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AIoTST-CR : AIoT Based Soil Testing and Crop Recommendation to Improve Yield

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ABSTRACT

Agriculture is a backbone of any country. Farmers need to test the soil fertility and nutrients present in the soil for proper growth of the crops. In traditional system, the farmers collect soil sample and submit to soil testing labs for testing the soil nutrients and get the soil test reports manually. Farmers based on his experience and the season; decide which crop to be taken in the farm. Based on soil testing reports farmers decide which fertilizers required for the proper growth of the crop. This process is time consuming and human efforts are required and hence crop yield is affected. The recent technologies in cloud storage, wireless sensors, and AI based algorithms are very instrumental in decision making process of crop growth life cycle. Farmers can make use of mechanical automation tools for seeding, watering, supplying fertilizers, crop cutting etc. for proper growth of the crop. However, to observe the crop growth during the entire life cycle of crop farmer has to take lot of efforts to check need of water, any problem of disease to the crop, any specific fertilizers required or not and whether there is a need of harvesting. A proper decision support system is needed for helping the farmers in all such activities. Such support can be provided to a farmer so that he will be well updated about the growth of his crop in the farm. To reduce the human efforts and improve the crop yield, Artificial Intelligence and IOT based soil testing and Crop Recommendation system (AIoTST-CR) is designed and developed. AIoT based handheld soil testing system has pH, Nitrogen, Phosphorous, Potassium and Soil moisture sensing capability. A mobile application is developed to fetch the sensed data from AIoT system. A historical data is inputted to give training to ML models. Machine learning algorithm is used to predict and recommend the crop to be taken. The results show AIoTST-CR which is AIoT based soil testing and crop recommendation system provides effortless and accurate recommendations of crop. Our findings indicate that AIoT based system provides high accuracy, which outperforms existing commonly, used machine learning based crop recommendation systems.

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1. INTRODUCTION

India is agricultural based country. Most of the Indians the primary source of income is depending on agriculture or its byproducts. This is having impact on food security and economic growth of India. The crop yield and its prediction is very important from National and International economies point of view as it is playing very important role in managing the food for all over the world. Therefore, the farmers are most important stake holder in agricultural economy. The farmers should be assisted with smart technologies to improve the overall crop productivity and in turn its yield. The ML based systems are useful for helping the farmers to predict the crop productivity. Farmers can do self-assessment by using such technology based solutions which shows farmers current state in terms of productivity and yield. Once farmers assess themselves for the productivity and yield, they can decide to take actions to improve the crop yield by enhancing quality of soil. In traditional system, the farmers collect soil sample from his farm and submit to soil testing laboratories for soil fertility testing. In the laboratories manual testing is done and soil health cards are issued to farmers in which detailed soil test reports are printed with Normal Range of each parameter. This process is time consuming and farmers' manual efforts are required. A novel AIoTST-CR handheld device is developed which can be used to classify the soil and recommend the crop. With the help of Artificial Intelligence and IOT (AIoT) based Soil Testing (ST) and Crop Recommedation (CR) system can effortlessly test soil nutrient contents and recommend the crop to be cultivated suitable to the soil. Soil moisture content is very important which affects the crop yield. It has direct impact on efficient photosynthesis, respiration, transpiration and transportation of micro nutrients and minerals from soil to crop. The content of moisture in soil is less then the crops can absorb water in soil and the soluble micronutrients are also absorbed by crop along with water. The soil testing efforts are more and it is its own disadvantages such as its time consuming and costly. Farmers do not want to involve themselves in costly and time consuming process of soil testing. In section II AIoT concept is explained. In section III, a detailed survey of research papers on AI & ML and IOT systems for agriculture and its results are explained. The section IV explains detailed methodology for the system under design. Section IV also contains the hardware design and system architecture. A detailed explanation of proposed design of mobile application is explained. This section also briefs about the machine learning systems used and developed for prediction of the crop and its crop yield. Section V describes detailed results and a discussion done on the results.

2. AIoT and AIoTST-CR : CONCEPT

The Artificial Intelligence of Things (AIoT) is the combination of Artificial intelligence (AI) technologies with the Internet of things (IoT) infrastructure to achieve more efficient IoT operations, improve human-machine interactions and enhance data management and analytics. There is rapid evolution in the field of AI, IoT sensors, and Wireless Communication infrastructures.

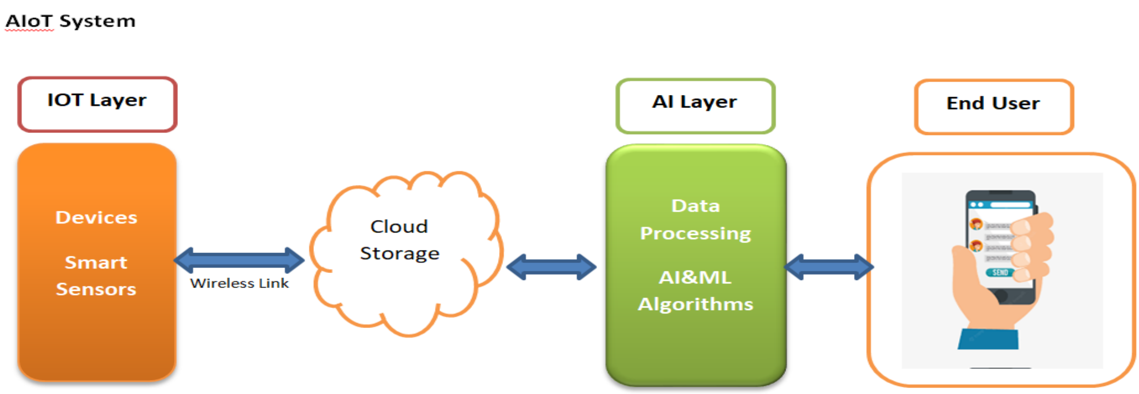


Figure 1 AIoT Model and Concept

IoT sensors are widely used to sense the data and using data acquisition system, sensed data is stored in cloud based data storage infrastructures. The AI systems are used to process the stored data by applying machine learning systems to extract the hidden patterns or information in the data which can be used to take decision. Hence the integration of IoT and AI is termed as Artificial Intelligence of Things (AIoT). The AIoT model and concept is depicted in Figure 1 above. This field is still in development stage and many researchers are putting their efforts for developing new algorithms and applications in AIoT field.
The AIoTST-CR is Artifitial Intelligence and IOT (AIoT) based Soil Testing(ST) and Crop Recommendation (CR) system. This system uses the AIoT model to test the soil and fetch the soil parameters in the mobile application. The AI algorithms are applied and crop is recommended based on the historical dataset available.

3. LITERATURE REVIEW

In research work done by Fariha Shahrin et. al. [1, 8] presented a hybrid mix of agricultural imaging and crop growth monitoring to predict the crop yield. Experiments are done in Habibganj district. Landsat-8 Multi-spectral band images are processed. Also remote sensing indices are used which correlates crop growth and crop yield. Using the K-means algorithm and Mask R-CNN algorithm, the changeover duration is calculated for assessment of growth of the crop. The paper is only based on soft computing methods. In the paper [2], researchers developed IoT based efficient models for finding the soil parameters and contents of atmospheric parameters for better crop growth. The system which is developed monitors temperature and humidity which are environmental parameters and soil moisture content by using NodeMCU and other sensors connected to it. A text message in the form of SMS is sent to farmer's registered contact number using Wi-Fi which includes various values of environmental parameters of farm. However, information is sent through only SMS. The work described in [3, 4] the researchers have developed a framework which checks Soil Nutrition based on IoT. In the work Plant Disease detection system is also developd. It uses different sensors for collection of the values which are related to plant. The values are in terms of images at different time intervals. This data is stored on mTHINGS portal. But in this research mobile application is not user friendly and local languages are not used. In [5, 7, 9] the work carried out by using various AI based algorithms such as decision tree based classification, gradient boost machine learning algorithm, random forest classification, adaptive boosting algorithm, and neural network for the prediction of overall gain for the crop such as corn dataset. The prediction is fully on soft computing based. A detailed survey is done in research paper [6, 10] and the major goal of the research work carried out in this paper is illustrating the detailed survey on research undertaken and completed on Smart technology based agriculture and identifying the important applications for farming using IoT and Artificial Intelligence. In research paper[12], a crop recommendation system is designed and developed which is very user friendly. If users input their location of farm then the crop recommendation system can fetch the related required information such as percentage of rain, type of soil based on the inputted location. The system recommends the suitable crop for the location. In the research work [13] it is shown that by using recent technologies such as IoT, WSN, machine learning techniques in agriculture the efforts of farmers are reduced. The paper proposed the prediction model for detecting the disease of Apple in the apple farms in Kashmir. It has used data analytics, Machine learning and IoT system for development. In the paper it is described that a survey was conducted to check that the farmers are having the knowledge about the trending technologies and its usage in precision agriculture. The paper shows that there is lot of challenges faced while implementing such technologies in our traditional farming methods. The research paper [14] throws a light on the recent technologies and trends which are developed for smart agriculture. The paper also describes the existing applications, and discusses the problems in existing applications. It also describes how these problems can be solved and it is implemented in the farming for better output.

The research paper [15] the author has made a survey for farming methods incorporated by farmers now a days and what are the challenges they are facing. He visited many farms and green poly houses for acquiring detailed about new trends and technologies in modern farming. A model is proposed which includes IoT systems having sensors to collect various values and send it over the cloud storage. The server can take actions based on the values fetched by sensors. In paper [16], a smart agriculture model is designed and deployed to bring it to notice the farmers the crop to grow as per the farm and soil conditions. The study is focused on the farming pattern in Telangana state. A Naïve Bayes classifier is used for recommendation of the crop to the farmers. It also recommends in general the crops and the environment condition required to proper growth of the crop. In the research work [17] the query based approach is used for environment sensors and soil sensors. The sensor data is fetched and indexing is done for the data. A Java program is written to fetch the sensor data and machine learning systems are used to build a model called SensorML which is a query tool called GeosensorQuery. In review paper [18], the researchers have done a detailed survey on wireless Sensors used in farming which is used to enhance the farmers' yield. The authors have shown that due to the huge advancements in technologies and development in farming, the objective of improving the farmers' overall yield will be achieved in coming years. Smart Agriculture is an emerging trend in which there will be lot of usage of sensor-based technologies which will perform a primary role. In the survey paper [19] the author made a survey on various applications developed on Big Data in precision agriculture. In the paper the author tried to make familiar with the various social and financial problems the farmers are facing due to low farming yield. To improve the yield, how the technology, devices, software tools and data analytics can be used, is illustrated in the article. In the research work [20], the developers designed a model which uses Machine Learning algorithms to recommend the proper crop suitable to the temperature. This model also warns that the crops which should not be taken due to threat of less yield. In work carried out in [21, 22, 23] developed a model based on IoT and ML which can be used for soil testing using the wireless sensors. Using ML algorithms it recommends the crop. This approach can be used to increase the health of soil due to appropriate usage of chemicals in the form of fertilizers. In review research paper [24], a detailed survey of literature based on AIoT techniques is highlighted. The concept of AIoT, the various smart wireless sensor based IoT devices and AI based algorithmic techniques accepted for development of AIoT systems are briefed. At the end, the author has briefed the various issues and challenges for accepting AIoT for precision farming. In research work [25], a detailed discussion is made on Agriculture 4.0. Smart agriculture, various important techniques and domains for the discovering Agriculture 4.0 are conferred in detail. Lastly the important applications of Agriculture 4.0 techniques are discussed in detail. The use of Agriculture 4.0 techniques are very much essential for the better life of farmers as it reduces lot of efforts during the growth of a crop in actual field. In the study paper [26], machine learning techniques are developed for prediction of crop yields for the crops such as Rice, Potatoes, Wheat and Maize which are the most important and common crops in Indian farming. The crop yield is predicted for the specific field based on location. The fertilizers and the quantity can be applied looking to parameters of soil and growth of crop. ML models are used to train and test the datasets and crops are predicted for the current inputted test data. In the research work and survey paper [27] compares AI based farming methods and the need for such farming are elaborated in context with U.S. and South Korean farming. The paper makes comparison between the agricultural resources and the overall yield of these two countries. The paper also emphasizes on technological and community based challenges which can directly or indirectly impact agricultural yield. This can form a very good motivation for developing and deploying precision agricultural solutions. The paper [28] elaborates the overview of recent theory and applications of IoT, Intelligent systems, cloud storage, machine learning techniques, social networks, and robotics and automation techniques. In the work [29] a detailed study, of LoRaWAN which is intelligent irrigation system based on sensors for tomato farming in polyhouse. The work done in papers [30, 31, and 32] is to make detailed review of different applications in smart agriculture. The important work done using various technologies such as IoT, AI, Machine learning, image processing, sensor technologies, ANN, robotics are briefed in the paper. In research article [33], a detailed review is done on how agricultural can be treated as industry and after applying all the methods of industry to agriculture what will be the production and overall gain. Also the different technologies to make industrial agriculture such as IoT, AI, Machine Learning, data analytics, blockchain technology are used are briefed. The paper [34] describes a detailed survey of the recent trends and technologies in the area of precision agriculture based on IoT. The document cited at [35] is a survey paper. The author has done a detailed survey on the agricultural applications, datasets available online, wireless sensors and the various issues in smart farming. In research work [36] researchers came to conclusion that Precision farming will help to use correct proportion of Nitrogen, Phosphorous and potassium using wireless sensors for soil test and machine learning systems. It will also instrumental in reducing the degradation of soil due to extra usage of chemical fertilizers. In research work [37], the special algorithm is developed and is used for analyzing complex images. The algorithm is used to apply for soil image analysis. Also the soil contents are also assessed using IoT based wireless sensors. In the research paper [38], the Support Vector Machine and Naive Bayes algorithms have played role in soil based crop recommendation. The researcher has developed methods in combination AdaBoost and Support vector machine and AdaBoost and Naive Bayes and concluded that the accuracy is more, when a combination of methods are used than single method. In research work [39], the author has predicted yield for wheat crop using data of physicochemical soil parameters which is fetched from spectroscopy sensors. The images from satellite are used in combination with this data. The unsupervised learning techniques are used to predict crop yield.

4. METHODOLOGY

The key aim of this research work is to design electronic hardware and develop a soil testing kit. The soil sensors such as NPK, moisture, temperature and pH are used in hardware design and the Node MCU is used for controlling the sensors.

The soil sensors will sense the above soil parameters and using wifi module on Node MCU all the data is stored on cloud storage. Firebase cloud is used to store the soil sensor data. The data which is stored on Fiberbase cloud is fetched in mobile application to see the contents of soil in the form of report. The Screenshot 1 is of mobile application in which it shows the soil parameters from FiberBase cloud are fetched and displayed. The detailed block diagram for AIoT based Soil Testing and Crop Recommendation i.e. AIoTST-CR is shown in Figure 2.

A soil parameter dataset [11] is downloaded from Kaggle site for predicting the best crop for the soil parameters sensed with the testing kit. The dataset contains Nitrogen, Phosphorous, Potassium, Temperature, Humidity, pH, rainfall and the suitable crop. The dataset contains total 2200 records. A supervised machine learning algorithms are used to train the system and test the models. A novel ensembling method is used to build a model that combines the predictions of multiple machine learning models together to recommend the right crop based on the soil specific type and characteristics with high accuracy. The independent base learners used in the ensemble model are Random Forest, Naive Bayes, and Linear SVM. Each classifier provides its own set of class labels with an acceptable accuracy. The class labels of individual base learners are combined using the majority voting technique.The accuracy of the various models is calculated and tested and then Ensembling is done for the individual classifier output using Majority Voting Technique. In the Figure 3 detailed system architecture is shown for the machine learning based model development and predicting the crop by using trained model.

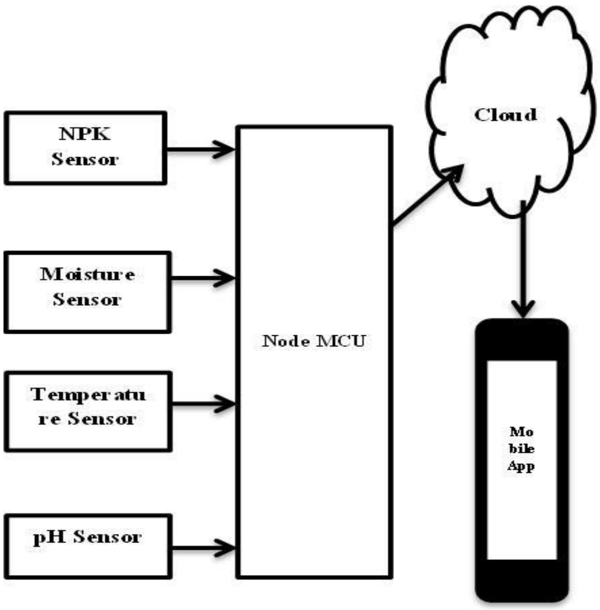
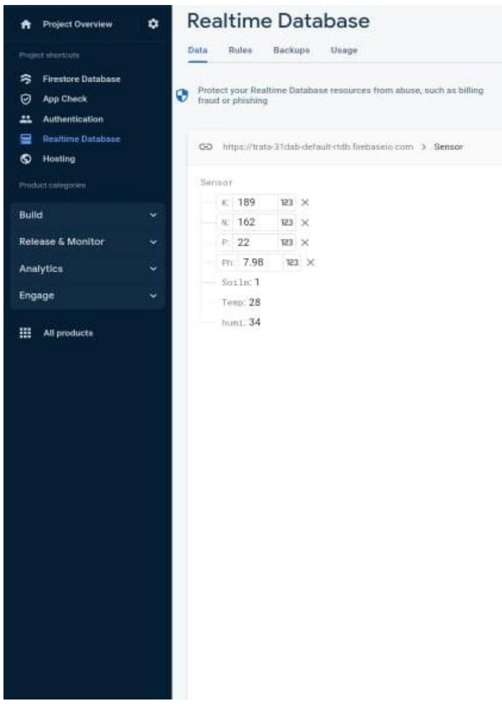


Figure 2. Block Diagram of AIoTST-CR model

For the experimental purpose, the five machine learning supervised algorithms such as Decision Tree Classification, Logistic Regression, SVM, Gaussian Naïve Bays and Random Forest Algorithm are used. The accuracy is calculated. Then the Ensembling is done for the individual classifier output using Majority Voting Technique. The frequent label is shown as predicted output with high accuracy. The classification algorithms Decision Tree, Gaussian Naïve Bays, SVM, Logistic regression and Random Forest are designed for accepting features of soil and predicting suitable crop for the given soil after ensembling the classification output.



Screenshot 1 Soil parameters sensed by IoT sensors

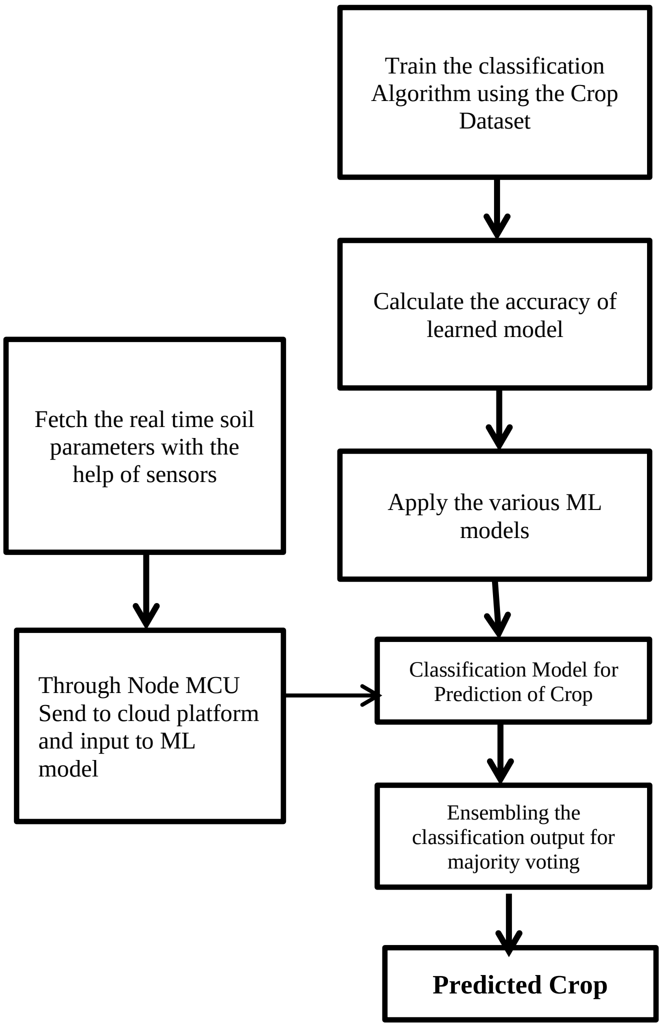


Figure 3. Detailed System Architecture

As a sample DecisionTree algorithm for crop prediction and calculating accuracy is illustrated below:

Algorithm : DecisionTree for Crop Prediction

Input : Crop Dataset
Output : Suitable Crop
-Preprocess the data
-Separate soil features & Crop label
-Split data as training 80% and testing 20%
-Apply the data to train DecisionTree
-Test trained model and calculate accuracy
-Cross Validate for k=5 (5 iterations)
-Check the accuracy for 5 iterations and store the accuracy.
-If accuracy is satisfactory then pickle the trained model on disk
-Use pickled model to predict the crop for test data.
-Display the suitable crop

Algorithm 1. Decision Tree Classification

5. RESULTS AND DISCUSSION

A dataset on soil parameters and crop label is downloaded from Kaggle portal[11]. Dataset contains total 2200 records. Each record contains the soil attributes such as Nitrogen, Phosphorous, Potassium, Temperature, Humidity, pH, rainfall and the suitable crop label. Before applying machine learning classification algorithms the features are separated from crop label. The machine learning classification algorithms such as Decision Tree, Gaussian Naïve Bays, SVM, Logistic regression and Random Forest are applied. The classification models are trained by using 80 percent of dataset for training and remaining 20 percent for testing. Each model is cross validated and cross validation score is calculated for five folds (k=5). The classification report for each classification algorithm can be displayed in which precision, recall, f1-score and support values are printed for each class. For the decision tree classification algorithm, classification report is shown in Table 1. All the classification results are ensembled and majority of the voting is used for deciding the more accurate crop prediction. The various accuracy measures are considered such as precision, recall, f1-score, support etc. Precision means the quality of a correct prediction done by the algorithm. In other words, Precision means the number of true positives upon the total number of positive predictions. The formula for precision is illustrated in (1).

$$Precision= TP/((TP+FP)) \quad (1)$$

The precision values for each class are displayed. Recall is also known as sensitivity or the true positive rate (TPR). Recall means the positive instances predicted as positive out of the total number of positive instances. Recall also means the number of TPs upon number of TPs + number of false negatives. The mathematical formula for recall is illustrated in (2).

$$Recall= TP/((TP+FN)) \quad (2)$$

The formula for the standard F1-score is illustrated in (3) which is harmonic mean of precision and recall.

$$F1=TP/(TP+1/(2)(FP+FN)) \quad (3)$$

A perfect model has an F-score of 1.

Table 1**.** Classification Report for Decision Tree Algorithm

Class	Precision	Recall	f1-score	Support
apple	1	1	1	13
banana	1	1	1	17
blackgram	0.59	1	0.74	16
chickpea	1	1	1	21
coconut	0.91	1	0.95	21
coffee	1	1	1	22
cotton	1	1	1	20
grapes	1	1	1	18
jute	0.74	0.93	0.83	28
kidneybeans	0	0	0	14
lentil	0.68	1	0.81	23
maize	1	1	1	21
mango	1	1	1	26
mothbeans	0	0	0	19
mungbean	1	1	1	24
muskmelon	1	1	1	23
orange	1	1	1	29
papaya	1	0.84	0.91	19
pigeonpeas	0.62	1	0.77	18
pomegranate	1	1	1	17
rice	1	0.62	0.77	16
watermelon	1	1	1	15
accuracy	0.9	440		
macro avg	0.84	0.88	0.85	440
weighted avg	0.86	0.9	0.87	440

The accuracy of each classification model is displayed in below Table 2. The cv_score for each classification models are shown in Table 3.

Table 2. Accuracy of Classification Models trained

Model	**Accuracy**
DecisionTree	0.900000
NB	0.990909
SVM	0.106818
Logistic_Regression	0.952272
RF	0.990909

Table 3. Classification Models with Cross Validation Score

Models	CV Score K = 1	CV Score K = 2	CV Score K = 3	CV Score K = 4	CV Score K = 5
DecisionTree	0.936364	0.909091	0.918182	0.870455	0.936364
NB	0.997727	0.995455	0.995455	0.995455	0.990909
SVM	0.277273	0.288636	0.290909	0.275	0.268182
Log_Regression	0.95	0.965909	0.947727	0.968182	0.943182
RF	0.997727	0.995455	0.997727	0.993182	0.988636

The experiments show that the accuracy of Naïve Bays and Random Forest classification is similar and high than the other models. A bargraph in Figure 4 is plotted against classification models versus accuracy which shows accuracy of Naïve Bays and Random Forest algorithms are the highest.

The Random Forest classification model is pickled on disk and used for further predictions. The pickled model is used in mobile application for recommendation of crop based on soil test data. A farmer should use the handheld soil testing kit by only putting the rods of kit in soil. The testing kit will sense the soil parameters and fetch in mobile application. We have tested the hardware designed for soil testing kit for several soil samples. To test our designed hardware is giving proper readings, we have given several soil samples to soil testing laboratory and soil parameter report is obtained out of which three sample reports are shown in Fig. 5 to Fig. 10. The table 4 to 7 shows the comparision between results received from soil testing lab and readings from the AIoTST device and the mobile application.

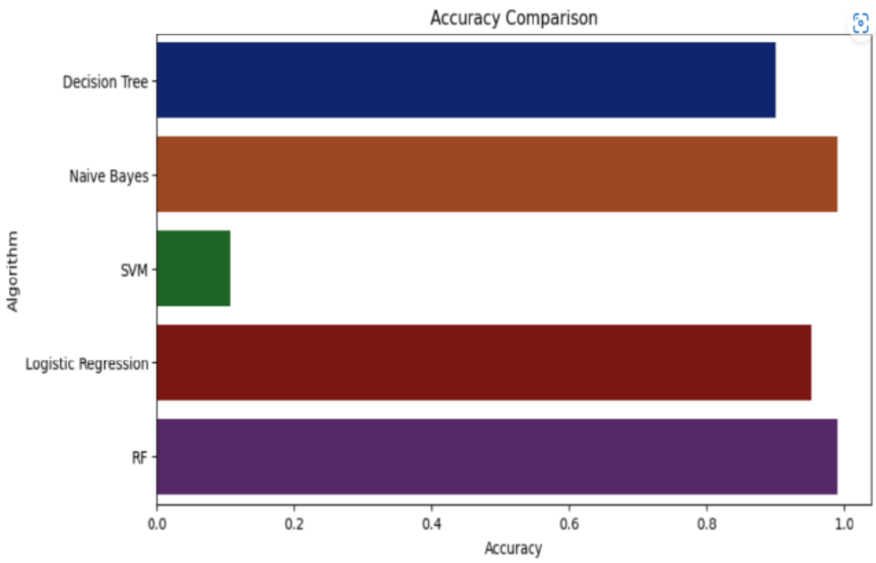
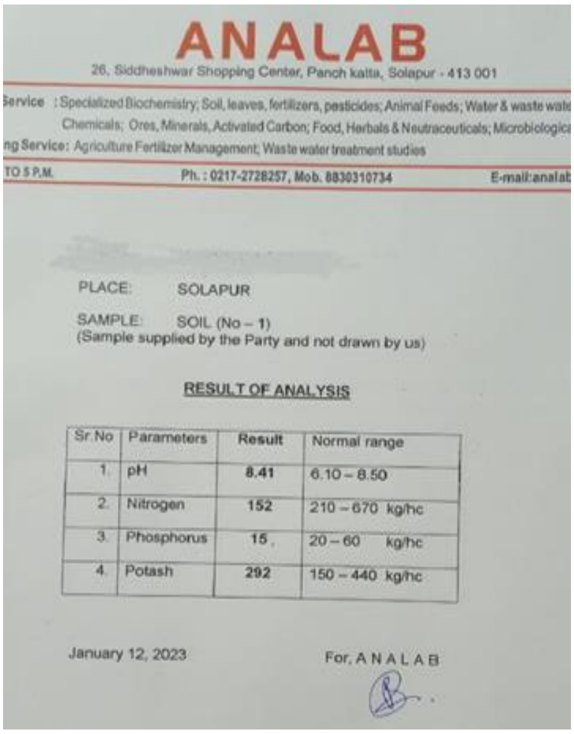


Figure 4. Graph of ML Algorithms Versus Accuracy



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SAMPLE: SOIL (No – 1)
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RESULT OF ANALYSIS

Sr.No	Parameters	Result	Normal range
1.	pH	8.41	6.10 – 8.50
2.	Nitrogen	152	210 – 670 kg/hc
3.	Phosphorus	15	20 – 60 kg/hc
4.	Potash	292	150 – 440 kg/hc

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Figure 5 Soil Report for sample 1 from Laboratory

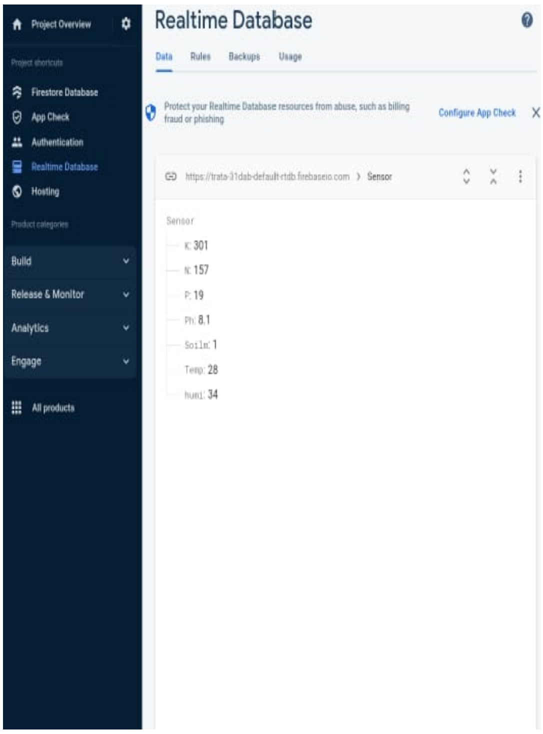
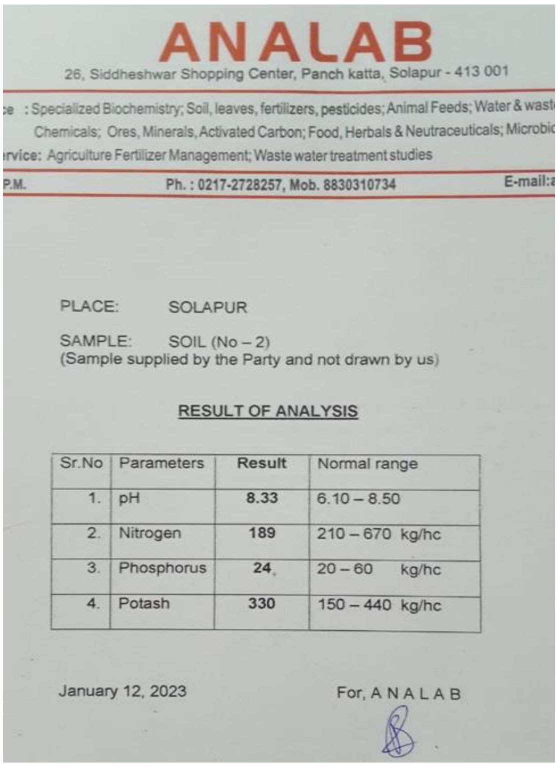


Figure 6 Soil Report for sample 1 from Soil Testing Kit



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PLACE: SOLAPUR
SAMPLE: SOIL (No – 2)
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RESULT OF ANALYSIS

Sr.No	Parameters	Result	Normal range
1.	pH	8.33	6.10 – 8.50
2.	Nitrogen	189	210 – 670 kg/hc
3.	Phosphorus	24	20 – 60 kg/hc
4.	Potash	330	150 – 440 kg/hc

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Figure 7. Soil Report for sample 2 from Laboratory

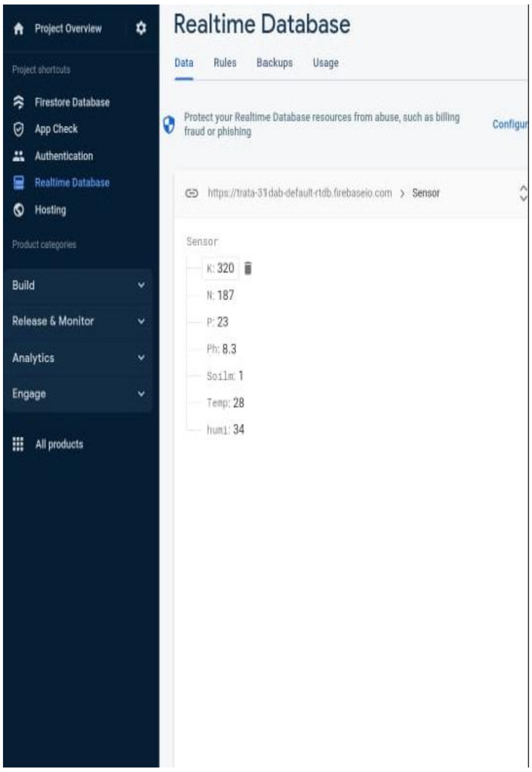
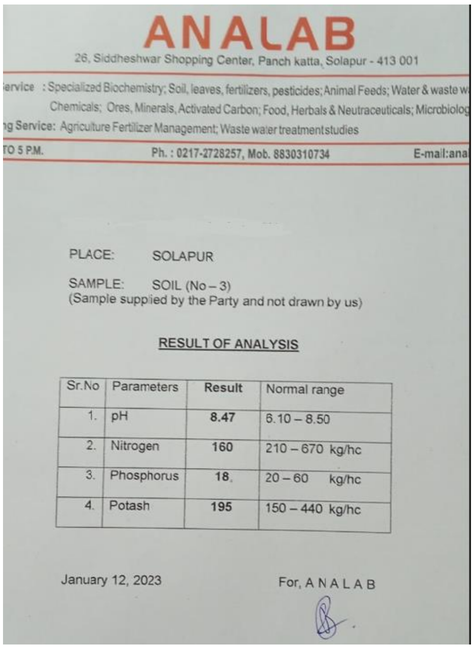


Figure 8. Soil Report for sample 2 from Soil Testing Kit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PLACE: SOLAPUR

SAMPLE: SOIL (No – 3)
(Sample suppied by the Party and not drawn by us)

RESULT OF ANALYSIS

Sr.No	Parameters	Result	Normal range
1.	pH	8.47	6.10 – 8.50
2.	Nitrogen	160	210 – 670 kg/hc
3.	Phosphorus	18.	20 – 60 kg/hc
4.	Potash	195	150 – 440 kg/hc

January 12, 2023 For, A N A L A B

Figure 9. Soil Report for sample 2 from Laboratory

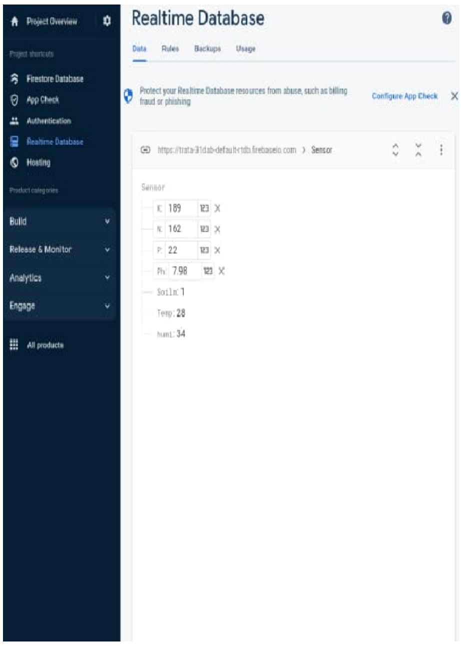

Figure 10. Soil Report for sample 2 from Soil Testing Kit

The mobile application will treat these soil values as input to different classification algorithms and the result is ensenbled to get majority of voting. After clicking to predict button the application is predicting the suitable crop based on majority voting and it is recommended to farmer. The farmer is getting recommendation of best suitable crop based on the contents of soil. The overall expenditure of farmer will be reduced. As the farmer is getting the recommendation of the crop suitable to the soil present in his farm, the crop yield will be more. There will not be much requirement of the fertilizers for growth of crop. So the overall crop yield of the farmer will increase.

Table 4. pH Value Comparison of Lab Results and AIoTST device

Soil Sample	Lab Results	AIoTST Results
1	8.41	8.1
2	8.33	8.3
3	8.47	7.98
4	7.9	8.1
5	8.63	8.53
6	8.83	8.79
7	7.5	7.9
8	7.71	7.8
9	8.53	8.42
10	7.69	7.64

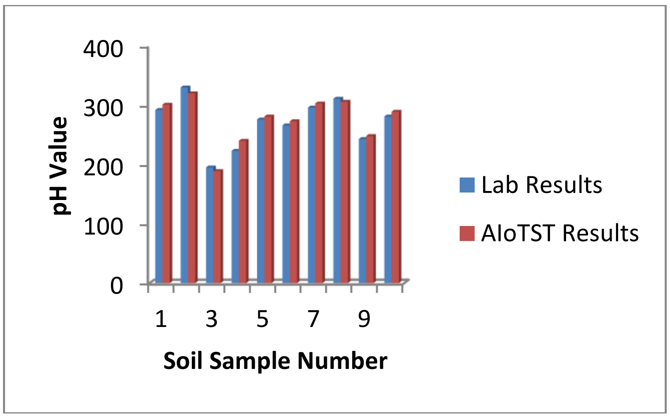

Figure 11. Comparative Chart for pH value from Lab Results and AIoTST device

Table 5. Nitrogen Value Comparison of Lab Results and AIoTST device

Soil Sample	Lab Results	AIoTST Results
1	152	157
2	189	187
3	160	162
4	177	181
5	169	163
6	183	179
7	184	178
8	191	188
9	187	186
10	166	168

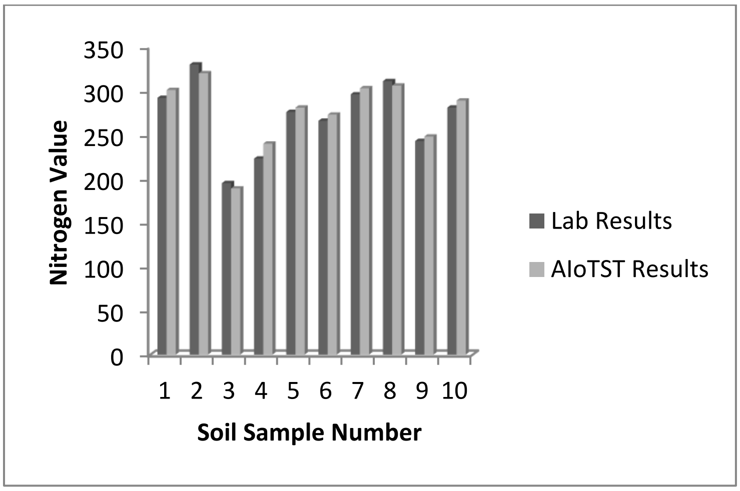

Figure 12. Comparative Chart for Nitrogen value from Lab Results and AIoTST device

Table 6. Phosphorous Value Comparison of Lab Results and AIoTST device

Soil Sample	Lab Results	AIoTST Results
1	15	19
2	24	23
3	18	22
4	17	17.5
5	21	20
6	23	23.5
7	17.5	18
8	18.6	19
9	19	20.3
10	22	21.5

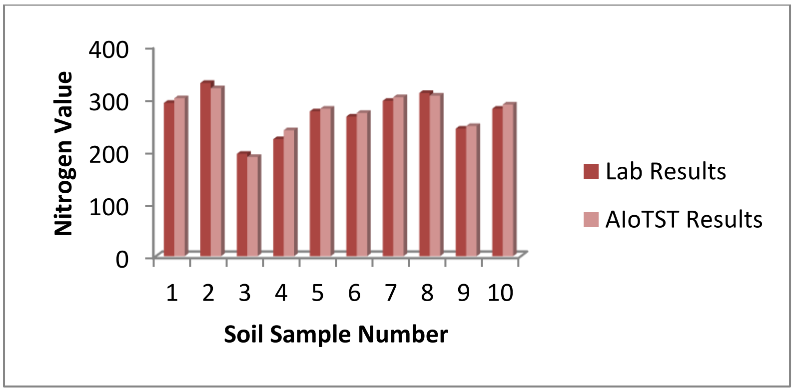

Figure 13. Comparative Chart for Phosphorous value from Lab Results and AIoTST device

Table 7. Potash Value Comparison of Lab Results and AIoTST device

Soil Sample	Lab Results	AIoTST Results
1	292	301
2	330	320
3	195	189
4	223	240
5	276	281
6	266	273
7	296	303
8	311	306
9	243	248
10	281	289

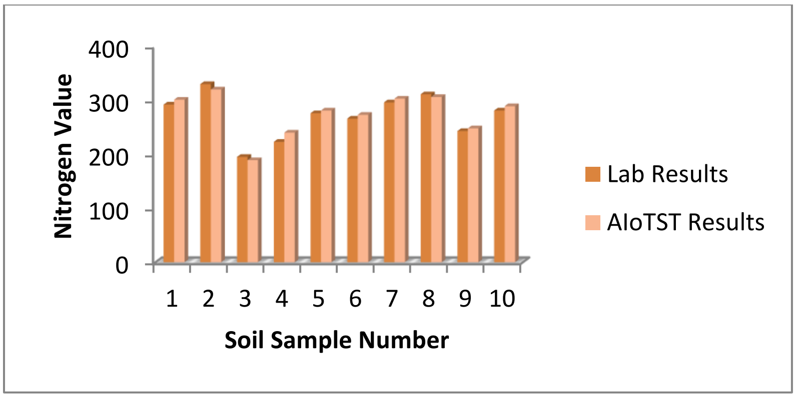

Figure 13. Comparative Chart for Potash value from Lab Results and AIoTST device

6. CONCLUSION AND FUTURE WORK

The developed system AIoTST-CR is very handy and useful for the farmers. There is no need for the farmers to go for soil testing laboratory to get tested their soil for the various nutrients. The farmers on their own can check the contents of soil such as pH, Nitrogen, Phosphorous, Potassium and Soil moisture using the AIoTST-CR system. The system also recommends the best crop to be taken in the farm. Moreover, the designed system AIoTST-CR is very much useful to protect the soil health by degradation due to excessive usage of chemical fertilizers. Thus the system guides and helps the agriculturist in choosing the accurate crop, as well as it also guides them for use of correct quantity of fertilizers. If the system is used continuously the overall crop yield of farmer will increase.

REFERENCES

[1] Fariha Shahrin, Labiba Zahin, Ramisa Rahman, Jahir Hossain, Abdulla Hil Kafi and A.K.M Abdul Malek Azad, " Agricultural Analysis and Crop Yield Prediction of Habiganj using Multispectral Bands of Satellite Imagery with Machine Learning," *IEEE 2020 Proceedings of 11th International Conference on Electrical and Computer Engineering (ICECE) DOI: 10.1109/ICECE51571.2020.9393066*

[2] Abhiram MSD, Jyothsnavi Kuppili and N.Alivelu Manga "Smart Farming System using IoT for Efficient Crop Growth" *proceedings of IEEE 2020 International Conference on Electrical, Electronics and Computer Science*

[3] Sashant Suhag, Sanskriti jadaun, Ayush Shukla, Nidhi Singh, Prashant Johri and Nidhi Parashar "IoT based Soil Nutrition and Plant Disease Detection System for Smart Agriculture" *10th IEEE International Conference on Communication Systems and Network Technologies DOI: 10.1109/CSNT51715.2021.9509719*

[4] Siddalinga Nuchhi, Vinaykumar Bagali and Shilpa Annigeri "IOT Based Soil Testing Instrument For Agriculture Purpose" *IEEE explore journal.*

[5] Farnaz Babaie Sarijaloo, Michele Porta, Bijan Taslimi and Panos Pardalos "Yield performance estimation of corn hybrids using machine learning algorithms" *Artificial Intelligence in Agriculture 5 (2021) 82–89*

[6] A. Subeesh , C.R. Mehta "Automation and digitization of agriculture using artificial intelligence and internet of things" *Artificial Intelligence in Agriculture 5 (2021) 278–291 indexed in ScienceDirect*

[7] Liu, D., Mishra, A.K., Yu, Z., 2016b. "Evaluating uncertainties in multi-layer soil moisture estimation with support vector machines and ensemble Kalman filtering.“ *J. Hydrol.538,243–255* *https://doi.org/10.1016/j.jhydrol.2016.04.02*

[8] Khaki, S., Wang, L., Archontoulis, S.V., 2020. A CNN-RNN framework for crop yield prediction. Front. *Plant Sci.* *https://doi.org/10.3389/fpls.2019.01750*.

[9] Lavanya, G., Rani, C., Ganeshkumar, P., 2019. An automated low cost IoT based Fertilizer Intimation System for smart agriculture. *Sustain. Comput. Inform. Syst. https://doi. org/10.1016/j.suscom.2019.01.002.*

[10] Bhuwan Kashyap and Ratnesh Kumar. Sensing Methodologies in Agriculture for Soil Moisture and Nutrient Monitoring. *IEEE Paper DOI 10.1109/ACCESS.2021.3052478. VOLUME 9, 2021*
[11] Soil Test parameters and crop recommendation data download from https://www.kaggle.co/datasets/atharvaingle/crop-recommendation-dataset
[12] A User-friendly AIoT-Based Crop Recommendation system (UACR): concept and architecture. Available from https://www.researchgate.net/publication/369938116_A_Userfriendly_AIoT_Based_Crop_Recommendation_system_UACR_concept_and_architecture
[13] Akhter, R.; Sofi, S.A. Precision agriculture using IoT data analytics and machine learning. *J. King Saud Univ. Comput. Inf. Sci. 2021, 34, 5602–5618.*
[14] Sivakumar, R.; Prabadevi, B.; Velvizhi, G.; Muthuraja, S.; Kathiravan, S.; Biswajita, M.; Madhumathi, A. Internet of Things and Machine Learning Applications for Smart Precision Agriculture. *In IoT Applications Computing; IntechOpen: London, UK, 2022; p. 135.*
[15] Dagar, R.; Som, S.; Khatri, S.K. Smart farming–IoT in agriculture. *In Proceedings of the 2018 International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India, 11–12 July 2018.*
[16] Priya, R.; Ramesh, D.; Khosla, E. Crop Prediction on the Region Belts of India: A Naïve Bayes MapReduce Precision Agricultural Model. *In Proceedings of the 2018 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Bangalore, India, 19–22 September 2018; pp. 99–104.*
[17] Hu, C.; Zhong, X.; Xu, J. Study on integrated discovery system of sensors for agriculture observation application. *In Proceedings of the 2014 The Third International Conference on Agro-Geoinformatics, Beijing, China, 11–14 August 2014; pp. 1–5.*
[18] Pajares, G.; Peruzzi, A.; Gonzalez-De-Santos, P. Sensors in Agriculture and Forestry. *Sensors 2013, 13, 12132 12139.*
[19] Bhat, S.A.; Huang, N.-F. Big Data and AI Revolution in Precision Agriculture: Survey and Challenges. *IEEE Access 2021, 9, 110209–110222.*
[20] Ali, S.M.; Das, B.; Kumar, D. Machine Learning based Crop Recommendation System for Local Farmers of Pakistan. Rev. Geintec-Gest. *Inov. Tecnol. 2021, 11, 5735–5746.*
[21] Gosai, D.; Raval, C.; Nayak, R.; Jayswal, H.; Patel, A. Crop Recommendation System using Machine Learning. *Int. J. Sci. Res. Comput. Sci. Eng. Inf. Technol. 2021, 7, 554–557.*
[22] Mulge, M.; Sharnappa, M.; Sultanpure, A.; Sajjan, D.; Kamani, M. Agricultural crop recommendation system using IoT and ML. *Int. J. Anal. Exp. Modal Anal. 2020, 12, 1112–1117*.
[23] Viviliya, B.; Vaidhehi, V. The Design of Hybrid Crop Recommendation System using Machine Learning Algorithms. *Int. J. Innov. Technol. Explor. Eng. (IJITEE) 2019, 9, 4305–4311*.
[24] Hasyiya K. A., Muhammad A. R., Khairul N. S., Wan Salihin Wong Recent Advancements and Challenges of AIoT Application in Smart Agriculture: *A Review Special Issue Accelerating Beyond Traditional Farming through Exceptional Approaches of AI and IoT Sensors 2023, 23(7), 3752; https://doi.org/10.3390/s23073752*
[25] Javaid, M.; Haleem, A.; Singh, R.P.; Suman, R. Enhancing smart farming through the applications of Agriculture 4.0 technolgies. *Int. J. Intell. Netw. 2022, 3, 150–164.*
[26] Pant, J.; Pant, R.P.; Singh, M.K.; Singh, D.P.; Pant, H. Analysis of agricultural crop yield prediction using statistical techniques of machine learning. *Mater. Today Proc. 2021, 46, 10922–10926.*
[27] O'Shaughnessy, S.A.; Kim, M.; Lee, S.G.; Kim, Y.; Kim, H.; Shekailo, *J. Towards smart farming solutions in the U.S. and South Korea: A comparison of the current status. Geogr. Sustain. 2021, 2, 312–327.*
[28] Khan, J.I.; Khan, J.; Ali, F.; Ullah, F.; Bacha, J.; Lee, S. Artificial Intelligence and Internet of Things (AI-IoT) Technologies in Response to COVID-19 Pandemic: A Systematic Review. *IEEE Access 2022, 10, 62613–62660*.
[29] Zhang, H.; He, L.; Di Gioia, F.; Choi, D.; Elia, A.; Heinemann, P. LoRa WAN based internet of things (IoT) system for precision irrigation in plasticulture fresh-market tomato. *Smart Agric. Technol. 2022, 2, 100053.*
[30] S. Katiyar and A. Farhana, "Smart agriculture: The future of agriculture using ai and iot," *Journal of Computational Science, vol. 17, no. 10, pp.984–999, 2021.*
[31] M. Pathan, N. Patel, H. Yagnik, and M. Shah, "Artificial cognition for applications in smart agriculture: A comprehensive review," *Artificial Intelligence in Agriculture, vol. 4, pp. 81–95, 2020.*
[32] S. K. S. Durai and M. D. Shamili, "Smart farming using machine learning and deep learning techniques," *Decision Analytics Journal,vol. 3, p. 100041, 2022.*
[33] Y. Liu, X. Ma, L. Shu, G. P. Hancke, and A. M. Abu-Mahfouz, "From industry 4.0 to agriculture 4.0: Current status, enabling technologies, and research challenges," *IEEE Transactions on Industrial Informatics, vol. 17, no. 6, pp. 4322–4334, 2020.*
[34] O. Friha, M. A. Ferrag, L. Shu, L. Maglaras, and X. Wang, "Internet of things for the future of smart agriculture: a comprehensive survey of emerging technologies," *IEEE/CAA Journal of Automatica Sinica, vol. 8,no. 4, pp. 718–752, 2021.*
[35] A. Mitra, S. L. Vangipuram, A. K. Bapatla, V. K. Bathalapalli, S. P.Mohanty, E. Kougianos, and C. Ray, "Everything you wanted to know about smart agriculture," *arXiv preprint arXiv:2201.04754, 2022*
[36] Suchithra, M.; Pai, M.L. Improving the prediction accuracy of soil nutrient classification by optimizing extreme learning machine parameters. *Inf. Process. Agric. 2020, 7, 72–82.*
[37] Dash, R.; Dash, D.K.; Biswal, G. Classification of crop based on macronutrients and weather data using machine learning techniques. *Results Eng. 2021, 9, 100203.*
[38] Balakrishnan, N.; Muthukumarasamy, G. Crop production-ensemble machine learning model for prediction. *Int. J. Comput. Sci. Softw. Eng. 2016, 5, 148.*

[39] Pantazi, X.; Moshou, D.; Alexandridis, T.; Whetton, R.; Mouazen, A. Wheat yield prediction using machine learning and advanced sensing techniques. *Comput. Electron. Agric. 2016, 121, 57–65*.

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