

An Intelligent Agro-Cloud Framework For Efficient Crop Cultivation

Dr. S.Anitha¹, Dr. A.Muthusamy², Dr.T.Thiruvankadam³

¹Assistant Professor, Department of Computer Science, Faculty of Science and Humanities, SRM Institute of Science and Technology, Tiruchirappalli, India anithaperiyasamy@gmail.com

²Assistant Professor & Head, Department of Computer Science, Faculty of Science & Humanities, SRM Institute of Science and Technology, Tiruchirappalli, Tamil Nadu, India muthusamy.arumugam@gmail.com

³Associate Professor, Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Andrapradesh, India. mailone.thiru@gmail.com

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Abstract

Agriculture is considered the backbone of the Indian economy. But, still, farmers are unable to get sufficient profit due to water scarcity, flooding, storm, insufficient labor, and poor agro marketing. Moreover, modern technologies are not practiced efficiently in farming due to ignorance, high cost, and small land size. The proposed cloud-based framework consists of three key layers i) input layer ii) storage and processing layer iii) application layer. The input layer collects data from various IoT devices like sensors, meters, cameras, robots (for weeding & spraying), drones, and satellite data. The agro-cloud stores and processes the input data from IoT devices at regular intervals of time. Layer 2 aids smart farming namely soil monitoring, crop growth, irrigation management, and pesticide& fertilizer control. Soft computing technologies such as artificial intelligence, neural networks, and machine learning algorithms can be employed to select the appropriate irrigation method based on the type of soil, crop, quality of water, and rainfall. The application layer interacts with the farmers through various applications like graphical user interface systems (GUI), SMS alerts, and IoT-based mobile applications. A farmer advisor mobile App is designed based on the recommended framework for efficient crop cultivation which provides timely information to farmers like formulating land, choosing seeds, planting, plant protection, and plant insurance. Thus, the proposed research aids the farmers in improving crop yield and reducing the workforce and resources.

Key Words: Agro-Cloud Framework; Crop cultivation; Internet of Things (IoT); Neural Networks; Machine Learning; Farmers Advisory MobileApp

1. Introduction

Smart farming [1] employs emerging technologies such as mobile communication, the Internet of Things (IoT), cloud computing, machine learning, artificial intelligence, and data analytics to automate farming and precision farming. The cycle of smart farming consists of four important states namely: i) data collection from the observation state ii) diagnostics to detect requirements and scarcity iii) taking decisions and iv) action state to implement the decisions. Google trends results of smart farming for the period from 2019 to 2022 are depicted in Figure 1.

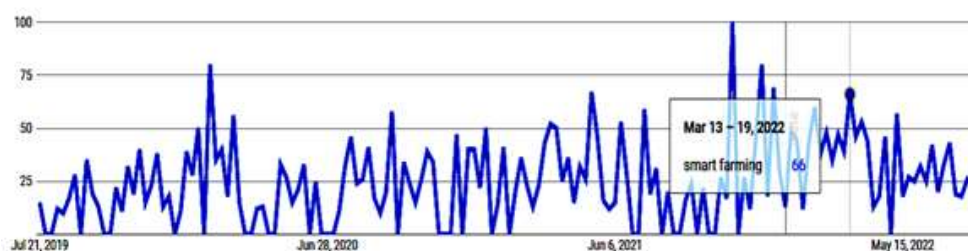


Figure 1: Google Trends for Smart Farming

According to UN projects [2], the population of the world will be extended to 9.7 billion by 2050 which will increase by 69% of the global food production. Precision farming and smart agriculture aid to attain the higher demand for food production. As stated in the forecast of smart farming market value [3], the smart agriculture market size will reach 23.14 billion dollars by 2022 as shown in Figure 2. Nowadays, precision agriculture employs information and communication technologies such as cloud computing and IoT to enhance crop yield and reduce cost. Moreover, precision farming significantly reduces the water consumption for irrigation, fertilizer, and pesticide for the cultivation of crops. In a multi-tier platform [4], a cyber-physical system (CPS) collects the data from agricultural devices and forwards the data to edge devices in the middle tier.

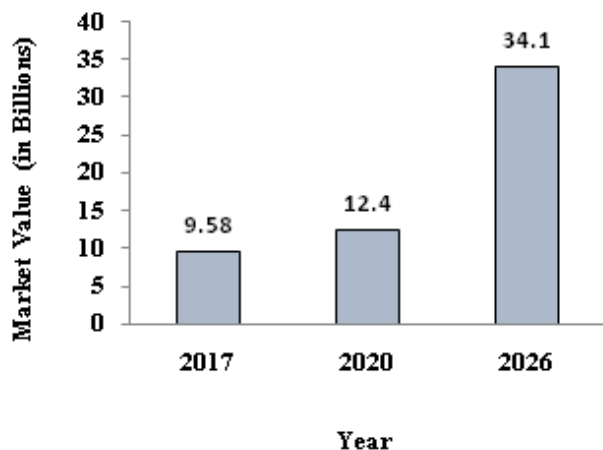


Figure 2: Global Market Size of Smart Farming

The top tier handles high computing and storage processing by cloud computing. In this intelligent green warehouse model [5], various key operations of smart farming namely planting, irrigation and fertilizer control, crop monitoring, and monetization are designed as an IoT-based e-business model. Farm Beats [6] is an AI and IoT-based model for smart farming which provides precision agriculture. In this system, various sensors, drones, and cameras are collecting data about crops, soil, humidity, and weather conditions. TV towers provide Internet access for long distances across the farmland as, Edge computing, cloud computing and machine learning aid precision agriculture techniques. Monetization is another big issue faced by the farmers in addition to crop cultivation. The extension of IoT based precision model in agriculture advocates crop price estimation and selling. Also, the agriculture model integrates the farmers with the end consumers without intermediate brokers. The proposed work is organized as follows Section 1 introduces the importance of emerging technologies in agriculture; Section 2 highlights the related research work; the proposed cloud-based agriculture framework is briefed in Section 3: the results are discussed in Section 4; the findings of the proposed work is concluded in Section 5; the future extension is mentioned in Section 6.

2. Related Works

This section highlights the various digital technologies in agriculture to increase the productivity of crops. Haseeb et al [7] designed an IoT-based Wireless Sensor Network (WSN) framework to automate smart farming. The various sensors like temperature sensor, humidity sensor, water sensor, heat sensor, and air sensor are collecting the data from farmland and forwarding it to cluster head node for taking decisions. Intelligent and secured data transmission between the sensor nodes and the base station is simulated with an NS2 simulator. The result shows significant performance such as 13.5% in the latency of throughput of network and 16% in the energy depletion. The exploitation of Information and Communication Technologies in agriculture helps to automate harvesting operations, mechanical weeding, irrigation, and pesticide control and also made easier communication among farmers and customers [8]. During the harvesting, crops are affected by insects and diseases due to uncertain climate changes. Spraying pesticides and fertilizers manually for larger farmland is tedious that needs more labor resources and cost. Unmanned aerial vehicles (UAVs) like drones are providing a feasible solution for spraying pesticides and fertilizers [9].

Yi-Chun Lin et al [10] developed a quality control framework for characterizing the crops in farmlands. The experimental results illustrate a significant improvement in the accuracy of multi-temporal data point clouds. Sharma R et al. [11] proposed an agricultural system based on Cyber-Physical System (CPS) for providing more yielding and efficient supply chain management. Various ICT technologies namely Cloud Computing, the Internet of Things, and Big data analytics are employed in the proposed agriculture system. Vitali et al [12] highlighted the utilization of IoT for smart farming. This survey

portrays the role of cloud computing to store heterogeneous data from farmland. Also, it explains the application of machine learning to process and analyze the data for better crop management. Manik Rakhra et al [13] designed an information system namely smart tillage which exploits meta-heuristic techniques for renting and sharing agricultural equipment.

P. K. R. Maddikunta et al [14] address energy wireless technology namely smart Bluetooth to control and operate unmanned aerial vehicles for smart farming. Spanaki et al [15] review the various disruptive technologies used in agriculture technology. Three application areas namely hardware, software, and machines like robotics. Anastasios et al [16] addressed the role of big data in agricultural intelligence. Also, various ICT tools to collect, store and analyze the data from farmlands. Symeonaki et al [17] designed a context-aware middleware framework for precision farming by incorporating cloud computing for processing the functionalities of sensor devices and IoT. Murugaiyan et al [18] demonstrated an IoT-based agriculture framework for sugar cane monitoring, pesticide and fertilizer control, and irrigation management. A five-layered precision agriculture model [19] is briefed in this research work. Layer 1 characterizes the physical level maneuvers, layer 2 frames safety rules, layer 3 deals with data-management systems, layer 4 suggest the appropriate irrigation models, and the final layer 5 provides the automation system for effective water management. In this decision support framework [20], a visual dashboard aids the farmer to monitor their crops and identify the disease by which crops are affected. A model [21] is designed to predict crop yield by analyzing the satellite data, temporal data, and environment data. In addition to Big data analysis, three machine learning algorithms namely linear regression, decision tree, and random forest are also employed to estimate the yield of wheat.

This review paper [22] highlights the importance of data-driven agriculture 5.0 for decision making and also, analyses the role of IoT, Big data and AI, and robotics in smart farming. This IoT-based system [23] employed various sensors like temperature sensors, soil moisture sensors, and humidity sensors for monitoring plant growth in various stages. A socio-cyber-physical system [24] is described to digitalize the diary system. This IoT-based fuzzy controller system [25] advocates smart irrigation that saves water and power resources and the experimental results show better performance than the drip and flooding system. In the proposed model [26], a low-power Wireless Sensor Network protocol is employed to implement low-cost precision agriculture applications. In this Internet of Everything (IoE) framework [27], data collected from sensors are stored in the cloud in which data mining techniques are applied for decision making. A ubiquitous technology-based intelligent framework [28] is implemented to increase yield, and reduce production cost. Soft computing-based frameworks namely neural network-based framework [29], fuzzy logic-based framework [30], and neuro-fuzzy hybrid framework [31] for augmenting the resources of mobile devices are discussed.

3. The Proposed Agro-Cloud Framework

The proposed three-layer architecture consists of three layers namely i) Input layer ii) Storage & Processing layer and iii) Application layer as shown in Figure 3. In the first input layer1, various agricultural sensors namely soil sensor, temperature sensor, location sensor, moisture sensor, and airflow sensor are collecting the data of crops in the farmland and forward the data to layer 2. The storage and processing layer exploits various information and communication technologies namely cloud computing, edge computing, big data analytics, mobile computing, Internet of Things, and Blockchain technologies to store and process the data received from the input layer1. Soft computing technologies namely neural networks, fuzzy logic, genetic algorithm, Machine learning, and deep learning advocate efficient crop cultivation based on the soil type, irrigation method, fertilizer & pesticide required for the crop, and post-harvesting support. This data analysis part of the proposed agro-cloud framework plays a vital role in cultivating high-quality and quantity crops based on multiple parameters like the soil type and weather conditions. After analysis of the crop data, results are formulated as various applications like web interfaces, and mobile apps in the application layer. Layer 3 provides an agriculture advisory system to the farmers regarding the state and central government schemes for cultivating crops, insurance for crops, crop monetization, and agro marketing.

3.1. Input Layer

In precision agriculture, several sensors namely moisture sensor, light sensor, temperature sensor, location sensor, pH sensor, airflow sensor, and mechanical sensors are used to measure numerous parameters of the crop, soil, and weather conditions. The various sensors which are used in smart farming are depicted in Table 1.

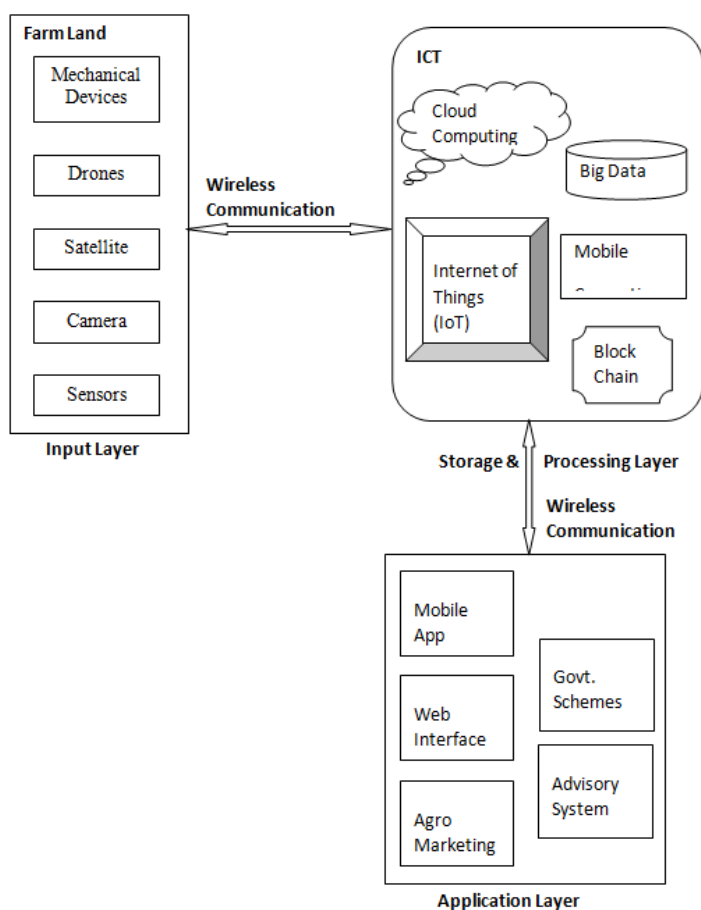


Figure 3: Intelligent Agro-Cloud Framework for Smart Farming

Table 1: Types of sensors in smart farming

Type of Sensors	Parameters Measured
Location sensor	Spatial data such as latitude, longitude, and altitude
Airflow sensor	Calculate absorptive of soil
Electrochemical sensor	Soil specifications such as nutrient level, pH value
Mechanical sensor	Compaction or resistance of soil
Dielectric Soil Moisture Sensor	To measure moisture levels
Optimal sensor	Water scarcity, Nitrogen deficiency, weed, and disease [16], to measure clay, &the organic content of the soil

The vast numbers of sensors are equipped with weather stations that detect climate changes namely flooding, drought, rainfall; humidity, wind direction, atmospheric pressure, and solar radiation. A camera monitors the growth of crops by measuring the chlorophyll, brightness, Leaf Area Index (LAI), and ripeness level. Satellite advocates wireless communication between any two layers and also to locate cropland, identification of diseases, and insects. Agricultural drones or unmanned aerial vehicles (UAVs) are six times more efficient than human labor. Agricultural drones aid the crop cultivation activities such as seeding, planting, crop monitoring, spraying of fertilizer, and pesticide. Moreover, mechanical devices like robots can also perform smart farming tasks namely seeding, planting, spraying, monitoring, and other post-harvesting activities for larger farmlands. Precision agriculture adopts various wireless communication technologies like Bluetooth, Wi-Fi, and cellular networks among the different layers as shown in Table 2.

Table 2: Communication technologies

Wireless Technologies	IEEE Standard	Data Rate (Kbps)	Range (Meters)	Network Topology	Energy Consumption	Cost

Bluetooth	802.15	1-3	100	Star	Medium	Low
WiFi	802.11	250	100	Star, Tree	High	High
WiMax	802.16	250	15	Star, Tree	Medium	High
LoWPAN	802.15.4	250	50	Star, Mesh	Very Low	Low
ZigBee	802.15.4	250 - 500	100	Star, Mesh	Low	Low
GPRS/3G/4G	802.21	12Kbps / 5Mbps / 12Mbps	Cellular based	Mobile-radio	Medium	Medium
5G	802.21	1 Gbps	Cellular based	Mobile-radio	Medium	Medium

3.2. Storage & Processing Layer

After receiving the input from layer1, the storage and processing layer performs the essential decision-making activities like selection of irrigation method, fertilizer, and pesticide based on the collected data. Irrigation is not required in all the scenarios like low temperatures, or rainy sessions. A neural network with 3 layers namely the input layer, hidden layer, and output layer is devised to decide whether to do irrigation or not as portrayed in Figure 4.

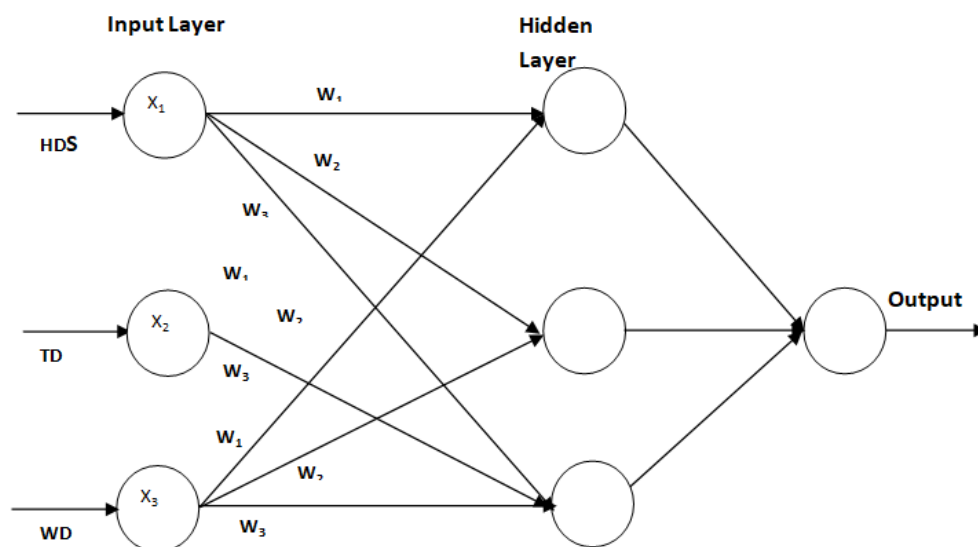


Figure 4: Multi-layer feed-forward neural network for deciding irrigation mode

Neurons in the input layer 1 gather data from humidity sensor (HD), temperature sensor (TD), and water level sensor (WD) to check the availability of the water level. The y_{in} is the net input that is determined by applying an adder function as presented in Equation 1.

$$y_{in} = x_1w_1 + x_2w_2 + x_3w_3 \quad [1]$$

Where x_i indicates the sensor data, and w_i represents their corresponding weights. An activation function is utilized to obtain the Y value which advocates the selection of irrigation mode.

$$Y = \begin{cases} \geq 0.5 & \text{irrigation} \\ < 0.5 & \text{no irrigation} \end{cases} \quad [2]$$

Soil monitoring analyses the humidity, soil type, nutrient level, moisture level, soil PH value, and weather condition. Crop growth is to monitor & control the crop cultivated land to get a better yield from the farmer's land.

Irrigation management cares the effective and reduced water utilization. Water holding capacity is high in clay soil when compared with sandy soil. The quality of irrigation water is measured in terms of its soluble salt content, and quantity. Water requirement for irrigation depends on the type of crops and irrigation methods such as sprinkler, drip, surge, and flood irrigation. The utilization of fertilizer is playing a vital role in the production of crops. But the excessive usage of chemical fertilizer reduces soil fertility over a longer period. The proposed system predicts the required quantities of fertilizers and pesticides thereby reducing the exploitation of surplus chemicals. Organic farming protects the fertility of the soil and eliminates the health hazards of chemicals like fertilizer, pesticides, and additives. Moreover, bio-fertilizers provide a pollution-free agro-eco system.

Fertilizer is a synthetic or natural material that is applied to the soil to provide crop nutrients. Fertilizer is mandatory for HYV seeds (High Yielding Variety) than the traditional seeds. There are three main plant nutrients namely nitrogen, phosphorus, and potassium (NPK) that can be applied individually or in a mixture. However, excessive usage of fertilizer reduces soil fertility and pollutes water. The proposed work recommends a genetic algorithm to deduct the required quantity of fertilizer for a specific crop. Genetic Algorithm to find the feasible amount of fertilizer is depicted below:

- Step 1:** Generate a random-sized initial population.
- Step 2:** Evaluate the existing solutions and allocate fitness value.
- Step 3:** Fetch the good solutions with fitness value.
- Step 4:** If a good solution is acknowledged in the current generations then terminate.
- Step 5:** Update the population by employing a crossover and mutation process for the formation of a different solution.
- Step 6:** Go to step 2.

Fertilizer recommendation is represented as NPK and calculating Required Fertilizer (RF) is indicated in Equation 3.

$$RF = \frac{(RR * 100)}{\% \text{ Nutrient of RF}} \quad [3]$$

Whereas, RR is the Recommended Rate. Consider x_1, x_2 and x_3 are the recommended rate of NPK and w_1, w_2 and w_3 are the corresponding weights of the fertilizers. The required amount of fertilizers (in kilograms) for Urea, Superphosphate, and Potash are shown in Equations. 4, 5 and 6.

$$Urea = \frac{(x_1 * 100)}{w_1} \quad [4]$$

$$SuperPhosphate = \frac{(x_2 * 100)}{w_2} \quad [5]$$

$$Potash = \frac{(x_3 * 100)}{w_3} \quad [6]$$

Liquid fertilizers can be easily applied to irrigation water compared with solid fertilizers. However, the application of organic manures is essential to prevent pollution and soil infertility. Also, proper scheduling of fertilizer increases the crop yield.

3.3. Application Layer

The application layer connects the proposed framework with farmers by sending SMS alerts. Anyone can access the devised system through their mobile devices. For example, fertilizer intimation in the proposed web application is illustrated in Figure 5.

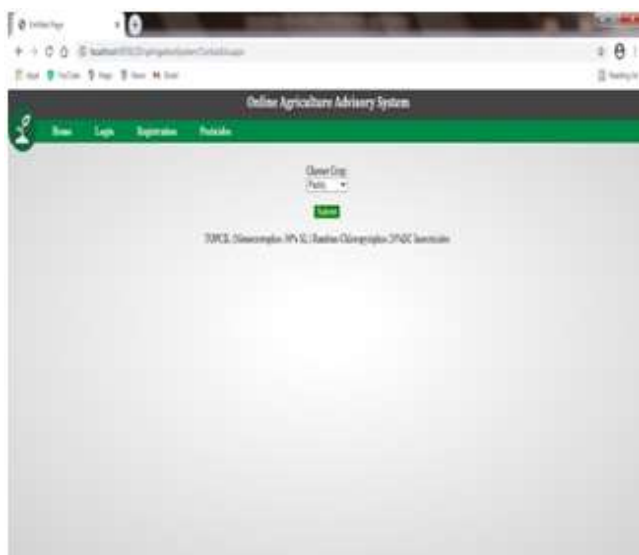


Figure 5: Pesticide Suggestion

The devised application consists of three main modules namely farmer registration, crop monitoring, and agro services. After the registration, farmers can get various automation services like irrigation, fertilizer, pesticide, supporting schemes from the Government, crop insurance, and information about crop rotation during a regular interval of time.

4. Results and Discussions

The proposed work exploits the smart irrigation dataset from Kaggle [32] for the investigation. Three machine learning classification algorithms, namely, J48, Random Forest, and Random Tree are employed in this experimental analysis. The accuracy of the classifiers generated by the Weka 3.8.6 tool is depicted in Table 3. The accuracy is the percentage of the right number of predictions on the unseen data.

Table 3: Accuracy of classifiers

Machine Learning Algorithm	Accuracy
J48	93.5
Random Forest	91
Random Tree	89

The results show that the accuracy of the J48 classifier (93.5%) is higher than the Random Forest (91%) and Random Tree (89%) classifiers as portrayed in Figure 6.

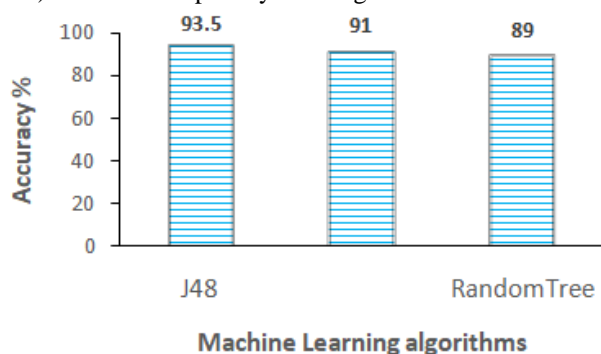


Figure 6: Accuracy of ML algorithms

The performance metrics of these machine learning algorithms such as True Positive (TP) Rate, False Positive (FP) Rate, Precision, and Recall is represented in Table 4, 5, and 6. Precision represents the accuracy of the model to predict a particular category. The recall is the capacity of the model to identify a specific category for example switching on/off of the motor.

Table 4: Performance metrics of the J48 algorithm

Motor Status	TP Rate	FP Rate	Precision	Recall
On	0.96	0.14	0.954	0.96
Off	0.86	0.04	0.878	0.86

Table 5: Performance metrics of Random Forest algorithm

Motor Status	TP Rate	FP Rate	Precision	Recall
On	0.933	0.16	0.946	0.933
Off	0.84	0.067	0.808	0.84

Table 6: Performance metrics of Random Tree algorithm

Motor Status	TP Rate	FP Rate	Precision	Recall
On	0.927	0.22	0.927	0.927
Off	0.78	0.073	0.78	0.78

In all the three machine learning algorithms, the performance metrics namely TP rate, FP rate, precision, and recall of J48 are higher than the Random Forest and Random Tree algorithms as illustrated in Figures 7, 8 and 9.

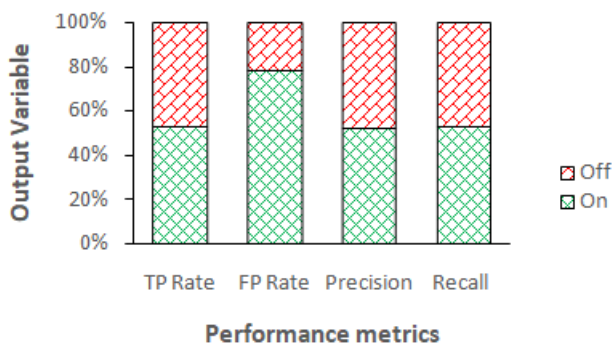


Figure 7: Performance metrics of the J48 algorithm

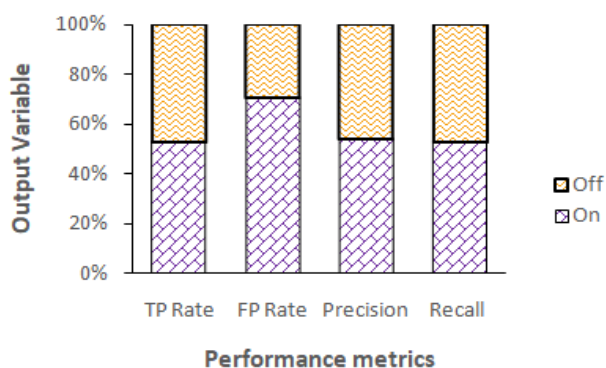


Figure 8: Performance metrics of Random Forest algorithm

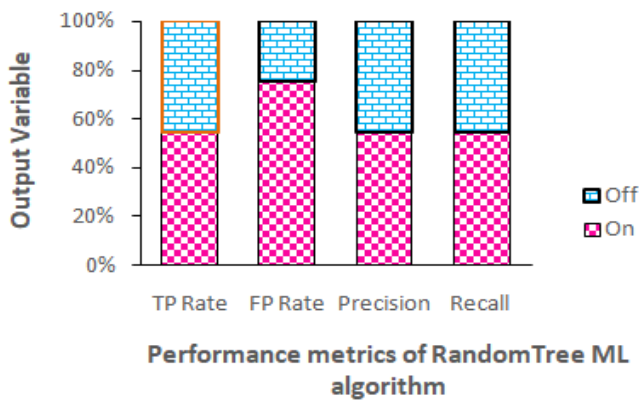


Figure 9: Performance metrics of Random Tree algorithm

5. Conclusion and Future Enhancements

Thus, the recommended agro-cloud framework exploits three technologies namely IoT, Cloud computing, and soft computing. A wide range of IoT devices like sensors, cameras, weeding robots, and drones can be utilized in the cultivation of crops. Agro-cloud is performing the storage and processing operations against the data received from IoT devices. Soft computing technologies are applied to analyze big data to offer various farming services regularly. The proposed three-layer Agro-cloud framework helps the farmers with the effective use of resources namely water, fertilizer, and pesticide to enhance the productivity, quality, and yield of the crops. A multi-layer feed-forward neural network is utilized for smart irrigation which uses the various ecological parameters like temperature, humidity, rainfall, soil type, and crop type. The devised research work significantly reduces the amount of water, fertilizer, and pesticide. Satellite and robotic drones can be used to collect geospatial data to analyze the images of the individual plants and parts of the plants in the cropland more precisely. The proposed research can be extended to precision agriculture by analyzing the continuous and real-time of unmanned aerial vehicles (UAVs).

References

- [1] Smart Farming: The Future of Agriculture, Available at <https://www.iotforall.com/smart-farming-future-of-agriculture>, accessed on 20th February 2022.
- [2] Smart Farming in 2020: <https://www.businessinsider.com/smart-farming-iot-agriculture>, accessed on 24th March 2022.
- [3] Forecast market value of smart agriculture worldwide, <https://www.statista.com/statistics/720062/market-value-smart-agriculture-worldwide/>, accessed on 25th April 2022.
- [4] Miguel A. Zamora-Izquierdo, José Santa, Juan A. Martínez, Vicente Martínez, Antonio F. Skarmeta, Smart farming IoT platform based on edge and cloud computing, *Biosystems Engineering*, Vol 177, 2019, Pages 4-17, ISSN 1537-5110, <https://doi.org/10.1016/j.biosystemseng.2018.10.014>.
- [5] Ruan, J., Hu, X., Huo, X. et al. An IoT-based E-business model of intelligent vegetable greenhouses and its key operations management issues. *Neural Computing & Applications*, 32, 15341–15356, 2020, <https://doi.org/10.1007/s00521-019-04123-x>
- [6] FarmBeats: Improving Farm Productivity Using Data-Driven Agriculture: <https://www.microsoft.com/en-us/research/publication/farmbeats-improving-farm-productivity-using-data-driven-agriculture/> accessed on 24th February 2021.
- [7] Haseeb K, Ud Din I, Almogren A, Islam N, An Energy Efficient and Secure IoT-Based WSN Framework: An Application to Smart Agriculture. *Sensors*, 2020; 20(7), <https://doi.org/10.3390/s20072081>.
- [8] Walter, A., Finger, R., Huber, R., & Buchmann, N. Opinion: Smart farming is key to developing sustainable agriculture. *Proceedings of the National Academy of Sciences*, 114(24), 6148–6150. 2017, doi:10.1073/pnas.1707462114.
- [9] UM Rao Mogili, B V L Deepak, Review on Application of Drone Systems in Precision Agriculture, *Procedia Computer Science*, Vol 133, 2018, Pages 502-509, ISSN1877-0509, <https://doi.org/10.1016/j.procs.2018.07.063>.
- [10] Yi-Chun Lin, Ayman Habib, Quality control and crop characterization framework for multi-temporal UAV LiDAR data over mechanized agricultural fields, *Remote Sensing of Environment*, Volume 256, 2021, 112299, ISSN 0034-4257, <https://doi.org/10.1016/j.rse.2021.112299>.
- [11] Sharma R., Parhi S., Shishodia A. (2021) Industry 4.0 Applications in Agriculture: Cyber-Physical Agricultural Systems (CPASs). In: Kalamkar V., Monkova K. (eds) *Advances in Mechanical Engineering*. Springer, Singapore. https://doi.org/10.1007/978-981-15-3639-7_97.
- [12] Vitali, G.; Francia, M.; Golfarelli, M.; Canavari, M. Crop Management with the IoT: An Interdisciplinary Survey. *Agronomy* 2021, 11, 181. <https://doi.org/10.3390/agronomy11010181>.

- [13] Manik Rakhra, Ramandeep Singh, Tarun Kumar Lohani, Mohammad Shabaz, Metaheuristic and Machine Learning-Based Smart Engine for Renting and Sharing of Agriculture Equipment, *Mathematical Problems in Engineering*, vol. 2021, Article 5561065, <https://doi.org/10.1155/2021/5561065>.
- [14] P. K. R. Maddikunta et al., Unmanned Aerial Vehicles in Smart Agriculture: Applications, Requirements, and Challenges, in *IEEE Sensors Journal*, doi: 10.1109/JSEN.2021.3049471.
- [15] Spanaki, K., Sivarajah, U., Fakhimi, M. et al. Disruptive technologies in agricultural operations: a systematic review of AI-driven AgriTech research. *Ann Oper Res*, 2021. <https://doi.org/10.1007/s10479-020-03922-z>.
- [16] Anastasios Lytos, Thomas Lagkas, Panagiotis Sarigiannidis, Michalis Zervakis, George Livanos, Towards smart farming: Systems, frameworks and exploitation of multiple sources, *Computer Networks*, Volume 172,2020, 107147, <https://doi.org/10.1016/j.comnet.2020.107147>.
- [17] Symeonaki, E.; Arvanitis, K.; Piromalis, D, A Context-Aware Middleware Cloud Approach for Integrating Precision Farming Facilities into the IoT toward Agriculture 4.0. *Appl. Sci.* 2020, 10, 813. <https://doi.org/10.3390/app10030813>.
- [18] Murugaiyan Pachayappan, C Ganeshkumar, Narayanasamy Sugundan, Technological implication and its impact in the agricultural sector: An IoT Based Collaboration framework, *Procedia Computer Science*, Volume 171, 2020, Pages 1166-1173, ISSN 1877-0509,<https://doi.org/10.1016/j.procs.2020.04.125>.
- [19] Malek, M., Dhiraj, B., Upadhyaya, D., Patel, D. (2022). A Review of Precision Agriculture Methodologies, Challenges, and Applications. In: Singh, P.K., Kolekar, M.H., Tanwar, S., Wierchoń, S.T., Bhatnagar, R.K. (eds) *Emerging Technologies for Computing, Communication and Smart Cities*. vol 875. Springer,Singapore.https://doi.org/10.1007/978-981-19-0284-0_25.
- [20] Javed, Z., Mumtaz, I., Zia, M.A., Nawaz, Q. (2022). AgroInfo DSF: A Smart Decision Support Framework for Precision Agriculture and Farming. In: Xu, J., Altiparmak, F., Hassan, M.H.A., García Márquez, F.P., Hajiyev, A. (eds), *Lecture Notes on Data Engineering and Communications Technologies*, vol 144. Springer,Cham.https://doi.org/10.1007/978-3-031-10388-9_7.
- [21] Mukesh Singh Boori, Komal Choudhary, Rustam Paringer, Alexander Kupriyanov,
 a. Machine learning for yield prediction in Fergana valley, Central Asia,*Journal of the Saudi Society of Agricultural Sciences*,
 b. 2022,ISSN1658-077X,<https://doi.org/10.1016/j.jssas.2022.07.006>.
- [22] Saiz-Rubio V, Rovira-Más F. From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. *Agronomy*. 2020; 10(2):207. <https://doi.org/10.3390/agronomy10020207>.
- [23] V. Grimblatt, G. Ferré, F. Rivet, C. Jégo and N. Vergara, Precision Agriculture for Small to Medium Size Farmers — An IoT Approach, 2019 IEEE International Symposium on Circuits and Systems (ISCAS), 2019, pp. 1-5, doi: 10.1109/ISCAS.2019.8702563.
- [24] Kelly Rijswijk, Laurens Klerkx, Manlio Bacco, Fabio Bartolini, Ellen Bulten, Lies Debruyne, Joost Dessen, Ivano Scotti, Gianluca Brunori, Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsabilization, *Journal of Rural Studies*, Volume 85,2021, Pages 79-90,ISSN0743-0167,<https://doi.org/10.1016/j.jrurstud.2021.05.003>.
- [25] R. Santhana Krishnan, E. Golden Julie, Y. Harold Robinson, S. Raja, Raghvendra Kumar, Pham Huy Thong, Le Hoang Son, Fuzzy Logic based Smart Irrigation System using Internet of Things, *Journal of Cleaner Production*, Volume 252, 2020, 119902,ISSN0959-6526,<https://doi.org/10.1016/j.jclepro.2019.119902>.
- [26] Placidi, Pisana, Renato Morbidelli, Diego Fortunati, Nicola Papini, Francesco Gobbi, and Andrea Scorzoni. 2021. "Monitoring Soil and Ambient Parameters in the IoT Precision Agriculture Scenario: An Original Modeling Approach Dedicated to Low-Cost Soil Water Content Sensors" *Sensors* 21, no. 15: 5110. <https://doi.org/10.3390/s21155110>.
- [27] Suresh Kumar, K., Balakrishnan, S. & Janet, J. A cloud-based prototype for the monitoring and predicting of data in precision agriculture based on internet of everything. *J Ambient Intelligent Human Computing* 12, 8719–8730 (2021). <https://doi.org/10.1007/s12652-020-02632-5>
- [28] T A Cahyanto and S Wahjuni and H Sukoco and H Rahmawan and S N Neyman, Intelligent ubiquitous technology as a precision agri-food framework: a proposed framework, *Conference Series: Earth and Environmental Science*, 012022, Vol: 1041, issue no: 1, 2022, doi: 10.1088/1755-1315/1041/1/012022.
- [29] Anitha. S., & Padma, T, Adaptive proximate computing framework for mobile resource augmentation, *Mobile Networks & Applications*, Springer, Print ISSN: 1383-469X, E-ISSN: 1572-8153, DOI: 10.1007/s11036-019-01278-8, June 2019.
- [30] Anitha S., & Padma, T, A web service-based IoT framework for mobile resource augmentation, *International Journal of Communication Systems*, e4475. <https://doi.org/10.1002/dac.4475>, 2020.
- [31] Anitha, S., & Padma, T., A Neuro-Fuzzy Hybrid Framework for Augmenting Resources of Mobile Device, *International Journal of Information Technology & Decision Making*, 20 (05), 1519-1555. doi: 10.1142/S0219622021500413, 2021.
- [32] Intelligent Irrigation System Dataset: <https://www.kaggle.com/datasets/harshilpatel355/autoirrigationdata> accessed on April 24th 2022.