Developing an IoT-Based Data Analytics System for Predicting Soil Nutrient Degradation Level

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Developing an IoT Based Data Analytics System For Predicting Soil Nutrient Degradation Level

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Abstract

Globally, agriculture seems to be the economic field, which occupies a major part in India's socio-economic structure. The parameters such as soil and rainfall plays a major role in agriculture dependency. Farmers will usually have the mindset of planting the same crop by using more fertilizers and following the public choice. In agriculture, crop productivity will be increased with the incorporation of new technologies. The most commonly used smart farming technologies such as Internet of Things (IoT) has the tendency to process the generous quantities of data from these devices. In the recent past, there has been major developments on the utilization of Machine Learning (ML) in various industries and research. For this reason, Machine Learning (ML) techniques are considered as the best choice for agriculture, which is then evaluated to predict crop production for the future year. In this paper, the proposed system uses IoT devices to gather infomration such as soil nutrient level, temperature of atmosphere, season of the atmosphere, soil type, fertilizer used and water PH level periodically. Fturther, the data gathered from the sensor will be passed to a principal component analysis (PCA), which are used to reduce features in order to obtain a better prediction level. Also, ML algorithms such as Linear Regression (LR), Decision Trees (DT) and Random Forest (RF) are impelemented to forecast and classify the crop yield from the previous data based on soil nutrient degradation level and recommends suitable fertilizer for every particular crop.

Keywords—Internet of Things (IoT), soil nutrient, crop yield, agriculture

1. Introduction

In a country like India, agriculture is the most prominent sector that gives major income to the country. In our country around 60% of land is used for the agriculture and more than 50% of population depends on agriculture. In the developing countries like India, Agricultural automation can help to achieve an effective yield and reduce human intervention. In agriculture sector, many techniques and invention of novel technologies can be slowly degraded due to huge inventors, who are more focused on building artificial products that lead to a diseased life. At present, people are not aware of crop cultivation over the right time and place. Therefore, they lead to uncertainty in food due to seasonal climatic environments based on the cultivation, techniques are changed against the basic assets such as air, water and soil. Now-a-days, IoT is incorporated in various sectors. Being an agricultural country, India needs some innovations in the field of agriculture. IoT has an ability to transfer information with unique identifiers based on the interconnection between electronic networks such as physical devices, artifacts on a network without having a contact between user-to-computer or human-to-human. The agriculture parameters are utilizing the IoT technology and system availability that draw in these objects to assemble and deal with the information. IoT enables things that are selected, recognized or potentially forced and remotely crosswise over the completed process of existing configuration, manufacture open gateways for all the additional obvious merge of the substantial earth into PC based frameworks, in addition to acknowledging the overhauled capacity, precision and cash interconnected favored stance. Precisely, when IoT is extended with sensors and actuators, the improvement modify into an occasion of the all the extra wide category of electronic physical structures, which in like manner incorporates headways, for instance, clever grids, splendid homes, canny moving and smart urban groups. All is especially specific through its introduced figuring configuration anyway can interoperate within the current Internet establishment. Many researchers in agriculture field have recommended ML to predict plant type by IoT based system. For remote monitoring of the soil properties, an IoT based system is required. From all the web-enabled devices, IoT can collect, send as well as process the data, which is often referred as Internet of Everything (IoE). It can be acquired by processors, embedded sensors or even communication hardware from the external environment.The data gathered from the sensors along with the proposed framework assists in making correct decisions and further the information stored on the server are analyzed using ML algorithm. The sensor will sense the data from the crop yield based on the varying factors such as soil moisture, humidity, soil temperature, pH quality, etc. These parameters have a direct influence on the crop development and it is managed by IoT systems that are used to predict the crop species until a predictive decision has been taken to advance the end user. The utilization of sensor data based on farming activities in the year of 2016 – 2019 are illustrated in figure.1.

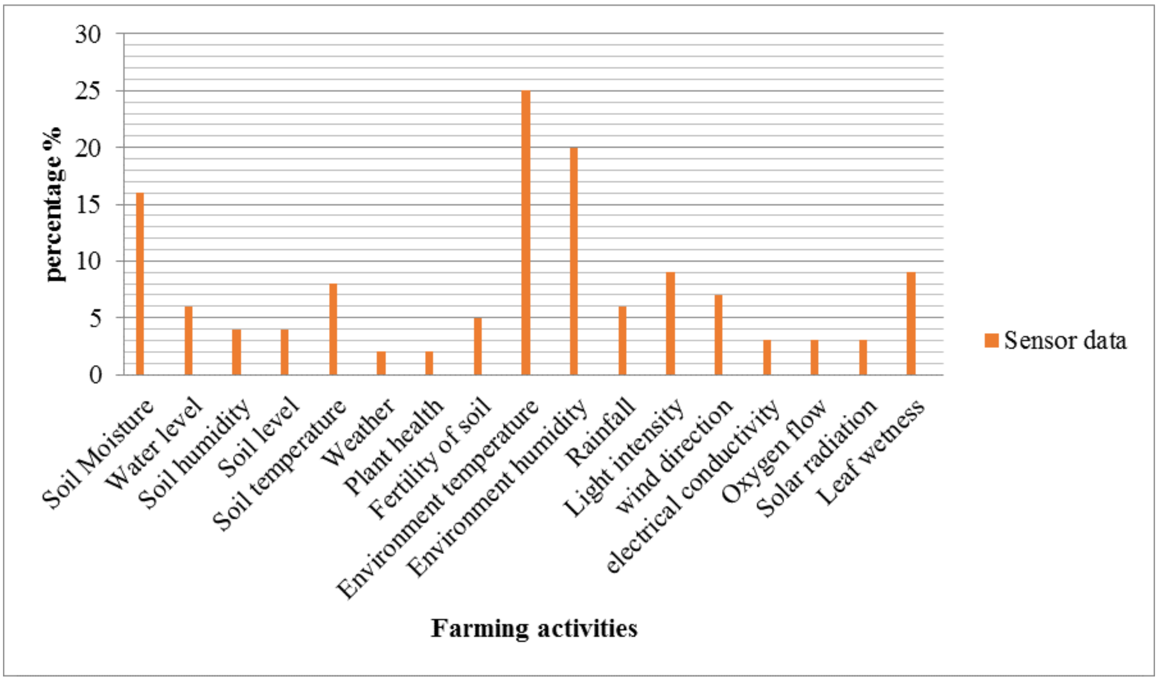

Figure.1 Utilization of Sensor Data based on Farming Activity

This intervention will be guiding the end user for further process. Then, it can be passed to a feature selection is otherwise known as variable or attribute selection. In this process, routine selection of the attributes are performed. Its less features becomes enviable because the model has less complexity results. ML is an area in the field of computer science, which has been the emerging technology based on Artificial Intelligence (AI). It focuses on systems programming, which can be developed to make data-based decisions and predictions.The crop was predicted based on the ML algorithms, which offers a better yield. This paper creates an effort to analyze the different ML and IoT techniques that are related to the agricultural sector in order to gather the soil nutrient level data, atmospheric data, and weather data. In this research work, a combination of ML algorithms are developed to predict the degradation in soil nutrient levels based on the past and current levels of nutrients in the soil, past and current levels of nutrients in the atmosphere, past and current weather conditions, and nutritional requirements for the crop planned at different stages of growth.

The organization of this paper is as follows. Section 2 describes the related survey regarding the technique based methodological contributions from the existing work, Section 3 defines the proposed methodology for predicting the degradation level of soil and finally Section 4 concludes the proposed work.

2. Literature Review

Bondreand Mahagaonkar [1] proposed the prediction of crop yield, which has main aim for creating a prediction model for future crop yield and it is evaluated by using ML techniques. Manjula et al.[2] investigates the soil nutrient supplements such as iron, zinc, calcium, nitrogen, potassium, magnesium, and sulphur, which are utilized by ML techniques namely Decision Tree(DT), Naïve Bayes(NB) and hybrid form of NB and DT approaches. The evaluation metrics of time and accuracy are compared with various classification algorithms based on the performance. Rohit Kumar Rajak et al. [3] described the techniques such as Support Vector Machine (SVM) and ANN, which are evaluated by using the specific metrics such as efficiency and accuracy and further it is applied to the collected soil testing lab dataset based on achievement of parameters to recommend a crop. This approach has been obtained from farm by soil database and the crop given by field experts. The drawbacks faced in this paper is less parameters are discussed which may not assist in generating better prediction of yielding the crop. The system proposed by Tatapudi and Varma [4] has to implement ML algorithms would integrate sensors such as soil temperature, soil Ph, soil humidity, moisture and rainfall for analyse the data from IoT device. In order to develop the productivity of smart farming based on these techniques, this work provides a better forecasting for farmers to recommend a crop in their field. In the proposed methodology, Kalman Filter (KF) is used with predictive processing and collect consistency data without noise for cluster-based Wireless System Network (WSNs) to relay the data. The method used for DT is otherwise known as predictive analytics based on weather forecasting seed identification and classification, prediction of crop field and disease for choice of learning. This platform integrates IoT components including cube based IoT Gateway and Mobius has to provide a crop growth monitoring solution to consumers [5]. Chlingaryan et.al [6] discusses technological developments for accurate crop yield prediction over the past 15 years in ML techniques. Rapid advancements in sensing technologies and ML techniques suggest to estimate of nitrogen status would offer cost-effective and comprehensive results for better yield based on environmental situation. The drawback faced in this paper is less optimized for targeted application of the sensor platform. Devi Prasanna and Rani [7] discuss the remote monitoring of soil properties using IoT which has potential to transform agricultural practices. And also, a ML model to predict the crop based on the soil properties which lead to increase the high yield productivity. RajaLakshmi etal.[8] developed an IoT based system using sensors to monitor the crop field. The researchers use the different sensors like soil moisture, light, temperature and humidity. The data collected from the sensors are sent to the micro controller, here it uses the arduino board and the data is stored in the database through the wireless transmission. The data will be processed in the last phase and the decision will be taken. If the values are below the expected level a message will be sent to the farmer. The drawbacks faced in this paper are much complexity of the hardware and significantly less efficiency. Patil et.al [9] proposes papers have given a rough idea about using ML with only one attribute which can improve the yields and several patterns are recognized for prediction. This system will be useful to justify which crop can be grown in a particular region. Oliveira et.al [10] presents the users with the ability to make strategic improvements such as selecting a more stable genetic variety before planting, or even modifying the crop type, to manage significant climatic differences that gets forward again in the crop cycle. In [11] the wheat crop safety was tracked using a smart phone captured by near-surface imagery. The crop has been categorized by computation as safe or unhealthy based on green level. In case of precision agriculture the application used sensors completely rely on either IoT based sensor or remote based sensing whereas IoT based sensor has utilized the multiple sensor for assessing the crop health and in the case of remote sensing based application some computation has been performed over spectral images to assess the crop health. A study on a framework for tracking the efficiency of indoor microclimate gardening has been addressed to Kaburuanet.al [12]. An IoT board of electronic sensors is deployed to track the growing process.Prado Osco et.al [13] paper proposes a system for predicting nutrient content in leaf hyperspectral measurements based on ML algorithms. The findings suggest that surface reflectance data is even more appropriate for predicting macronutrients for the Valencia-orange leaves, whereas first-derivative spectra are higher related to micronutrients.Balducciet.al [14] research is the design and implementation of realistic tasks, ranging from crop harvest forecasting to data restoration of lost or inaccurate sensors, leveraging and evaluating different ML approaches to determine where resources and investments can be focused. PA concept is the product of rapid advances in the IoT and cloud computing models, which incorporate context-awareness and real-time measures [15]. Wolfertet al. [16] and Biradaret al. [17] describe analyses of smart-farm sectors, while multiple discipline applications leveraging IoT sensors are explored in the works of [18,19]. The drawbacks of this paper ha provide less security system to the field as well as to yield. Table.1 discussed the comparative study various technology based agriculture using IoT

Table. 1 comparative study of predicting the agriculture using IoT

Year/Author	Technologies Used	IoT Sub Verticals	Data collection	Drivers of IoT	Solution for Current Issues
Athira et al (2017) [23]	ZigBee	1. Pest controlling 2. Weather monitoring	1.Soil moisture 2.Temperature 3.Water level	1. To avoid crop failure, anticipate and resolve drought conditions. 2. Continue to monitor climatic conditions.	1. Low cost 2. Efficient crop development 3. Plants are growing faster.
Mathew et al (2017) [24]	1. Raspberry pi 2. Mobile technology 3. Wi-Fi	Nutrient Management	1. Temperature in the climate. 2. Prosperous level 3. Nitrogen stage 4. Humidity degree	Can enhance the fertilizer amount.	1. If factors were observed. 2. Enhanced the volume of fertilizer.
Rajakumar et al (2017) [25]	Mobile technology	Crop production	1. Soil level 2. Soil nutrient	Interfacing different soil nutrient sensors.	1. Improve the harvest. 2. Control the costs of the agricultural product.
Pooja S et al (2017) [26]	1. Raspberry Pi 2. Wi-Fi	1.Weather Monitoring 2.Precision Farming	1.Temperature 2.Moisture 3.Soil 4.Light intensity 5.Vapor	Use of decision making algorithm.	1. Crop yield increased. 2. Reduced consumption of crops.
Jawahar et al (2017) [27]	1.Mobile technology	1.Crop management 2.Water Management	1.Temperature 2.Humidity 3.Soil moisture 4.Water level	Excess water from the area of agriculture was added to the tank.	Update the farmers with the field's living condition.
Tran et al (2017) [28]	1.ZigBee 2.Raspberry Pi	1.Crop management 2.Nutrient	1.Temperature 2.Humidity	1.Reduce the consumption of energy	1. Reduced use of electricity. 2. Must adapt to

		Detection		2.Increase the number of sensors	environmental and soil changes.
Viswanathan et al (2017) [29]	Wi-Fi	1.Crop management 2.Warehouse Management	1.Temperature 2.Wetness 3.Rain fall 4.Soil Moisture 5. Light intensity	1. Smart warehouse management	1. Costs eliminated. 2. More contact with people. 3. Strong trustworthiness 4. Increased production of crops.
Janani V et al (2017) [30]	1.Wi-Fi 2.Raspberry Pi	1.Soil Management 2.Nutrient Detection	1.Soil Measures: Soil pH , Soil Humidity, Soil Temperature	2. Soil management with the consideration of nutrient, fertilization	Reduces the question of finding the correct crop for the region.

3. Proposed Method

The proposed work emphases for predicting the degradation level of soil based on effective usage of IoT devices and choice of learning to choose the crop.This system analyzes soil nutrient levels based on various conditions including pasts and current soil level of nutrients present in the soil, current and past levels of nutrients present in the atmosphere, past and current whether conditions (local and global) from the meteorological data, and details of the nutrient requirements of the planned crop during every stage of its growth, the nutrient data will be gathered using appropriate sensors. The gathered data will be passed to a feature selection to obtain better prediction level and the classification of ML algorithms has to predict the soil nutrient level degradation if it is right for the farmer to start cultivation of that crop.The main aim of this paper is to develop a method which can forecast the type of crop depends on soil properties and weather which can recommends appropriate fertilizer to every specific crop. The proposed block diagram is as shown in figure.2. There are three main components used in the system.

1.IoT device – Radio Frequency Identification (RFID)

2. Feature Reduction using Principal Component Analysis (PCA)

3. ML algorithm for prediction

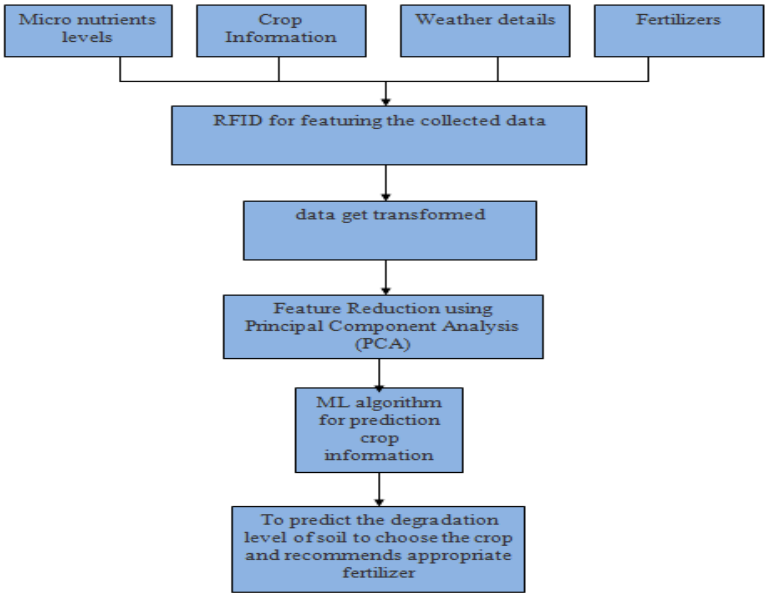

Figure.2 Flow Chart for the Proposed Method

In order to increase the crop's production rate based on the study, the farmer has to resolve on the process of choosing the finest crop for such a certain soil.

3.1 IoT Devices

According to the exponential growth in IoT systems and WSN applications, different communication standards have been implemented during the last few decades. Based on the bandwidth, battery timing, quantity of free channels, data rate, cost and other issues [20] of each protocol has its own requirements.

Sensors such as light, soil moisture, soil humidity, soil temperature etc. are used in IoT-based smart agriculture to monitor the field of the plants and improve the watering system. The farmers had the capacity to track field conditions from almost anywhere.This device can detect the soil micro nutrient levels using soil moisture sensor and monitor the details of weather based on soil nutrient level, fertilizer control, water PH and temperature for specific plant. All these devices have been used to track the plant, as well as to produce the information. The most widely used wireless networking protocols in IoT based agricultural applications are:

RFID

RFID systems are otherwise known as RF tag. It contains two components namely transponder and reader with very low radio frequency. This tag has reading characteristics with unique information and programmed by electronically. There are two tag systems are available in RFID technologies namely (i) active reader tag system and (ii) passive reader tag system. The systems of active reader tag utilize high frequency signals with high power consumption and it is highly expensive whereas passive reader tag has low power consumption. In [21] an RFID-based smart agriculture network based on IoT has been implemented. Soil nutrient level, temperature, soil moisture and water PH data obtained by sensor reading were included in the device and these readings have been sent to the cloud through RFID communication protocols.The sensor senses data from the crop yield for varying factors such as soil moisture, humidity, soil temperature, PH quality, etc. These parameters have a straight impact on crop development which are managed by IoT systems can be used to predict the crop species until a predictive decision has been taken to forward the end user. This intervention will be guiding the end user for further process.

3.2 Feature Reduction using Principal Component Analysis (PCA)

In this paper implanting the data into a low-dimensional linear subspace, PCA technique has been used to minimize dimensionality. The aim of PCA has highest variance to obtain the data [20]. Additional features are generated from grouping the existing features linearly [22].In the x-dimensional space, the instance of the data set would be mapped to y-dimensional subspace, so that x less than y. The set are generated y-new dimensions were being called Principal Components (PC).The PC is limited to the highest deviation are extracted because it has been identified in all of its previous elements. Therefore, the initial module covers the greatest variance, then each module which tracks to cover the smallest variance value. In this proposed work, the gathered data from the sensor will be passed to a PCA are used to reduce features in order to obtain better prediction level. There are numerous attributes in weather but PCA has attribute selection like humidity, temperature, moisture, rainfall etc. whereas in soil the PCA attribute selection like soil nutrient level, soil type, soil moisture, soil temperature etc. similarly, crop information the PCA attribute selection like seasonal crops, whole year crop, short time plantation crops etc. These significant features are extracted and then the ML algorithms are implemented to predict and classify the degradation level of soil to choose the crop based on soil nutrient level.

3.3 ML Algorithm for Prediction

ML is a common tool used to resolve agricultural issues. It is used to define useful classifications and movement patterns in the study of broad data sets. The ultimate purpose of the ML framework seems to be extracting the information from a collection of data and transform it into a comprehensible framework for further use. Fertilizer Recommendation can be done using fertilizer data, crop and location data. In this part suitable crops and required fertilizer for each crop is recommended. It can be used to display weather information, temperature information as well as humidity, atmospheric pressure and overall description.

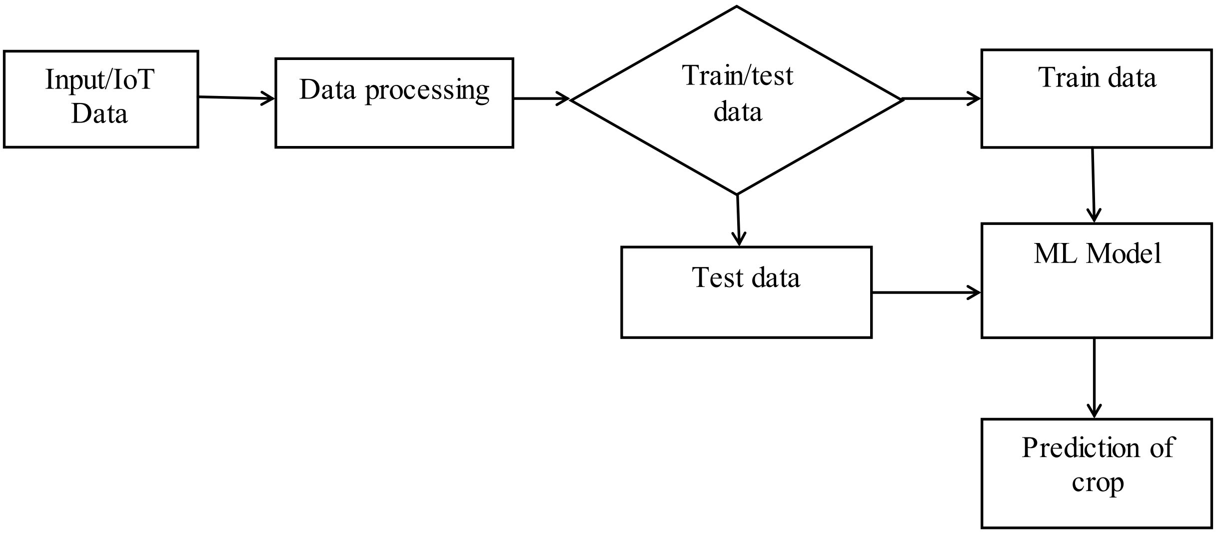

Figure.3 Block diagram of ML Algorithm for Prediction

In the above figure.3, sensors are mounted on the farm to detect soil humidity, soil moisture, rainfall, soil temperature, and PH-related data whereas ML algorithms have been used to classify sensed information. The results of the forecast demonstrate which soil is suitable for various crops and the soil quality.

1. Linear Regression (LR)

This study has been focused with several ML algorithm for predicting the crop and one of the basic regression algorithm is LR which is said to be simple LR whereas the single dependent variable datasets deals with simple LR but in the case of two or more dependent variables deals with multiple LR. The variables used for predicting the value dependent variable is said to be independent variables, Hence the LR model which consists of multiple predictor variable is known as Multiple LR model. Thus the expression of equation 1 illustrate the two predicted variables x1 and x2 are shown below

$$Y=\beta 0+ \beta 1\ x1\ + \beta 2\ x2\ + \epsilon \qquad (1)$$

$\beta 0$,1 , $\beta 2$ are coefficient of LR.

x1, x2 are independent variables.

The crop is able to predict accurately using crop prediction variables based on several dependent factors namely soil nutrients, historical crop production and weather. This study depends upon these variables that are considered as location dependents which influence the study to introduce user location need to be suggested as the input for the IoT system. Both these variables are dependent on the environment and so the user's position is used as an input to the system. Hence, this IoT system collects the soil properties from the soil repository over respective area in accordance with the current user location. Similarly, the technique used in weather parameters has been extracted from the datasets of weather and the crop gets cultivated only when suitable condition has been convinced. These involve major parameters associated with weather and soil. Moreover, these constraints have been compared and suitable crops gets verified using ML model as LR by predicting the crops.The prediction is completely depend upon previous history data of crop productions which assists in finding out the concrete parameter of weather and soil while comparing it with the present conditions that may aid in predicting the crop with high accuracy. The frequent crop prediction is beneficial using LR algorithm and the users are available with various suggestion of crop discussed about crop duration. This is achieved by applying ML algorithms like LR on agriculture data and recommends fertilizer suitable for every particular crop.

2. Decision Tree (DT)

DT is act as a classification algorithm which has performs one of the ML model and this model is a basic learning that operation as an educational decision making. Based on the various parameters, the model is generated from the data or investigations and the design is focused in identifying from the experienced example of usual rules. Hence, the mode of decision tree has executed two dissimilar tasks in accordance with weather the features of variable is constant or dissimilar but in the case of crop, the classification tree has assisted for generating regression tree.

3. Random Forest (RF)

RF is an algorithm for supervised learning. RF constructs and combines multiple DTs to achieve more accurate as well as stable prediction. RF searches for the most significant parameter of all when dividing each node, then it searches for the best of them from the sub-set of random features.It produces a paradigm that is more robust in large diversity. Within this algorithm only specific features for node separation are taken into consideration. The trees should be made more dynamic, using arbitrary thresholds for the function set instead of looking for the highest available thresholds. RF testing approach employs the general bootstrap strategy of combining, or bagging, to tree learners.

4. Conclusion

An IoT based approach to predict the level of soil nutrient degradation based on the past and current levels of micro nutrients, crop information, fertilizers and prediction of both past and current weather in order to planned crop's nutritional requirements. In the past, farmers used to suffer heavy losses due to poor quality produce due to degraded nutrient levels in the soil. The levels of nutrients may degrade due to various factors including wrong crop chosen without computing the later nutrient levels that will affect the yield. This proposed research work aims at developing an IoT based system that takes into various factors that impact the soil nutrient levels, which may impact the yield from the planned crop. This alerts the farmer to choos e an alternative crop to avoid a loss. This paper proposes a system to predict crop yield from previous data by applying ML algorithms like LR, Decision tree and Random Forest which recommends suitable fertilizer for every particular crop. The prediction of crop yield based on location and proper implementation of algorithms have proved that the higher crop yield can be achieved. From above work conclude that for soil classification Random Forest, linear regression and decision tree have achieved better accuracy compared to other ML algorithm. The work can be extended further to add following functionality. Mobile application can be built to help farmers by uploading image of farms. Crop diseases detection using image processing in which user get pesticides based on disease images. Implement Smart Irrigation System for farms to get higher yield.

References

[1] Devdatta A. Bondre and Santosh Mahagaonkar, " Prediction of Crop Yield And Fertilizer Recommendation Using Machine Learning Algorithms", International Journal of Engineering Applied Sciences and Technology, Vol. 4, Issue 5, ISSN No. 2455-2143, Pages 371-376, 2019.

[2] E. Manjula, and S. Djodiltachoumy, "Data Mining Technique to Analyze Soil Nutrients based on Hybrid Classification", IJARCS,2017.

[3] Rohit Kumar Rajak, Ankit Pawar, MitaleePendke, Pooja Shinde, Suresh Rathod, and AvinashDevare, "Crop Recommendation System to maximize Crop yield using Machine Learning", IRJET, Issue-12,2017.

[4] Ashok Tatapudi, P Suresh Varma, “Prediction of Crops based on Environmental Factors using IoT & Machine Learning Algorithms”, International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-9 Issue-1, November 2019.
[5] Patil, S., and S. R. “Internet of Things Based Smart Agriculture System Using Predictive Analytics”. Asian Journal of Pharmaceutical and Clinical Research, Vol. 10, no. 13, Apr. 2017, pp. 148-52, doi:10.22159/ajpcr.2017.v10s1.19601.
[6] Anna Chlingaryan, Salah Sukkarieh, Brett Whelan, “Machine learning approaches for crop yield prediction and nitrogen status estimation in precision agriculture: A review”, Computers and Electronics in Agriculture, Volume 151, 2018, Pages 61-69, ISSN 0168-1699.
[7] Valavala Nalini Devi Prasanna and Dr. B.Kezia Rani, “A Novel IOT Based Solution for Agriculture Field Monitoring and Crop Prediction Using Machine Learning” , International Journal of Innovative Research in Science,Engineering and Technology, Vol. 8, Issue 1, January 2019.
[8] R. N. Rao and B. Sridhar, "IoT based smart crop-field monitoring and automation irrigation system," 2018 2nd International Conference on Inventive Systems and Control (ICISC), Coimbatore, 2018, pp. 478-483.
[9] Pavan Patil and Virendra Panpati, “Crop Prediction System using Machine Learning Algorithms”, IRJET, Volume-07 Issue-02, Feb 2020.
[10]Igor Oliveira, Renato L. F. Cunha, Bruno Silva, Marco A. S. Netto.2018.”A Scalable Machine Learning System for Pre-Season Agriculture Yield Forecast” ,2018, IEEE DOI
10.1109/eScience.2018.00131
[11] Hufkens, K.; Melaas, E.K.; Mann, M.L.; Foster, T.; Ceballos, F.; Robles, M.; Kramer, B, “Monitoring crop phenology using a smartphone based near-surface remote sensing approach”, Agric. For. Meteorol. 2019, volume-265, pp:327–337.
[12] Emil Robert Kaburuan and RiyantoJayadia, Harisno, “A Design of IoT-based Monitoring System for Intelligence Indoor Micro-Climate Horticulture Farming in Indonesia” ,International Conference on Computer Science and Computational Intelligence,
ScienceDirect, 2019, pp: 459–464.
[13] Lucas Prado Osco et.al, “A Machine Learning Framework to Predict Nutrient Content in Valencia-Orange Leaf Hyperspectral Measurements”, remote sensing, 2020.
[14] Fabrizio Balducci, Donato Impedovo and Giuseppe Pirlo, “Machine Learning Applications on Agricultural Datasets for Smart Farm Enhancement”, machines, 2018.
[15] Sundmaeker, H.; Verdouw, C.; Wolfert, S.; PrezFreire, L, Internet of Food and Farm 2020, “In Digitizing the Industry—Internet of Things Connecting Physical, Digital and Virtual Worlds”, River Publishers: Gistrup,Denmark, 2016; Volume 2.
[16] Wolfert, S.; Ge, L.; Verdouw, C.; Bogaardt, M.-J, “Big data in smart farming a review”, Agric. Syst. 2017, 153,69–80.
[17] Biradarand, H.B.; Shabadi, L, “Review on IoT based multidisciplinary models for smart farming”,In Proceedings of the 2nd IEEE International Conference on Recent Trends in Electronics, Information Communication Technology (RTEICT), Bangalore, India, 19–20 May 2017; pp. 1923–1926.
[18] Ramya, R.; Sandhya, C.; Shwetha, R, “Smart farming systems using sensors”,In Proceedings of the 2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), Chennai, India, 7–8 April 2017; pp. 218–222.
[19] Yoon, C.; Huh, M.; Kang, S.G.; Park, J.; Lee, C, “Implement smart farm with IoT technology”, In Proceedings of the 20th International Conference on Advanced Communication Technology (ICACT), Chuncheon-si Gangwon-do, Korea, 11–14 February 2018; pp. 749–752.
[20] Al-Sarawi, S.; Anbar, M.; Alieyan, K.; Alzubaidi, M. Internet of Things (IoT) communication protocols. In Proceedings of the 2017 8th International Conference on Information Technology (ICIT), Amman, Jordan, 17–18 May 2017; pp. 685–690.
[21] Wasson, T.; Choudhury, T.; Sharma, S.; Kumar, P. Integration of RFID and sensor in agriculture using IOT. In Proceedings of the 2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon), Bangalore, India, 17–19 August 2017; pp. 217–222.
[22] Sumathi Doraikannan, Prabha Selvaraj and Vijay Kumar Burugari, “Principal Component Analysis For Dimensionality Reduction For Animal Classification Based On LR”, International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-8 Issue-10, August 2019.
[23] G. Arvind and V. Athira and H. Haripriya and R. Rani and S. Aravind, "Automated irrigation with advanced seed germination and pest control," in IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), 2017.
[24] A. Rau and J. Sankar and A. Mohan and D. Das Krishna and J. Mathew, "IoT based smart irrigation system and nutrient detection with disease analysis," in IEEE Region 10 Symposium (TENSYMP), 2017.
[25] S. Rajeswari and K. Suthendran and K. Rajakumar, "A smart agricultural model by integrating IoT, mobile and cloud-based big data analytics," in International Conference on Intelligent Computing and Control

(I2C2), 2017.
[26] S. Pooja and D. Uday and U. Nagesh and S. Talekar, "Application of MQTT protocol for real time weather monitoring and precision farming," in International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT), 2017.
[27] A. Roselin and A. Jawahar, "Smart agro system using wireless sensor networks," in International Conference on Intelligent Computing and Control Systems (ICICCS), 2017.
[28] R. Maia and I. Netto and A. Tran, "Precision agriculture using remote monitoring systems in Brazil," in IEEE Global Humanitarian Technology Conference (GHTC), 2017.
[29] M. Mekala and P. Viswanathan, "A novel technology for smart agriculture based on IoT with cloud computing," in International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (ISMAC), 2017.
[30] N. Ananthi and J. Divya and M. Divya and V. Janani, "IoT based smart soil monitoring system for agricultural production," in IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), 2017.