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Micronutrient Classification in IoT based Agriculture using Machine Learning (ML) Algorithm

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Abstract— **Agriculture appears to be the demographically most important economic area in India's socioeconomic structure. People are now unaware of crop cultivation's proper timing and location. As a result, they cause food insecurity since seasonal climatic settings dependent on agriculture practices are changing against essential assets such as air, water, and soil. As a result, Machine Learning (ML) techniques are the best option for agriculture and are being tested to predict agricultural growth. This paper proposed horticulture IoT monitoring sensor board to develop an IoT architecture in agriculture industry for monitoring the Micro and Macro Nutrients of Soil and analyze various soil parameters present in the Thiruvarur District in Tamil Nadu. The framework aids in generating right decisions based on data collected from IoT sensors and saved on the server before being evaluated using ML algorithms. The ML model is used to categorize the dataset based on the micro and macronutrient threshold values acquired from the National Food Security Mission (NFSM). The evaluation can be done by using various ML classification algorithm such as Naive Bayes (NB), Logistic Regression (LR), Random Tree (RT) and K-Nearest Neighborhood (KNN). The classification method is compared and evaluated through accuracy, Relative Absolute Error (RAE), Root Mean Square Error (RMSE), Root Relative Squared Error (RRSE), Mean Absolute Error (MAE). The KNN classifier attains lower MAE, RMSE and RRSE value of 0.2398, 0.3908, and 94.1845 and outperforms the other three classifier but RT algorithm attains lower RAE value of 66.24 than KNN.**

Keywords: Micronutrient, Soil, Agriculture, ML, IoT, Crop, Sensor

1. INTRODUCTION

Agriculture is the most important sector in a country like India, providing the majority of the country's income. There are various factors that influence potential growth and output, including the surface quality, irrigation, environment and fertilizer management. Agriculture is the backbone of every Indian economy. Agricultural advancements are required to meet the needs of a country like India, which is experiencing increased food demand due to population growth. Agriculture has long been regarded as India's primary and most important society. Plants that have been customized for their needs are grown by ancient people in their own land. Agriculture is worsening as a result of the introduction of new creative technologies and processes. As a result, many persons with creative minds concentrated on inventing synthetic commodities, which are composite objects that commit to an unhealthy lifestyle. Nowadays, many people have no idea how to grow crops at the correct time and in the correct place. Such farming practices frequently adjust seasonal meteorological circumstances against basic resources like air, land and water which leads to food poverty. There is no correct solution or engineering to handle the situation they encounter after examining all of the challenges and issues, such as temperature, climate and moisture. There are numerous approaches to increase agricultural growth in India. Plant productivity and crop value can be increased and enhanced in a variety of ways [1].

Indian soil is not only low in primary plant nutrients such as Nitrogen (N), Phosphorus (P), and in certain scenario Potassium (K) is considered but they have also become low in subsequent nutrients such as Sulphur (S), Magnesium (Mn) and Calcium (Ca). Micronutrient deficiencies have also been reported, including zinc, boron, and lesser level iron, copper, manganese and molybdenum. Micronutrient deficiency has increased in volume and scope over the last three decades as a result of increased usage of high-analysis fertilizers, increased cropping intensity and high-yielding crop cultivators. Rice, wheat, and pulses productivity has become a major constraint to the production. As a result, individual nutrient insufficiency must be corrected as soon as possible in order to prevent future spread. In India, the NFSM initiative would address micronutrient deficiencies has major in rice, wheat, and pulses-growing states.

IoT is now being used in a variety of industries whereas India is an agricultural country, it requires agricultural advancements. The Internet of Things (IoT), sometimes known as the Internet of Everything (IoE), is made up of all web-enabled devices that employ embedded sensors, processors, and communication gear

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to gather, communicate, and act on data from their surroundings. The farm is equipped with a number of sensors that provide information about the soil factors such as soil micronutrient and macronutrient levels. These basic soil metrics will aid in describing the soil as a result, in making informed judgments. IoT sensor is used to collect the data and sent to microcontroller in an arduino board and then stored in a database through wireless communication. This paper analyze agriculture growth duration of sunshine in every day based on soil micronutrient levels, humidity, temperature and macronutrient levels. In order to analyze the agricultural growth, IoT has used to monitor real-time data [2].

ML is a new technology that focuses to learn from data and make predictions and decision based on it. It is utilized to examine massive data sets and to create meaningful classifications and patterns in data sets. In general, the objective of the ML system is to extract information from a collection of data and turn it into a usable framework. The crop yield based on agriculture growth using ML algorithms which has been resulting in a higher yield. This research work has an attempt to investigate the agriculture growth based on IoT sensor to develop an agriculture industry for monitoring the Micro and Macro Nutrients of Soil and analyze various soil parameters using ML algorithms.

The paper is organized as follows: section 2 depicts the associated survey based on ML technique and IOT sensors, section 3 defines the proposed methodology based on IoT based monitoring system, section 4 describes results and discussion based on evaluation performance, and section 5 concludes.

2. LITERATURE REVIEW

According to Nandhini and Shankar [3] describes for predicting the quality of crop growth which helps to increase or decrease of crop growth. Therefore this paper describes prediction of disease which can overcome these problems while comparing the seed features with corresponding sample dataset. Seeds are categorized in accordance with crop prediction diseases and growth using the SVM algorithm. Turkoglu and Hanbay [4] described the prevention of loss of productivity. The accurate diagnosis of plant diseases at the right time is essential in the prevention of losses and losses in productivity or reduced quantities of agricultural products. These approach based on ML can be used to resolve these problems. Vats et al. [5] uses descriptive analyze which predicts the future in farm production. This paper produces a combined dataset and use several supervised techniques on this combined dataset to determine the actual estimated cost of several techniques. The additional functionality in LS-SVM in comparison with Support Vector Maker was explained. This technique is used to solve problems with classification and regression. Kima et al. [6] describes the trends in crop pest prediction using ML. The field of agriculture also concentrates on it with the beginning of data mining. Different studies at home and abroad are currently under way using ML technology, and their uses are on the rise. The SVM classification, multiple linear regression, Bayesian network and neural network technology are introduced and certain cases of their use are described. According to Tatapudi and Varma [7] describes to implement ML algorithm based on analyzing the information which would integrate sensors like temperature, Ph, humidity, moisture and rainfall. This study assists farmers in forecasting which crops to plant in their agricultural fields depending on the factors listed above, permitting Smart Farming to be more productive. Paramasivam and Anbazhagan [8] describe chemical parameters, micro and macro nutrient parameters are used to define the circumstance and soil quality. Shafi et al. [9] introduce crop health monitoring using two-module IoT-based smart solution. Initially, this system has to monitor the status of crop health in real time using wireless sensor network. Thus, it collects multi-spectral imagery from a low-altitude remote sensing platform, which is then analyzed to distinguish good and unhealthy crops. Murugesan et al [10] demonstrate that crop prediction models may be achieved using ML with an accuracy of up to 75%. This paper achieved 100% prediction of crop production with 14 micronutrient soil features which can be used by expert advisory to harvesting stage from seed stage. Patil et al. [11] propose a rough idea of ML with only one attribute that can increase yields and distinguish multiple patterns for predictions. This approach will be beneficial in determining which crops may be cultivated in a specific location. The study by Prado Osco et al. [12] presents a technique for forecasting nutritional content using ML algorithms. The results show that surface reflectance data is even better for forecasting macronutrients in Valencia-orange leaves, but first-derivative spectra are more closely connected to micronutrients. More and Singla [13] intended, for analyzing the effect of different ML techniques in agriculture. This research extended the knowledge about ML methods used with IoT in agriculture. Deepa et al. suggested for crop selection using decision-making technique [14] that aids in crop yield improvement. The input of soil, water, season, support and infrastructure were the six key criteria used to classify the input variables. The priority weights for the variables are determined using a rough dominance-based technique [14]. According to the Rajalakshmi et al proposes to monitor the crop field using IoT sensor based system [15]. Rao et al [16] produces an image characteristic features which receives input image using image processing unit that capture image in the infected area and collect the sensor data using IoT system. The hardware device such as microcontroller which has been coupled to a wireless technology called Zigbee to view the

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conditions remotely in the form of images. Ramesh and Rajaram [17] discusses for predicting on-field disease using cloud analytics which can be developed by IoT reference architecture. The evaluation process can be more subjective, tedious and time consuming. Anand et al [18] examines the soil nutrient in real time and makes recommendations based on the PH of the soil. The primary purpose of this research is to monitor soil nutrients in the field and deliver suitable fertilizers. Sindhu and Indirani [19] present a methodology that assesses which crops are appropriate for each soil type. This technology is designed to assist farmers in increasing their output, and suggestions are offered via a smartphone application. Ramesh and Vydeki [20] proposes to determine the crop disease in early stage which are developed through mobile based embedded hardware environment. Disha and Wankhede[21] present a study of different machine learning classifiers such as Naive Bayes, J48, KNN, SVM, Random Forest, and JRip for forecasting whether soil is suitable for a specific crop in a given location. Most of the paper have proposed their work by considering Sulfur, Iron, EC, Boron , OC , Zinc, Copper, pH, Nitrogen, Phosphorus, Magnesium, and , Potassium etc feature, but most focus on pH, N, P, K. Naive Bayes classifier gives good result as related to other classifier of machine learning for large dataset. Kanakamedala et al. [22] employ multilinear regression to estimate surplus water levels and micronutrients for agricultural production since farmers want analog data rather than digital data. So that they can take the required precautions to keep the field from being harmed. Archana et al [23] investigated irrigation management studies to determine saline solids in soil. It employs two ways to enhance agricultural yield facilities. The first is bioremediation, in which different kinds of plants may be cultivated and plant growths can be replaced on a regular basis. However, before planting the plants, plants with high saline tolerance should be sown. The second technique identifies items that restrict salinity so that steps may be implemented to increase/decrease salinity based on soil requirements. Md. Hafizur Rahman et al [24] investigated the effect of residential sewage on soil composition in order to improve soil efficiency. The system was primarily focused on phosphorous, zinc, nitrogen, and potassium components in this study. The model thoroughly investigated the controlled release of nano fertilizers and their effect on agricultural soil areas. According to the research, the use of sewage has greatly boosted agricultural yield. Meena et al [25] established a model for the delivery of organic and inorganic fertilizers to crops, as well as the consequences of their supplementation. Crops are harmed in the long term as a result of the application of different fertilizers to the crop in order to boost yield. This module uses the DTPA extractor to detect the micronutrients used by the soil. Zinc and copper can have a negative impact on agricultural yield when used over an extended period of time. Crop yields improve as a result of organic matter. It also flawlessly combines micro and macronutrient substances.

3. RESEARCH METHODOLOGY

The proposed research work describes an increasing demand for efficient strategies in the data mining in agriculture prediction. Initially, the goal of this research was to create a system that employs IOT devices to collect soil nutrient levels on a regular basis. The data collected from IoT sensors, which the recommended framework aids in making correct decisions, and stored on the server are analyzed using machine learning algorithms. This research proposes an efficient factor that affects the agriculture growth using different parameters such as micro nutrient level like Fe, Mn, Zn and Cu and macro nutrient level like N, K, P, soil temperature, soil moisture, pH quality, crop information, fertilizer, etc which can be processed using IoT systems. The system analyze data and processed in the server obtained from the sensors and evaluated using ML algorithm. This system aids to make proper decision making about an agriculture growth. The physicochemical properties of such soils were determined. The pH and moisture level of the soil are among the physical factors examined. The pH and EC conditions of soil samples S1–S9 indicate the soil's quality. While the percentages of micronutrients such as Fe, Mn, Zn, and Cu in S1 soil samples range from low to sufficient, and the remaining shows a low index in percentage, the percentage of macronutrients present in the samples shows a large difference in their results due to the location of soil sample acquisition. The figure.1 has shown an overall block diagram of proposed IoT architecture with ML algorithm.

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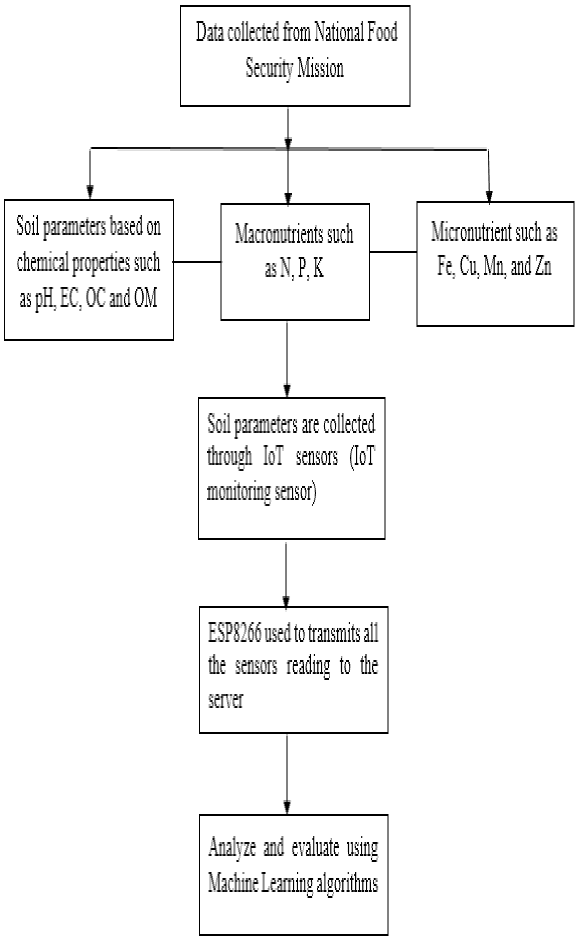

FIGURE.1 OVERALL BLOCK DIAGRAM OF PROPOSED ARCHITECTURE

3.1 Data Collection from IoT devices

The data acquired from IoT hardware devices through arduino board which perform as a microcontroller and the database gets stored using wireless communication. The physical parameters of such soils includes soil moisture, soil pH, soil temperature were identified by physico-chemical properties. Basic soil chemical characteristics were determined in the analyzed soil samples such as EC, OC and OM. Then the soil characteristics of chemical parameters such as micronutrient of Fe, Cu, Zn, Mn and macronutrient of N, P,K. These parameters are collected from soil sample using IoT sensor were present in seven various district of Thiruvarur. Soil samples were obtained from Mannargudi, Kudavasal, Thiruvarur, Needamangalam, Valangaiman, Thiruthuraipoondi and Nannilam Taluks, yielding 35 different species of soil fungi. The Physico-chemical characteristics and soil nutrient status are shown in Table.1.

TABLE.1 EXPERIMENTAL- PHYSICO-CHEMICAL CHARACTERISTICS AND SOIL NUTRIENT STATUS

Chemical properties	Ranges		Mean
	Low	High	
chemical properties			
pH	7.32	8.75	7.9
EC	0.09 dsm-1	0.62 dsm-1	0.331 dsm-1
OC	0.21 %	0.32%	0.30 %
OM	0.31 %	0.74 %	0.61 %
Available Macronutrients (kg.ha-1)			
N	127.95	83.556	189.72
P	2.36	17.67	12.17
K	130.69	274.04	152.597
Available Micronutrients (mg.kg-1)			
Fe	3.1	6.64	4.62
Mn	1.03	2.63	2.26
Cu	0.20	1.14	0.607
Zn	0.18	0.80	0.48

In terms of macronutrient critical limits, the recorded macronutrients are 86.5 percent low, 13.5 percent medium in nitrogen, 100 percent low in P2O5, and 100 percent medium in potassium. Among micronutrients, Fe is sufficient in 97 percent of cases, Mn is deficient in 100 percent of cases, Zn is sufficient in 53 percent of cases, and Cu is deficient in 45 percent of cases. Despite the fact that the soils investigated had enough levels of accessible micronutrients, shortages were also discovered. The results showed that the soil properties pH, EC, and OC were the most important in controlling the availability of micronutrients. These parameters might be modified to address any current or future micronutrient deficits in these soils.

3.2 IoT-based Monitoring System

Figure 2 depicts the suggested agricultural IoT based sensor board which is made up of a microcontroller board which includes physical, chemical, micronutrient, macronutrient soil sensors and a module of WLAN IEEE 802.11 whereas the developed board and all kind of modules are available in large quantities. The sensor board has to read output of multiple data using low cost Arduino Uno Rev3 which is available in the microcontroller board connected with Arduino Sensor Shield V5.0 from the multiple sensors. It is built around the ATMega328P microcontroller. It's a tiny, low-power board that can be used for a variety of tasks. An Arduino Sensor Shield V5.0 has been utilized in the board as an interface shield to provide additional connections to various sensors and wireless connectivity modules. It permits the connection to the access point from the board which is transmitted by the wireless module.

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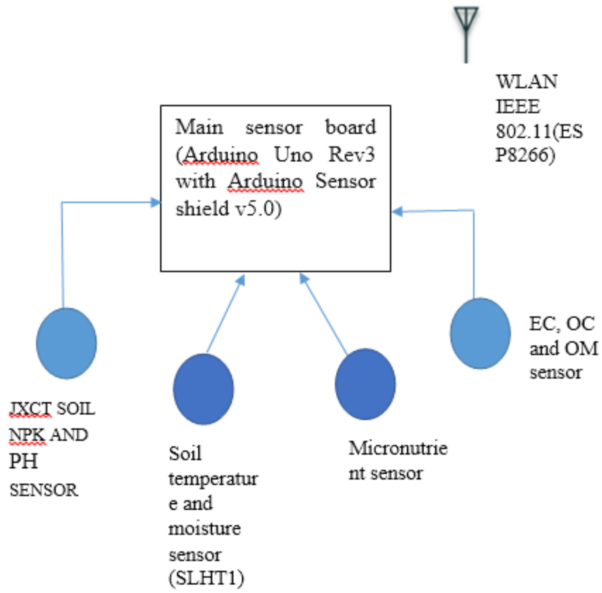

FIGURE.2 IOT SENSOR MONITORING BOARD

JXCT sensors are installed on the board. To determine the level of NKP macronutrients and PH in the area is surrounding the plant. SLHT1 is primarily assisted to define the soil temperature and moisture whereas the soil sensors have been used to record micronutrient levels as well as chemical aspects of the soil. The sensor values are acquired and sent to the sensor board every two seconds. The board is linked to an ESP8266, which sends all sensor data to the server. After, the sensor data is transmitted from the sensor data from each board via wireless access point to the server. The data readings and images from the sensors are sent to the logging server. This sensor data from access point can be managed by fault-tolerance, highly available and consistent messaging mode has clustered like Kafka. Once the data get clustered, the collected sensor data have been sent to the ML training server.

3.2.1 Soil Data sample collected from IoT sensor

The Internet of Things (IoT) technology has improved every aspect of the average person's life by making everything smart and intelligent. The Internet of Things (IoT) is a shared network of things that communicate with one another over the internet. Smart agriculture is an important application of IoT. Because the demand for agricultural products is constantly increasing, society requires a smart IoT implementation in agriculture to meet these rising demands. Farmers are currently dealing with a variety of agricultural issues, including overflowing water, crop loss caused by climate changes, and a shortage of micronutrients in the soil.

The development of intelligent smart farming through IoT-based devices is changing the future of agriculture production by not only improving it but also making it more cost-effective by minimizing water and fertilizer waste and increasing crop output. The suggested system monitors crop fields by employing sensors to measure soil moisture, humidity, temperature, and PH levels. These elements are depicted in table.2.

TABLE.2 DIFFERENT TYPES OF SENSORS

S. No	Sensor types and name	Properties and Merits
1.	 JXCT Soil NPK Sensor	Soil N (nitrogen), P (phosphorus), and K (potassium) content must be measured to estimate how much more nutrient content should be applied to soil to boost crop fertility.
2.	 Soil EC sensor	Probe sensitivity, long service life and Strong anti-interference.
3.	 JXBS-3001 Soil PH Sensor	The soil ph sensor is a high-functioning, digital-display soil tester that can swiftly test the ph of various types of soil. The soil meter is precise, quick, stable, has a wide range, has a clear display, is portable, and is simple to use.

The soil quality is defined through PH and EC characteristics present in the soil sample which is considered with nine different soil samples from S1 to S9. The S1 soil sample micronutrient percentage for Mn and Zn is low while compared with S2, S3, S5 and S9 and for Fe and Cu percentage is higher than S2, S4 to S9. Similarly, the macronutrient percentages in the samples are also illustrating a huge difference over their outcome because of location selection to obtain soil samples. According to the data acquisitions from IoT sensors are randomly picked in term of

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samples as S1 to S9 are shown in table.2. The limit of macronutrient such as N, P, K are mentioned as >100, >10 and 150 – 300 whereas the value of N is lower than the limit for all nine samples (S1 to S9). Similarly, the value of K for sample S1 and S9 are within the limit and in the case of P, except S3 sample all other eight sample are lower than the limits as illustrated in table.3. Moreover, this collected data samples through micro and macro nutrient sensors of IoT devices and stored in server which are taken from the Thiruvarur district.

TABLE.3 IOT SENSOR BASED ON AGRICULTURAL MICRO AND MACRO NUTRIENTS SOIL CONTENT LEVEL

Soil Sample	Macronutrients					Micronutrients			
	pH	EC	N (kg/acre)	P (kg/acre)	K (kg/acre)	Fe (%)	Mn (%)	Zn (%)	Cu (%)
S1	7.1	0.6	63	25	168	4.75	0.92	0.42	1.43
S2	8.3	0.2	71	2.6	16	3.17	1.42	1.22	0.91
S3	7.8	0.1	77	10.8	131	3.0	1.81	0.46	1.62
S4	8.2	0.1	67	1.4	28	1.17	0.62	0.86	0.3
S5	7.7	0.4	63	2.0	42	2.08	1.0	0.86	0.23
S6	8.1	0.1	64	0.6	33	1.08	1.19	0.26	0.23
S7	8.1	0.08	53	1.2	25	1.08	0.38	0.08	0.23
S8	7.8	0.1	57	1.2	33	2.83	1.46	0.2	0.42
S9	8.2	0.3	63	3.0	250	2.25	1.31	0.82	0.75
Limits	6-11	<1	>100	>10	150-300	>4 %	>4 %	>4 %	>4 %

The threshold classification level for selected crops to Micronutrients related to Thiruvarur District are illustrated in table.4.

TABLE.4 RELATIVE RESPONSIVENESS OF SELECTED CROPS TO MICRONUTRIENTS

Crop	Fe	Cu	Mn	Zn
Apples	High	Normal	Low	Normal
Corn	Normal	Low	Low	High
Cotton	High	Low	High	Normal
Grain Sorghum	Low	Normal	Normal	High
Lettuce	Normal	High	High	Normal
Peanut	High	Low	Normal	Low
Sweet Potato	High	Low	High	Normal
Tomato	High	High	Normal	Normal
Wheat	Low	High	High	Low
Paddy	High	Normal	Normal	High

4. RESULT AND DISCUSSION

The collected soil sample data from IoT device is used to identified and analyzed based on the threshold classification level for selected crops to Micronutrients using ML algorithm. The ultimate goal of the ML framework appears to be to extract knowledge from a collection of data and turn it into a usable framework for future use. Table.5 and figure.3 shows the result of classification based on 100 samples in terms of correctly and incorrectly classified samples. The result shows that the KNN and LR achieves higher percentage of accuracy with correctly classified than the NB and DT based on threshold classification level for selected crops to Micronutrients.

TABLE.5 CLASSIFICATION ACCURACY FOR VARIOUS ML ALGORITHM

Classifier	Corr. Classified	Incorr. Classified
NB	62.5	37.5
LR	81.25	18.75
RT	56.25	43.75
KNN	81.25	18.75

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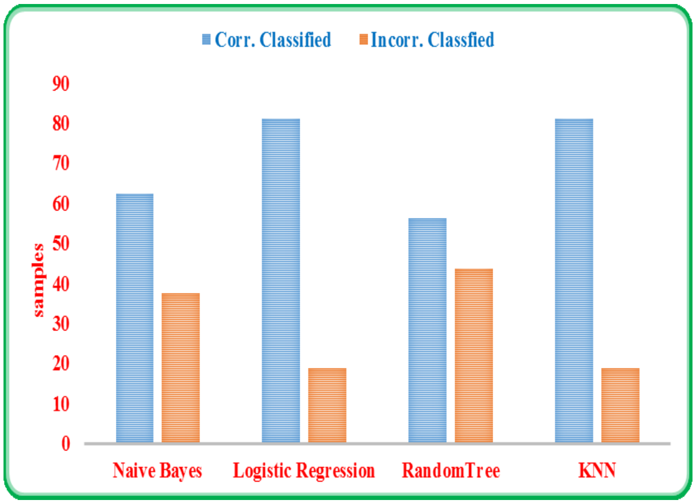

FIGURE.3 CORRECTLY AND INCORRECTLY CLASSIFIED INSTANCE FOR VARIOUS ML ALGORITHM

Table.6 shows error measurement parameter for evaluating MAE and RMSE. It is evident from figure.4 that KNN classification algorithm provides best performance as compared to other studied algorithm. KNN attains minimum error rate.

TABLE.6 ERROR RATE EVALUATION PARAMETERS OF MAE AND RMSE FOR SOIL SAMPLE DATA

Classifier	MAE	RMSE
NB	0.3526	0.4346
LR	0.333	0.5243
RT	0.2875	0.4946
KNN	0.2398	0.3908

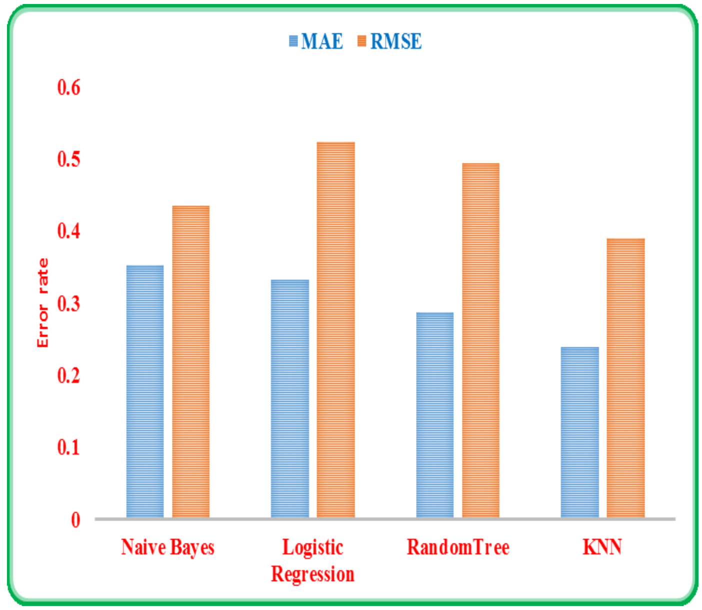

FIGURE.4 GRAPHICAL REPRESENTATION OF MAE AND RMSE EVALUATION

Table.7 shows error measurement parameter for evaluating RAE and RRSE. It is evident from figure.5 that RT classification algorithm gives best performance for evaluating RAE as compared to other studied algorithm. KNN classification algorithm gives best performance for evaluating RRSE when compared to other classifier. KNN and RT attains minimum error rate.

TABLE.7 ERROR RATE EVALUATION PARAMETERS OF RAE AND RRSE FOR SOIL SAMPLE DATA

Classifier	RAE	RRSE
Naive Bayes	100.807	105.051
Logistic Regression	75.6661	110.063
RandomTree	66.24	105.367
KNN	68.6783	94.1845

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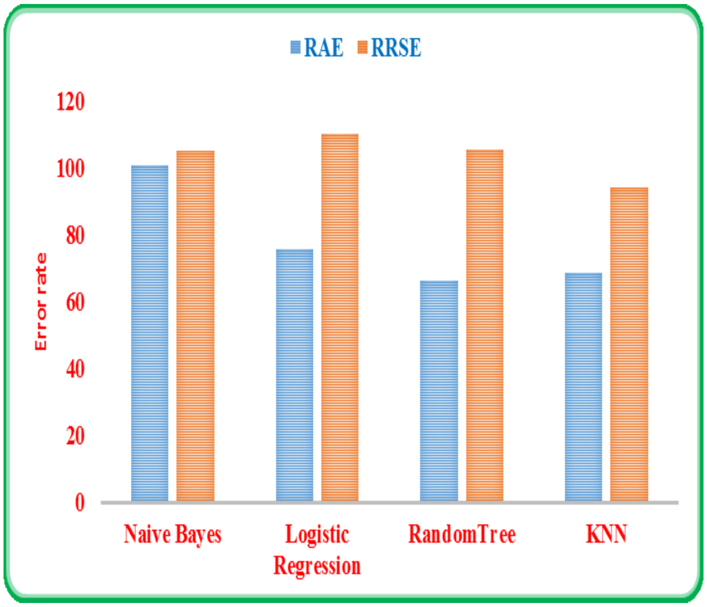

FIGURE.5 GRAPHICAL REPRESENTATION OF RAE AND RRSE EVALUATION

Table.8 and figure.6 shows eight parameters for evaluating accuracy of algorithms. KNN classification algorithm has performed better while compared to other traditional ML algorithms. KNN attains higher accuracy rate and minimum error rate. NB algorithm has second higher accuracy and it also have over all good performance.

TABLE.8 ACCURACY PARAMETERS FOR SOIL SAMPLE DATA

Classifier	TP	FP	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area
Naive Bayes	0.9090	1.0000	0.6670	0.9090	0.7690	0.1740	0.3640	0.6190
Logistic Regression	0.5710	0.3330	0.5710	0.5710	0.5710	0.2380	0.6510	0.5520
RandomTree	0.5630	0.2950	0.5190	0.5630	0.5300	0.2700	0.6830	0.5570
KNN	0.6670	0.0000	1.0000	0.6670	0.8000	0.7870	0.7690	0.7440

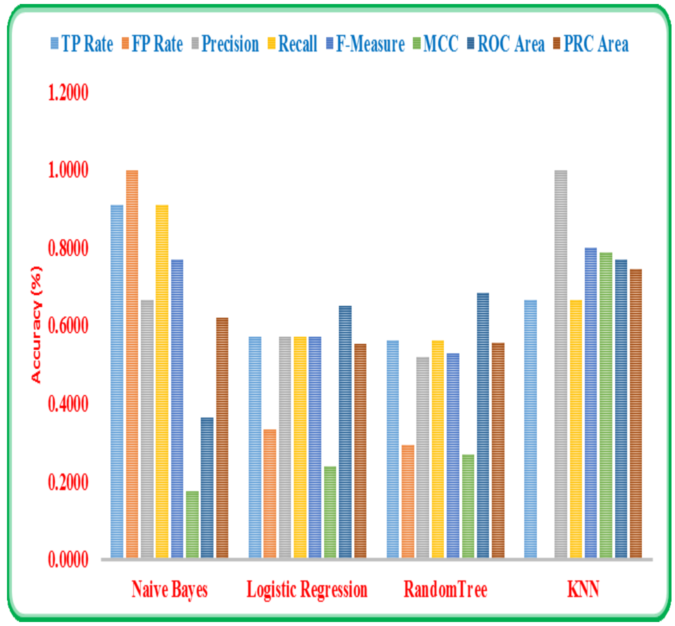

FIGURE.6 GRAPHICAL REPRESENTATION OF ACCURACY PARAMETERS FOR SOIL SAMPLE DATA

5. CONCLUSION

This suggested study activity intends to design an IoT-based system that takes into account many aspects that affect soil nutrient levels, which may affect agricultural output. In order to boost the real-time sensor use in agriculture, IoT needs to be enhanced using ML approaches. These system assists in making appropriate decisions and collecting information acquired from IoT sensors, which is then processed on the server and analyzed using ML algorithms. These classifiers can be analyzed and validated the level of micronutrient based on threshold classification. Based on these classification, KNN obtains the higher accuracy rate than the other classifier which can classified the correctly instance by 81.25% as same as LR. KNN classification algorithm gives best performance for evaluating MAE, RMSE, RAE, RRSE when compared to other classifier. KNN attains higher accuracy rate and minimum error rate. Hence, KNN attains 100% accuracy which is the best choice for agriculture and evaluated to agriculture growth. Therefore, this IoT application is quite easy and benefit for the farmers to understand the soil of their field. This notifies the farmer to plant a different crop in order to avert a loss. Further, this research work is enhanced to analyze and predict the factors affecting the growth of agriculture by stochastic model and explores the suitable parameters for increasing the growth of agriculture using strength of soil nutrients.

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