoT-based smart farming system is very good at getting live temperature and soil moisture data. Farmers will be able to grow more food and take better care of food production with the help of the system proposed in this report. The system will always be there to help farmers by giving them accurate live feeds of soil moisture and environmental temperature with more than 99% accuracy. In this paper, we talked about how IoT can help farmers in the future by giving them a lot of useful services. IoT can be used to make a lot of smart apps that people use a lot. Farmers can use smart devices to put the right amount of resources in the right place and at the right time. This kind of farming costs less. This system runs a lot of machines and equipment very well and gathers data from them in the field, letting you know when there are problems. Farming with IoT helps prevent food shortages by making the best use of land that is already available at a low cost. Smart farming is a new idea that is quickly becoming popular in the farming world. This gives you automated farming methods, the ability to collect useful data, and very strict crop control. The main goal of Smart Farming is to get the most out of each piece of land by using modern methods to get the best quality, quantity, and financial return. Lastly, some possible solutions are looked at by looking at related research projects.

REFERENCES

[1] K. N. Bhanu, H. J. Jasmine, and H. S. Mahadevaswamy, “Machine learning Implementation in IoT based Intelligent System for Agriculture,” in 2020 International Conference for Emerging Technology (INCET), Karnataka, India, 2020.

[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, no.1, pp. 1250-1257, 2020.

[3] B. Kumar, “Blockchain-based authentication model for education data storage,” International Journal of Industrial and Systems Engineering, vol. 51, no. 4, pp. 498–515, 2025.

[4] V. Ramalingam, B. Kumar, S. K. Gupta, D. M. Alsekait, and D. S. AbdElminaam, “A hybrid federated learning framework with generative AI for privacy-preserving and sustainable security in IoT-enabled smart environments,” Scientific Reports, vol. 16, Art. no. 3071, 2026.

[5] B. Kumar, W. Shamas, J. Sandeep, and D. Albalushi, “Developing an advanced cybersecurity framework and blueprint: A contemporary approach to counter hacking through reverse engineering techniques,” in Smart Cyber Physical Systems, Proceedings of ICSCPS 2024, Singapore: Springer, 2024, pp. 27–37.

[6] B. Kumar, N. B. Najmusseher, P. K. Nizar Banu, and R. Dwivedi, “Epileptic seizure detection contribution in healthcare sustainability,” in AI and IoT: Driving Business Success and Sustainability in the Digital Age, B. Awwad, Ed., Studies in Systems, Decision and Control, vol. 601, Cham, Switzerland: Springer, 2025, pp. 225–235.

[7] D. Sumathi, S. Ayyappan, A. Sivasangari, B. Ramakrishna, P. Kanagaraju, and F. B. Kunwar, “Random forest with SHAP analysis for identifying environmental determinants of air quality in urban regions,” Journal of Environmental Protection and Ecology, vol. 26, no. 8, pp. 2963–2973, 2025.

[8] D. Sumathi, S. Ankam, P. P. Adivarekar, K. S. S. Sandeep, R. Gomathi, and R. Shobarani, “Early plant disease detection using graph isomorphic networks: Enhancing crop yield through leaf analysis,” Journal of Computer Science, vol. 21, no. 9, pp. 2065–2073, Oct. 2025.

[9] D. Sumathi, A. Mishra, and D. K. Jha, “AI-based stress prediction: Integrating psychological and behavioral data using deep learning,” in Proc. International Conference on Innovative Computing and Communication (ICICC), Lecture Notes in Networks and Systems, vol. 1435, vol. 6, no. 1, pp. 145–158, 2025.

[10] D. Sumathi and P. Poongodi, "Scheduling Based on Hybrid Particle Swarm Optimization with Cuckoo Search Algorithm in Cloud Environment," IIOAB JOURNAL, vol. 7, no. 9, pp. 358-366, 2016.

[11] G. V. Shrimant, K. Ravindranath, G. S. Prasad, and G. Syam, “A mathematical model for secure Cloud-IoT communication: Introducing the revolutionary lightweight key mechanism,” Journal of Discrete Mathematical Sciences and Cryptography, vol. 26, no. 5, pp. 1341–1354, 2023.

[12] V. S. Gaikwad,“Secure and swift: A proactive approach to defend lightweight key exchange mechanisms against replay, masquerade, and message forgery attacks in cloud-IoT communication,” Communications on Applied Nonlinear Analysis, vol. 31, no. 3S, pp. 533–546, 2024.

[13] K. Ravindranath and V. S. Gaikwad, “IoT device-to-cloud continuous authentication using lightweight key establishment mechanism,” Journal of Electrical Systems, vol. 19, no. 2, pp. 148–162, 2023.

[14] V. S. Gaikwad, “IoT cloud ecosystems: An in-depth platform comparison,” in Bridging Academia and Industry Through Cloud Integration in Education. Hershey, PA, USA: IGI Global Scientific Publishing, 2025, pp. 247–280.

[15] G. S. Prasad and V. S. Gaikwad,“A survey on user awareness of cloud security,” International Journal of Engineering & Technology, vol. 7, no. 2.32, pp. 131–135, 2018.

[16] V. S. Gaikwad and J. Wakle,“Real-time keylogging and system monitoring for device activity auditing,” IOSR Journal of Computer Engineering, vol. 27, no. 5, pp. 13–20, 2025.

[17] S. P. Gudapati and V. Gaikwad,“Light-weight key establishment mechanism for secure communication between IoT devices and cloud,” in Intelligent System Design: Proceedings of Intelligent System Design: INDIA 2019. Singapore: Springer, 2020, pp. 549–563.

[18] S. Sutar, K. Jose, V. Gaikwad, V. Mishra, D. Wankhede, and M. Karnik,“Enhancing data management: An integrated solution for database backup, recovery, conversion, and encryption capabilities,” International Journal of Intelligent Systems and Applications in Engineering, vol. 12, no. 6S, pp. 720–734, 2024.

[19] A. A. Manikjade et al.,“Numerical simulation and investigation of flow patterns around three side-by-side cylinders arranged in line with an oscillating central cylinder,” CFD Letters, vol. 17, pp. 95–108.

[20] N. Ambhore, S. Shelke, D. Washimkar, A. Dhumal, V. Gaikwad, and O. Borawake,“Artificial intelligence for tool condition monitoring: A comprehensive review,” Letters in Applied NanoBioScience, vol. 14, no. 4, p. 257, 2025.

[21] D. S. Wankhede and R. Selvarani, “Dynamic architecture-based deep learning approach for glioblastoma brain tumor survival prediction,” Neuroscience Informatics, vol. 2, p. 100049, 2022.

[22] D. S. Wankhede, “Analysis and prediction of soil nutrients (pH, N, P, K) for crop using machine learning classifier: A review,” in Innovations in Communication and Computing. Singapore: Springer, 2022, pp. 111–121.

[23] M. Preetha, D. S. Wankhede, R. Kumar, G. Ezhilarasan, S. Khurana, and G. S. Sahoo, “Leveraging AI-driven systems to advance data science automation,” in Proc. 1st Int. Conf. Emerging Research in Computational Science (ICERCS), 2023.

[24] D. S. Wankhede, V. Gaikwad, M. Karnik, S. Kapase, and O. Bakkam, “The decentralized smart contract certificate system utilizing Ethereum blockchain technology,” Procedia Computer Science, vol. 230, pp. 923–934, 2023.

[25] D. S. Wankhede, C. J. Shelke, V. K. Shrivastava, R. Achary, and S. N. Mohanty, “Brain tumor detection and classification using adjusted InceptionV3, AlexNet, VGG16, VGG19 with ResNet50–152 CNN model,” EAI Endorsed Trans. Pervasive Health Technol., vol. 10, Art. no. 6377, 2024.

[26] D. S. Wankhede, C. J. Shelke, and A. George, “An enhanced algorithm for predicting IDH1 mutations and 1p19q mitigation in glioma tumor,” in AIP Conf. Proc., vol. 3217, no. 1, Art. no. 020025, 2024.

[27] C. J. Shelke, D. S. Wankhede, P. M. Paul, V. K. Shrivastava, and R. Achary, “Enhanced prediction of glioma brain tumors using deep learning algorithm,” in AIP Conf. Proc., vol. 3217, no. 1, Art. no. 020022, 2024.

[28] D. S. Wankhede, B. Karare, A. D. Warange, P. Bhokardankar, and K. S. Tidke, “Blockchain-enabled thyroid detection using voting classifier and deep convolutional neural network,” in Proc. 3rd Int. Conf. Networks and Advances in Computational Technologies (NetACT), 2025.

[29] P. V. Deshmukh, A. K. Shahade, M. R. Shahade, D. S. Wankhede, and P. H. Gohatre, “Breast cancer detection using a novel hybrid machine learning approach,” Ingénierie des Systèmes d’Information, vol. 30, no. 3, Art. no. 301, 2025.

[30] P. V. Deshmukh, A. K. Shahade, D. S. Wankhede, M. R. Shahade, N. N. Sakhare, and P. H. Gohatre, “Optimizing NLP processes with human insight and machine intelligence,” Ingénierie des Systèmes d’Information, vol. 30, no. 5, pp. 1339–1347, 2025.

[31] K. Chitra, S. S. Priscila, E. S. Soji, R. Rajpriya, B. Gayathri, and A. Chitra, “Transforming electrical simulation and management with smart grid technologies,” International Journal of Engineering Systems Modelling and Simulation, vol. 16, no. 4, pp. 241–253, 2025.

[32] M. V. Soosaimariyan, H. L. Allasi, K. Chitra, and J. B. Gnanadurai, “Enhanced EMG-based hand gesture recognition by using generalized deep infomax networks,” Journal of Sensors, vol. 2025, no. 1, p. 9496890, 2025.

[33] K. Lakshmi and K. Chitra, “Stress Net: Multimodal stress detection using ECG and EEG signals,” Journal of Data Science, vol. 2024, no. 59, pp. 1–8, 2024.

[34] S. Rishabh, K. Chitra, and C. S. Yap, “A study on non-fungible tokens marketplace for secure management,” INTI Journal, vol. 2024, no. 18, pp. 1–8, 2024.

[35] S. Shreyash, S. Gaur, K. Chitra, and M. Y. N. Zuhaili, “EasyLearnify – A student study portal,” INTI Journal, vol. 2024, no. 17, pp. 1–6, 2024.

[36] P. Jothilingam, “Digital twin technologies for ICS: Leveraging virtualization and sensor data for FAT/SAT, commissioning and predictive risk detection,” International IT Journal of Research, vol. 1, no. 1, pp. 45–49, Oct. 2023.

[37] P. Jothilingam, “Modernization of industrial legacy control systems: Migration strategies, risk mitigation, and operational continuity in critical infrastructures,” International Journal of Unique and New Updates, vol. 5, no. 2, pp. 39–44, Aug. 2023.

[38] P. Jothilingam, “Systems and management innovation in Industry 4.0: Redefining organizational models, human–machine collaboration, and process efficiency,” in Proc. Int. Conf. Innovative Trends in Engineering and Technology, India, Jul. 2022, pp. 699–706.

[39] P. Jothilingam, “Industrial Internet of Things (IIoT): AI-driven anomaly detection and multi-protocol communication across Modbus and EtherNet/IP networks,” International Journal of Enhanced Research in Science, Technology & Engineering, vol. 11, no. 3, pp. 138–143, Mar. 2022.

[40] R. M. Lingaraju, C. S. Pillai, and A. B. Jayachandra, “Object recognition using Lucas–Kanade technique and support vector machine based classification in video surveillance systems,” International Journal of Engineering and Advanced Technology, vol. 9, no. 1, pp. 2219–2224, Oct. 2019.

[41] S. J. Niranjan, R. M. Lingaraju, B. V. B. Prabhu, and V. N. Vinaykumar, “Coconut disease prediction using neural attention mechanism with Adamax optimizer-based convolutional neural network,” International Journal of Environmental Sciences, vol. 11, no. 5, pp. 2352–2360, 2025.

[42] S. J. Niranjan, R. M. Lingaraju, and J. A. Babu, “Spiralizer strategy with wolf pack algorithm and temporal convolution network–gated recurrent unit for coconut crop yield prediction,” SN Computer Science, vol. 5, Art. no. 1108, 2024.

[43] V. V. N. Nagaraju, A. B. Jayachandra, A. Stateczny, S. H. Yogesh, R. M. Lingaraju, and B. P. B. Veeranna, “Dual strategy based improved swarm intelligence and stacked LSTM with residual connection for land use land cover classification,” IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 18, pp. 4188–4198, 2025.

[44] D. Narasappa, "Integrating Zero Trust Architecture with Automation and Analytics for Resilient Cybersecurity," 2025 3rd International Conference on Data Science and Network Security (ICDSNS), Tiptur, India, 2025, pp. 1-6.

[45] D. Narasappa, "AI-Driven Security Measures for IoT Networks Utilizing Machine Learning for Anomaly Detection," 2025 IEEE 4th World Conference on Applied Intelligence and Computing (AIC), GB Nagar, Gwalior, India, 2025, pp. 134-139.

[46] Kumar, P.R., Mohammad, G.B., Narsimhulu, P., Narasappa, D., Maguluri, L.P. et al. (2025). Computer Modeling Approaches for Blockchain-Driven Supply Chain Intelligence: A Review on Enhancing Transparency, Security, and Efficiency. Computer Modeling in Engineering & Sciences, 144(3), 2779–2818.

[47] I. Ganie and S. Jagannathan, "Adaptive control of robotic manipulators using deep neural networks," Proc. 6th IFAC Conf. Intell. Control Autom. Sci. (ICONS), vol. 55, no. 15, pp. 148–153, 2022.

[48] I. Ganie and S. Jagannathan, "Continual online learning-based optimal tracking control of nonlinear strict-feedback systems: Application to unmanned aerial vehicles," Complex Eng. Syst., vol. 4, no. 1, 2024.

[49] I. Ganie and S. Jagannathan, "Continual optimal adaptive tracking of uncertain nonlinear continuous-time systems using multilayer neural networks," Proc. 2023 Amer. Control Conf. (ACC), San Diego, CA, USA, 2023, pp. 3395–3400.

[50] B. Lakshmikanth and T. Jesudas, "Influence of stainless steel short fibres as reinforcements in enhancing the performance of aluminium 7075 alloy matrix composites," Transactions of the Indian Institute of Metals, vol. 77, pp. 495–501, 2024.

[51] T. Jesudas, S. Ramesh, and R. M. Arunachalam, "Prediction and optimization of micro EDM process parameter using multiple regression and artificial neural network," Elixir Mechanical Engineering, vol. 66, pp. 20895–20900, 2014.

[52] S. Dhanalakshmi, T. Jesudas, and M. Pradeep Kumar, "A stir casting process-based experimental analysis of the wear properties of an Al 6063 alloy reinforced with ceramic particles," Romanian Journal of Materials, vol. 55, no. 2, pp. 107–120, 2025.

[53] J. Dineshkumar and T. Jesudas, "Hybrid polymer matrix development using cashew nut shell liquid as an additive into epoxy resin," Journal of the Chinese Institute of Engineers, vol. 46, no. 4, pp. 380–388, 2023.

[54] D. K. Gupta, S. K. Sharma, P. K. Gaur, and A. P. Singh, "Lovastatin loaded solid lipid nanoparticles for transdermal delivery: In vitro characterization," Res. J. Pharm. Technol., vol. 15, no. 3, pp. 1085–1089, 2022.

[55] S. Mishra, S. K. Sharma, J. Yadav, and B. Kasana, "A review on how exactly diuretic drugs are working in our body," J. Drug Deliv. Ther., vol. 3, no. 5, pp. 115–120, 2013.

[56] J. Yadav, S. K. Sharma, and L. Singh, "Evaluation of antidepressant activity of leaves extract of Moringa oleifera using FST and TST model on Swiss albino mice," World J. Pharm. Res., vol. 5, pp. 967–976, 2016.

[57] S. Mishra, S. K. Sharma, A. Rizvi, and A. Chowdhary, "Physicochemical standardization and phytochemical screening of potential medicinal herb: Vetiveria zizanioides (roots)," Int. J. Phytother., vol. 1, pp. 1–6, 2014.

[58] J. R. Rogers, Y. Wang, N. F. Khan, K. Mott, V. K. Nomula, D. Wang, P. C. Fiduccia, M. Burcu, and X. Liu, "Landscape assessment of clone-censor-weight methodology application in real-world data studies: A scoping review," in Proceedings of the Pharmacoepidemiology and Drug Safety Conference, vol. 33, pp. 424–424, Nov. 1, 2024.

[59] A. Satyanaga and H. Rahardjo, "Role of unsaturated soil properties in the development of slope susceptibility map," Proc. Inst. Civ. Eng. – Geotech. Eng., vol. 175, no. 3, pp. 276–288, 2022.

[60] Q. Zhai, H. Rahardjo, A. Satyanaga, and G. Dai, "Estimation of tensile strength of sandy soil from soil–water characteristic curve," Acta Geotechnica, vol. 15, pp. 3371–3381, 2020.

[61] H. Rahardjo, Nio, A. Satyanaga, F. R. Harnas, and E. C. Leong, "Comprehensive instrumentation for real time monitoring of flux boundary conditions in slope," Procedia Earth Planet. Sci., vol. 9, pp. 23–43, 2014.

[62] Y. Kim, H. Rahardjo, M. M. Nistor, A. Satyanaga, E. C. Leong, and A. W. L. Sham, "Assessment of critical rainfall scenarios for slope stability analyses based on historical rainfall records in Singapore," Environ. Earth Sci., vol. 81, no. 2, p. 39, 2022.

[63] A. Satyanaga, H. Rahardjo, and C. J. Hua, "Numerical simulation of capillary barrier system under rainfall infiltration in Singapore," ISSMGE Int. J. Geoengineering Case Hist., vol. 5, no. 1, pp. 43–54, 2019.

[64] H. Rahardjo, M. M. Nistor, N. Gofar, A. Satyanaga, Q. Xiaosheng, and S. I. C. Yee, "Spatial distribution, variation and trend of five-day antecedent rainfall in Singapore," Georisk: Assess. Manag. Risk Eng. Syst. Geohazards, vol. 14, no. 3, pp. 177–191, 2020.

[65] A. Satyanaga, H. Rahardjo, Z. H. Koh, and H. Mohamed, "Measurement of a soil-water characteristic curve and unsaturated permeability using the evaporation method and the chilled-mirror method," J. Zhejiang Univ. – SCIENCE A, vol. 20, no. 5, pp. 368–374, 2019.

[66] H. Rahardjo and A. Satyanaga, "Sensing and monitoring for assessment of rainfall-induced slope failures in residual soil," Proc. Inst. Civ. Eng. – Geotech. Eng., vol. 172, no. 6, pp. 496–506, 2019.

[67] A. Satyanaga, N. Bairakhmetov, J. R. Kim, and S.-W. Moon, "Role of bimodal water retention curve on the unsaturated shear strength," Appl. Sci., vol. 12, no. 3, p. 1266, 2022.

[68] Y. Kim, A. Satyanaga, H. Rahardjo, H. Park, and A. W. L. Sham, "Estimation of effective cohesion using artificial neural networks based on index soil properties: a Singapore case," Eng. Geol., vol. 289, Art. no. 106163, Aug. 2021.

[69] S. K. Somayajula, "Enterprise Data Migration Success Patterns: Lessons from Large-Scale Transformations," International Journal of Research in Computer Applications and Information Technology (IJRCAIT), vol. 8, no. 1, pp. 757-776, Jan.-Feb. 2025.

[70] S. K. Somayajula, "Demystifying Modern Data Warehousing: From Traditional to Cloud-Native Solutions," International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 2025.

[71] S. K. Somayajula, "Building a Career in Enterprise Data Architecture: A Practical Guide," International Research Journal of Modernization in Engineering Technology and Science (IRJMETS), vol. 7, no. 1, Jan. 2025.

[72] S. K. Somayajula, "Advanced ETL Optimization: A Framework for Next-Generation Data Integration," International Journal of Computer Engineering and Technology (IJCET), vol. 16, no. 1, pp. 381-406, Jan.-Feb. 2025.

[73] S. Somayajula and A. Orlovsky, "Proof, Truth and Contradiction in the System and Meta-System: Comprehensive Mathematical Solutions and Implementation Framework," 2025.

[74] S. Arul Krishnan, V. P. Rameshkumaar, K. Prakash, and D. Sugandaran, "Impact of celebrity endorsement on cause-related marketing and purchase intention of FMCG consumers in Chennai," Journal of Statistics & Management Systems, vol. 26, no. 7, pp. 1627–1641, 2023.

[75] S. Arul Krishnan, V. P. Rameshkumaar, R. Sathya Aarthi, and S. Karthikeyan, "Role of job design on institutional support and work-life equilibrium of women teachers in Chennai," Journal of Statistics & Management Systems, vol. 26, no. 7, pp. 1549–1563, 2023.

[76] S. Karthikeyan, V. P. Rameshkumaar, and B. Balaji, "Subscribers of Indian Mobile Telecom: Satisfaction with Experience and Loyalty," International Journal of Management, vol. 11, no. 9, Oct. 15, 2020.

[77] S. Pundir, V. G. Murugan, P. Raman, V. P. Rameshkumaar, and P. Sudharsan, "Automatic Stock Price Prediction and Classification Based on Hybrid with AI Feature Selection Method," in Proc. 2024 5th International Conference on Recent Trends in Computer Science and Technology (ICRTCST), pp. 149–154, Apr. 9, 2024. IEEE.

[78] S. G. K. Peddireddy, "Advancing Threat Detection in Cybersecurity through Deep Learning Algorithms," FMDB Transactions on Sustainable Intelligent Networks., vol.1, no. 4, pp. 190–200, 2024.

[79] S. G. K. Peddireddy, "Integrating AI for Proactive Network Defense against Emerging Security Vulnerabilities," FMDB Transactions on Sustainable Computer Letters., vol. 2, no. 4, pp. 232–241, 2024.

[80] S. G. K. Peddireddy, "Optimizing Resource Allocation in Multi-Cloud Environments for Cost Efficiency and Scalability," FMDB Transactions on Sustainable Computing Systems., vol. 2, no. 4, pp. 167–177, 2024.

[81] V. Hiremath, "Quantum Networking: Strategic Imperatives for Enterprises and Service Providers in the Emerging Quantum Era," Journal of Computational Analysis and Applications (JoCAAA), vol. 31, no. 3, pp. 617–631, Dec. 2023.

[82] V. Hiremath, "AI-Optimized Adaptive Routing for High-Performance Data Centers: A Predictive Framework for Dynamic Network Optimization," 2025 IEEE 4th World Conference on Applied Intelligence and Computing (AIC), GB Nagar, Gwalior, India, 2025, pp. 152-157.

[83] V. Hiremath, "Optimizing SDN Controller Placement for Enhanced Performance and Scalability in Large-Scale Networks," 2025 International Conference on Intelligent Communication Networks and Computational Techniques (ICICNCT), Bidar, India, 2025, pp. 1-6.

[84] D. K. Arora et al., "An in vitro assessment of microleakage of pit and fissure sealants and restorative materials using dye penetration method," Journal of Pharmacy and Bioallied Sciences, Feb. 2025.

[85] R. Nagar et al., "In vitro analysis of compressive strength of three different aesthetic restorative materials," Journal of Pharmacy and Bioallied Sciences, Feb. 2025.

[86] N. Maiti et al., "Assessment of the efficacy of photobiomodulation (PBM) therapy in periodontal treatment: a longitudinal study," Journal of Pharmacy and Bioallied Sciences, vol. 16, no. Suppl 3, pp. S2449–S2451, Jul. 2024.

[87] V. S. A. Anala, A. R. Pothu, and S. Chintapalli, "Enhancing Preventive Healthcare with Wearable Health Technology for Early Intervention," FMDB Transactions on Sustainable Health Science Letters., vol.2, no.4, pp. 211–220, 2024.

[88] V. S. A. Anala and S. Chintapalli, "Scalable Data Partitioning Strategies for Efficient Query Optimization in Cloud Data Warehouses," FMDB Transactions on Sustainable Computer Letters., vol. 2, no. 4, pp. 195–206, 2024.

[89] A. R. M. T. Islam, Md. N. Uddin, Md. F. R. Joy, R. Proshad, T. Kormoker, A. H. Anik, M. S. Rahman, Md. A. B. Siddique, and M. A. Alshehri, "Tracing sources-oriented ecological risks of metal(loid)s in sediments of anthropogenically-affected coastal ecosystem from northeast bay of Bengal," Mar. Pollut. Bull., vol. 211, p. 117354, 2025.

[90] A. R. M. T. Islam, M. Abdullah-Al Mamun, M. Hasan, M. N. Aktar, M. N. Uddin, M. A. B. Siddique, M. H. Chowdhury, M. S. Islam, A. B. M. M. Bari, and A. M. Idris, "Optimizing coastal groundwater quality predictions: A novel data mining framework with cross-validation, bootstrapping, and entropy analysis," J. Contam. Hydrol., p. 104480, 2024.

[91] Md. A.-A. Mamun, A. R. M. T. Islam, Mst. N. Aktar, M. N. Uddin, Md. S. Islam, S. C. Pal, A. Islam, A. B. M. M. Bari, A. M. Idris, and V. Senapathi, "Predicting groundwater phosphate levels in coastal multi-aquifers: A geostatistical and data-driven approach," Sci. Total Environ., vol. 953, p. 176024, 2024.

[92] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. A. H. Badsha, M. H. Chowdhury, and A. R. M. T. Islam, "Hexavalent chromium removal from aqueous medium by ternary nanoadsorbent: A study of kinetics, equilibrium, and thermodynamic mechanism," PLoS ONE, vol. 18, no. 12, e0290234, 2023.

[93] G. C. Saha, M. A. Hasanath, M. N. Uddin, and M. Hasan, "Sustainable Utilization of Textile Dyeing Sludge and Coal Fly Ash by Brick Production Through Traditional Kilns," Nature Environ. Pollut. Technol., vol. 21, no. 3, 2022.

[94] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. T. Rahman, and M. M. Rashid, "Development and Characterization of Novel Mn–Fe–Sn Ternary Nanoparticle by Sol–Gel Technique," in Advances in Civil Engineering, S. Arthur, M. Saitoh, and S. K. Pal, Eds. Singapore: Springer, 2022, vol. 184, Lecture Notes in Civil Engineering.

[95] M. T. Rahman, G. C. Saha, M. A. Hasanath, and M. N. Uddin, "Potential Use of Dying Sludge, Pet Granules and Fly Ash in Light Weight Concrete Block," in Advances in Civil Engineering, S. Arthur, M. Saitoh, and S. K. Pal, Eds. Singapore: Springer, 2022, vol. 184, Lecture Notes in Civil Engineering.

[96] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. T. Rahman, and M. M. Rashid, "Development and Characterization of Novel Mn–Fe–Sn Ternary Nanoparticle by Sol–Gel Technique," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 29–34.

[97] M. A. Hasanath, M. N. Uddin, and M. Ashraf, "Fabrication of Eco-friendly Water Purifier by Pedaling Energy," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 29–34.

[98] M. A. Hasanath, M. N. Uddin, and G. C. Saha, "Assessment of beverage sludge as agricultural soil," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 254–260.

[99] M. T. Rahman, G. C. Saha, M. A. Hasanath, and M. N. Uddin, "Potential Use of Dying Sludge, Pet Granules and Fly Ash in Light Weight Concrete Block," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 254–260.

[100] B. Kumar and O. Al Falhi, "Digital transformation through APIs," in Proc. Int. Conf. on Communication, Information Technology and Internet of Things (COM-IT-CON), 2022.

[101] K. Al Aufi and B. Kumar, "Security testing of Android application using Drozer," in Proc. Int. Conf. on Computational Sciences and Sustainable Technologies, Springer CCIS, 2024, pp. 8–18.

[102] B. Al Barwani, E. Al Maani, and B. Kumar, "IoT-enabled smart cities: A review of security frameworks, privacy, risks, and key technologies," in Proc. 1st Int. Conf. on Innovation in Information Technology and Business (ICIITB 2022), Advances in Computer Science Research, vol. 104, Springer, 2022, pp. 169–181.