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Soil Classification & Prediction of Crop Status with Supervised Learning Algorithm: Random Forest

Original Article

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Crop Management System (CMS) was developed in an Ionic framework with a Real-Time Firebase database for loop backing and decision support. The main two features were; Soil classification where the soil was classified based on temperature, humidity, and soil properties such as soil moisture, soil nutrients, and soil PH level using Random Forest Algorithm. By Bootstrap method using Random Forest, samples from the dataset were selected & then classification trees was generated. The other feature was crop precision where the condition of the crop was and examined using temperature, humidity, soil moisture, soil PH levels, and soil nutrients (N, P, K). IoT device was used to fetch data from the field and then compare with already stored ideal values, suitable for optimal yield, in CMS database then process using the application to suggest the crop for cultivation and to optimize the usage of water and fertilizers. Currently, we classify the soil using Random Forest Algorithm & suggest the suitable crop for the classified type of soil & also measure the soil moisture and soil nutrients of agricultural field Acre based on the reading results we are suggesting the crop to is cultivated and pre-requisite which would be needed in future. The proposed method gives an accuracy of 96.5% as compared to existing methods of Artificial Neural Networks and Support Vector Machines.
Keywords: CMS; Crop Precision; NPK; Random Forest; Soil Classification.

Author's Contribution
All authors have contributed equally.

Conflict of interest
The authors declare no conflict of interest in publishing this manuscript in IJIST.

Project details. NIL

Introduction

As the world is trending into new technologies and implementations therefore it is a necessary goal to trend up in agriculture. Various types of researchtypes of research have been undergone to improve crop cultivation. Precision Agriculture (PA) will have an affected decrease in the the cost desired[1]. PA is a farming management concept based on measuring, and responding to inter and intra-field changeability in crops [2]. PA allows a farmer to recognize accurately for healthy crops, what parameters are required, and in what quantity at a specific period [3]. The crop selection is based on the environmental conditions of the area such as temperature, humidity, soil, and other parameters of soil like soil type, soil moisture, and soil nutrients [4]. All collected information needs to be analyzed to produce agronomic recommendations [5]. To improve crop productivity efficiently, it is necessary to monitor the environmental conditions in and around the field [6]. This information is along the features of the soil where the crop is planted for in-depth investigations [7]. The disamination of agricultural information at the correct time to a farmer guarante to enhance the output, production [8]. Classification of soil is important for the identification of soil properties. Soil is an important source of nutrients required by plants for their growth [9]. Soil classification helps to predict soil behavior, which helps to predict soil performance for growing agricultural crops [10]. Old-style classification systems contain the use of table and flowcharts [11]. This type of manual method takes more time; hence a fast, reliable computerized system for soil classification is required in order to ensure time\cost effectiveness.[12]. Climatic aspects only do not provide complete solution to determine the crop yield[13]. Although there are other aspects that reduce output to a cosiderable amount. To overcome this problem, automation must be implemented in agriculture [14]. Thus, to give a solution for every problem, it's essential to improve an integrated system that will deal with all perspectives which are influencing the production in each stage[15] [16].But due to various problem complete automation is agriculture is not achieved. The agricultural industry is one of the most significant aspects of the economic growth of a country, it is essential to bring automation in agriculture which comparatively improves the crop yield and supports in developing economies [17]. Automation deployment in agriculture leads to effective crop monitoring without human involvement in the field. IoT is the system of physical objects embedded with sensors, software, and electronic components like microcontrollers, as sensors and microcontrollers cannot be connected to the internet directly [18]

Figure 1. Precision agriculture tool for maximizing crop yield

IoT is being used in several real-time applications. Online crop monitoring using IOT supports the farmers/landlords to stay connected to their fields from any place and anytime. Several sensors are used to monitor and gather information about the field. Pakistan is originally known as an agricultural country, where the crop production depends on the interaction between plant and soil properties.Enhancement in crop production is reflected by the chemical, physical and biological conditions of the soil. Root absorbs the required quantity of water and nutrients from the soil where biochemical reactions take place [19]. However, proper distribution of fertilizers is required to achieved promised yield. How much amount of nutrients is required dependent on the condition of N P K fertilizers in the soil. Now a day's in Pakistan, the conventional method of farming is less profitable. Increased farming costs and low fertility of soil make farming low profitable and very difficult [20]. But with help of the latest farming technologies like precision agriculture, farmer can exercise practices efficiently. They can get three to four times more profit as compared to traditional farming [21].

Abdul Karim Mirjat et al. proposed Precision Agriculture & Crop Management System with Android Application & Web Development. The major form of this research was on the two most important parameters of agriculture which are soil content and Moisture. The results were calculated on basis of temperature, humidity, and soil moisture & these parameters are not sufficient for accurate results [22].

Prathibha et al. proposed IoT Based Monitoring System in Smart Agriculture. The proposed system reduces human activity such as daily visits to the crop fields because this system generates an MMS for the farmer on daily basis and it also allows users to check actual changes in crop yield [23]. MMS is a more costly messaging service and may not be supported on all phones.

Suma, N et al. proposed IOT Based Smart Agriculture Monitoring System that includes GPS-based remote-controlled monitoring, moisture & temperature sensing, intruder scaring, and security. It determines temperature, humidity, moisture, and intruder detection. This system cannot determine the NPK values to protect crops from damage.

Lee, Meonghun, et al. proposed agricultural production system based on IoT. Agribusiness is the order of cultivating and incorporates development based on dirt for the development of harvests and the raising of creatures to give sustenance, fleece, and different items.

S. Yoo et al. proposed A2S: Automated Agriculture System Based on WSN. Accuracy agribusiness (or exactness cultivating) presents the data and correspondence innovation into conventional techniques for horticulture and water system to advance the parameters which are utilized in an agrarian generation. Utilizing accuracy innovation, the point-by-point examination of the soil richness and yield information can be executed.

Serkan Balli et al. proposed Human activity recognition from smartwatch sensor data using a hybrid of principal component analysis and RF algorithm. The purpose of this research is to detect human movements as an important task in various areas such as healthcare, fitness, and eldercare. The data set to which the principal component analysis has been applied was classified by RF, support vector machine, C4.5, and K-nearest Neighbour (KNN) methods, and their performances were compared. The most successful result was obtained from the RF method [24].

ARİF ÖZYANKI et al. classified the soil by predicting LL & PI utilizing grain size distribution analysis values. Soil classification was determined using estimated values. In this models, 70% of the data was used for training, 15% for validation, and 15% for testing. As a result, 75 of 88 classifications were found to be correct soil classifications. This gives an accuracy of about 85% on training data. 18 of 20 classifications were found to be correct in soil classifications. This gives an accuracy of about 90% on test data. It is concluded that the accuracy ranges according to the previous study from 85% to 90% in soil classification.

Utpal Barman et al. processed the soil images to generate a digital soil classification system. Soil texture is the main factor to be considered before cultivation. Soil images are processed through different stages like pre-processing of soil images for image enhancement, extracting the region of interest for segmentation, and texture analysis. Support Vector Machine (SVM) classifier is used to classify the soil images using a linear kernel. The proposed method provided an average of 91.37% accuracy for all the soil samples [25]. This method is a very costly and time-consuming process.

N.Saranya et al. proposed "Soil Classification and Harvest Proposal Implemented using Machine Learning Techniques". A model is developed for classifying the soil series using suitable machine learning algorithms. A suitable crop type is suggested for a particular soil type. The proposed model require soil and crop datasets as input. They used SVM, KNN, and a Logistic

Regression algorithm to classify the soil types. Among them, the logistic regression has obtained the maximum accuracy of 88.5% using SVM, 92.3% using KNN, and 96.4% from Logistic Regression.

In previous research, authors process soil images and extracted the region of interest for segmentation, and texture analysis for feature vector using the SVM Authors used grain size distribution analysis values of soil to analyze Liquid Limit (LL) and Plasticity Index (PI) and based on LL & PI they classify the soil using ANN algorithm. We have used parameters, such as temperature, humidity, soil moisture, soil nutrients (N P K), and soil PH level to classify the soil using a Random Forest classifier to get more accurate results. The purpose of this paper is to facilitate farmers that they can produce a yield in good quantity as well as good quality. We also facilitate landlords to choose suitable crops based on the soil classification using the Random Forest (RF) algorithm.

Materials & Methods

In this section, we have discussed the proposed methodology in detail as below.

Data Acquisition:

The hardware shown in Figure 2 that contains the Arduino UNO board connected with the HC-05 Bluetooth Model, TCS3200 Color Sensor (NPK Tester), DHT22 Humidity and Temperature, LM393 Soil Moisture Sensor & Soil PH Sensor. Sensors were used to gather data from the field through Arduino UNO by getting commands using the HC-05 Bluetooth Module through the application. These components are useful for farmers to fetch accurate soil moisture details if the soil require water or not, to fetch how much N P K quantity available in the soil and what is the PH level of the soil.

1. **Arduino UNO:**

An open-source microcomputer well known as Arduino Uno is constructed on the microchip ATmega328P microcontroller & produced by Arduino. cc. This board is prepared with multiple analog and digital input/output (I/O) pins, as shown in Figure 3(a) that might interact with multiple extension shields (boards) and different circuits.

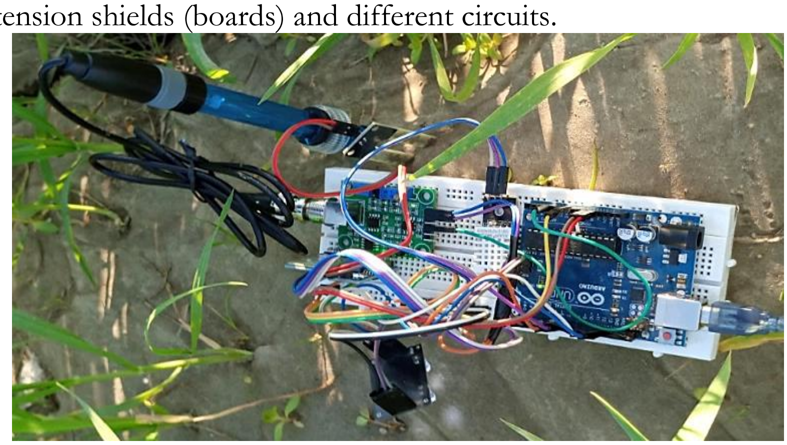


Figure 2. Hardware implementation

2. **HC-05 Bluetooth Module:**

Figure 3(b) shows the HC-05 Bluetooth module. This module can add full-duplex wireless functionality to your application and is a very cool module. With the usage of this module, you can communicate between two microcontrollers such as Arduino, or communicate with any other gadget with Bluetooth function such as a Laptop or a Mobile Phone.

3. **LM393 Soil Moisture Sensor:**

To detect the moisture of the soil, the moisture sensor is used which comprises two probes as shown in Figure 3(c). These two probes are covered with soaking gold that defends Nickel from corrosion. These probes are utilized to permit the current from the soil and then the sensor readout the resistance to acquire the moisture values (LM393 Soil Moisture Sensor, 2016).

(a) (b) (c)

Figure 3. Arduino uno, hc-05 bluetooth module, lm393 soil moisture sensor

4. **Temperature & Humidity Sensor:**

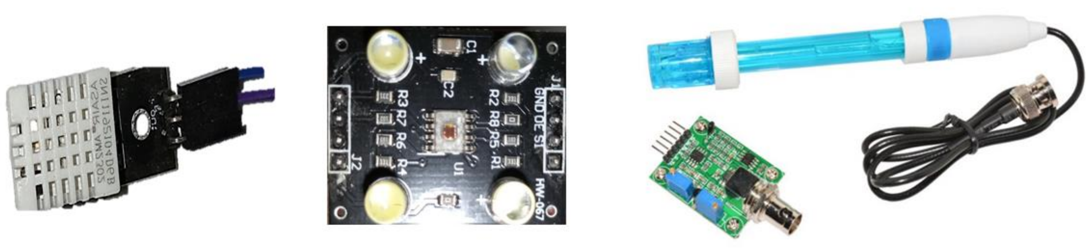
This module uses the DHT22 which is a joint temperature and humidity sensor assembly as shown in Figure 4(a). The DHT22 sensor is able to record a temperature between the range of -0 to 125℃ with an exactness of -/+ 0.5℃ and humidity between the full range of 0 to 99.9% with an exactness of -/+ 2%.

5. **TCS3200 Color Sensor:**

TCS3200 color sensor module is well-matched with Arduino, that contains 4 white LEDs and a TAOS TCS3200 RGB sensor chip as shown in Figure 4(b). This module's essential component is the TCS3200 chip which is a Color Light-to-Frequency Converter. To sense the object properly for the sensor, white LEDs are utilized that provide proper lighting. This chip can detect a broad range of colors and it provides the result in the form of consistent frequency.

6. **Soil PH sensor:**

To measure alkalinity or acidity of a solution, PH is investigated. The PH scale ranges between 0 and 14. The concentration of hydrogen [H] + ions present in certain solutions indicates by PH. It can precisely be capable by a soil PH sensor that computes the potential variance among two electrodes: an electrode of glass that is sensitive to hydrogen ions and a reference electrode (silver chloride or silver) as shown in Figure 4(c).



(a) (b) (c)

Figure 4. Temperature & humidity sensor, tcs3200 color sensor, soil ph sensor

Crop Management System:

The CMS (Crop Management System) application was developed in the Ionic framework and was is connected with the firebase database. The main two features of CMS are soil classification & crop precision. Soil Classification is where the soil is classified based on real-time values of temperature, humidity, and soil properties such as soil moisture, soil nutrients, and soil PH level with ideal values of the trained dataset using RF algorithm & crop precision. The condition of the crop is measured using real-time values of temperature, humidity, soil moisture, soil PH levels, and soil nutrients (N, P, K) with ideal values stored in the database with respect to (the WRT) query. The website was also developed for iPhone and android users Figure 5 shows the research methodology to conduct this research.

The most popular Machine Learning (ML) algorithm is RF which belongs to the supervised learning technique. It depends on the idea of ensemble learning, which is a method of joining different classifiers to tackle an unpredictable problem & to increase the performance of the model. Random Forest has some successful applications in different sectors are Credit Card Fraud Detection, Diabetes Prediction, Breast Cancer Prediction, and Stock Market Prediction. We used the RF algorithm to classify the soil because as compared to other algorithms, RF requires a small amount of time for learning and predicts high accuracy, it executes efficiently even for a big dataset.

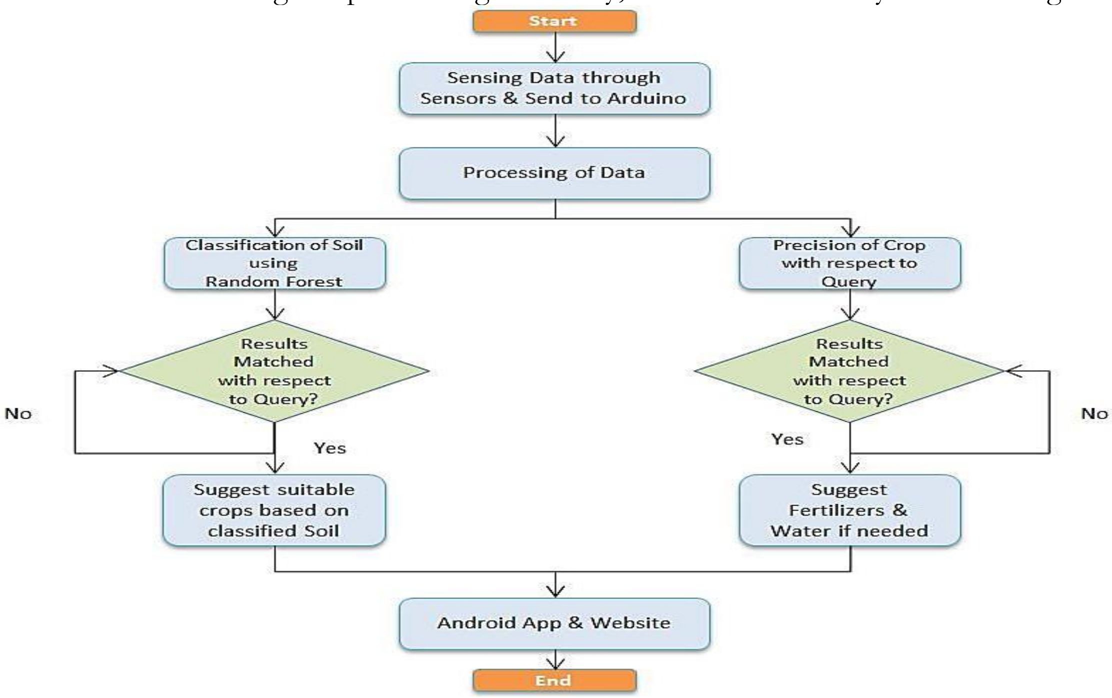


Figure 5. Research methodology to classify soil & predict crop status

The most successful result was obtained from the RF method [9]. By the Bootstrap method in RF, samples from the dataset are selected & then classification trees are generated. The decision tree involves N number of trees determined by the user during classification. The process used to generate each tree in the RF technique is essential in terms of determining the results. If the training and test for the dataset to be used in RF are not predefined, 2/3 of the entire dataset is used as training (In-Bag) and 1/3 used as (OOB, Out-Of-Bag) as shown in Figure 6.

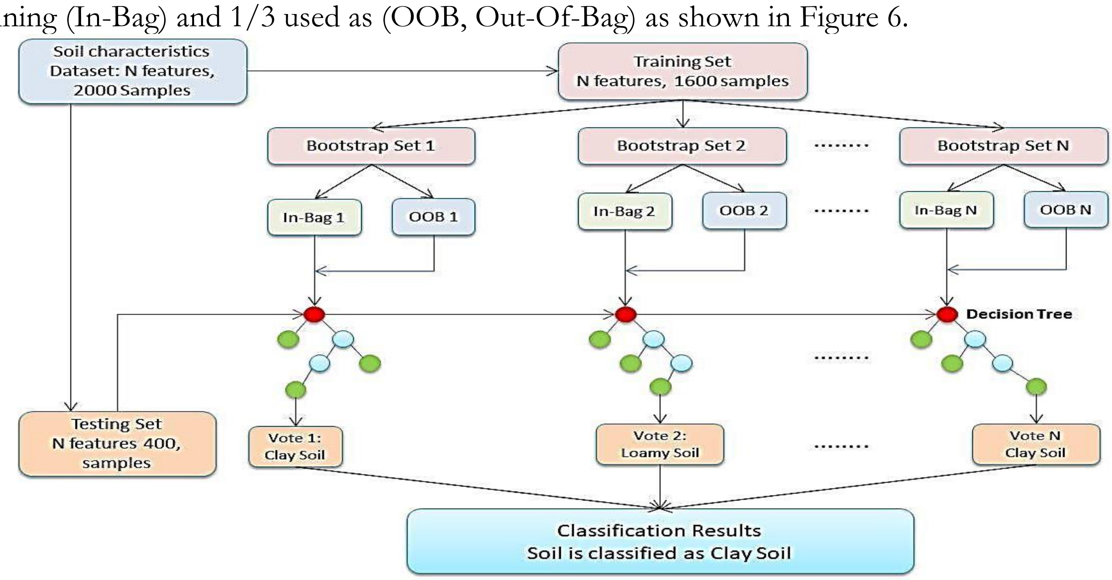


Figure 6. Random forest algorithm

The sample was generated using N bootstrap methods, and the In-Bag and Out-Of-Bag data was divided for each sample. The error rate was computed by analysis of all the trees with the separated OOB data, and then the OOB error of the decision forest was computed by taking the average rate of these errors. The parameters used by Artificial Neural Network (ANN) algorithm were the Plasticity Index & Liquid Limit of soil but the parameters used by RF are Temperature, Humidity, Soil Moisture, Soil PH Level, and Soil Nutrients.

Result & Analysis

The Figure 7 shows real-time data such as temperature, humidity, soil moisture, soil PH level & soil nutrients (N P K) sensed through the sensors that are embedded with Arduino UNO. This sensed data was further used by the application to precise the crop and classify the soil for a suitable crop. Using this approach, landlords and farmers can obtain the following outcomes:

- Suitable Crop Selection
- Crop Health Status
- Soil Moisture & Nutrients Quantities
- Efficient Cultivation
- Yield Quantities

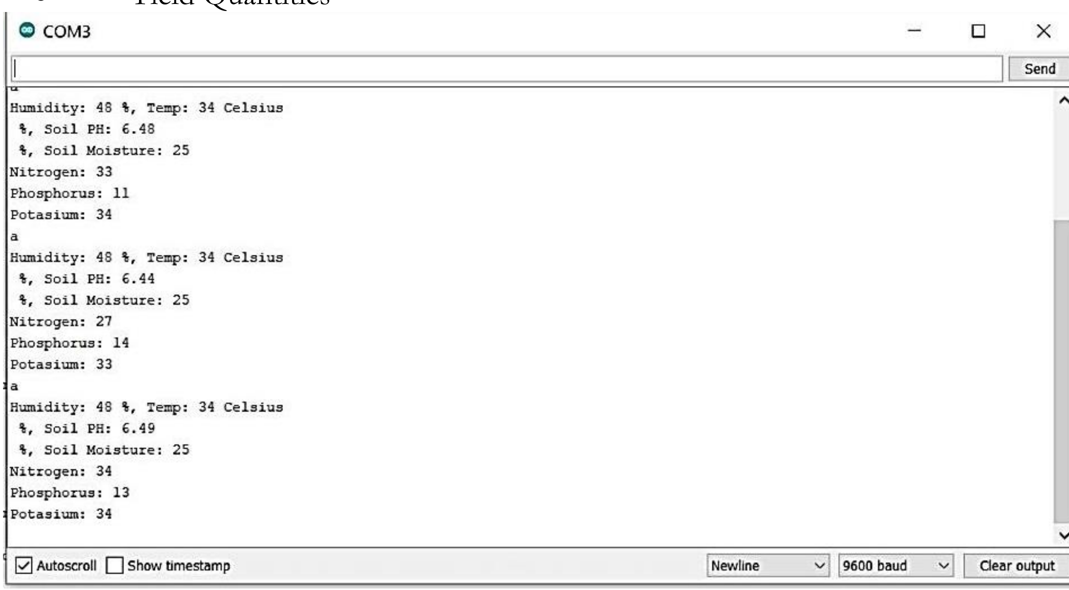


Figure 7. Real-time sensed data using arduino

The Figure 8 shows the Crop Management System(LMS) that stores crop data and provides basic information to landlords and farmers about soil and crops which they want to know. Agriculture experts can store and update the information about the crops as they discovered new diseases and their pesticides to overcome those diseases. The CMS was developed in the firebase database to store the crop data. The CMS was linked with the application to store real-time data monitoring. The ideal values, such as crop name, crop time period, season, temperature, humidity, soil moisture, soil PH level, nitrogen, phosphorus & potassium, and other fertilizers were stored in the CMS.

This android application play a very vital role in the recommendation of crop time for cultivation. The Android App and Website were developed and maintained to help Landlords and farmers to get information about the crops and what type of fertilizers what quantity they use and what time period they follow for provision of water, which soil is best for which crop.

By using this app, landlords and Agriculture Experts can register themselves by log in to the app and save different crop statuses in the database and can make temporal analysis for certain changes and in time analysis as shown in Figure. 9.

The Agriculture Experts can insert the data of pesticides used against diseases in specific crops depending and may get an appropriate solution as in Figure 10.

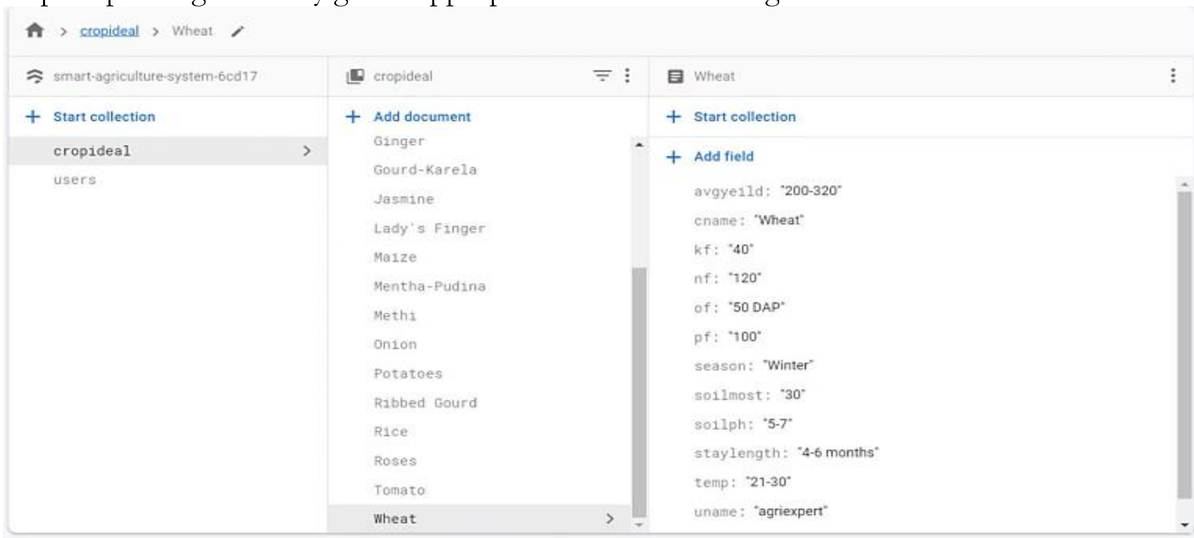


Figure 8. Firebase database of crop management system

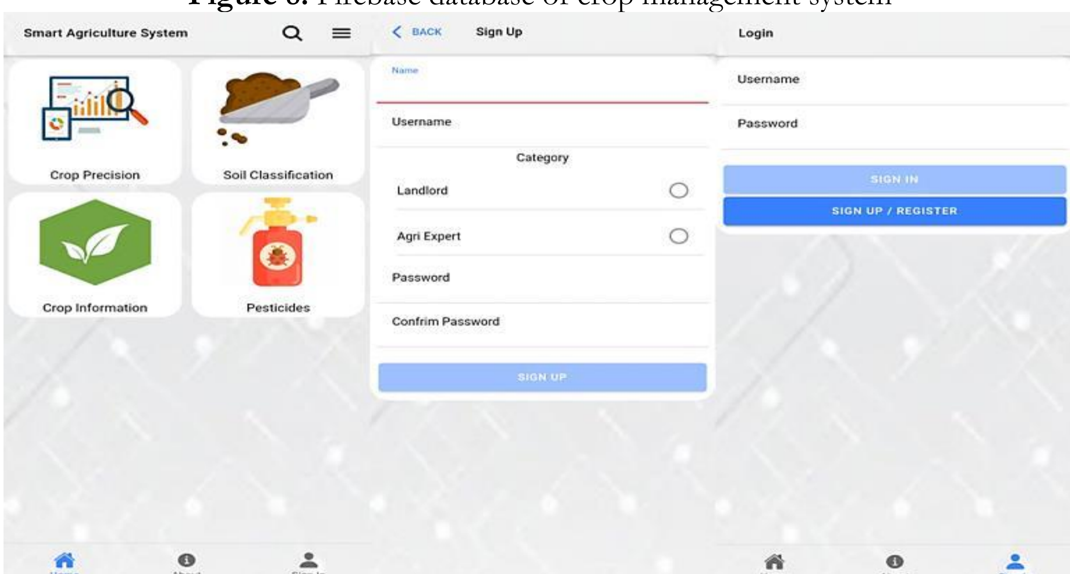


Figure 9. Android application – user registration

This application also helps estimate the contribution of a particular crop in regional economy through damage assessment. It is helpful for decision-making to take in time decision.

The classification method for import\export is the most essential part of the system as the algorithm's implementation occurs.Data is sensed through sensor nodes and stored in the database which is used as test dataset, In our case data was required from Sindh Agriculture University, Tando Jam, Pakistan, which was used as training dataset. The dataset was comprisesed of a total number of 2000 samples divided into 80% of training data and 20% of test data. The RF classifier was used to classify 6 different soil classes Clay, Chalky, Loamy, Silty, Sandy, and Peaty. Total of 430 soil samples belong to Clay Soil, 293 soil samples belong to Chalky Soil, 343 soil samples belong to Loamy Soil, 323 soil samples belonging to Silty Soil, 310 soil samples belong to Peaty Soil and 301 soil samples belong to Sandy Soil.

Firstly, RF read the dataset and the feature extraction took only necessary data from the test and train dataset. These features support cultivation to increase at all levels. The number of trees has been selected as 10. The next step is to train the model as RF Classifier. After training our model, we have passed real-time data from the system and our model predicts results as shown in

"Figure. 11.The classification accuracy has been calculated at 96.5% and the computational complexity on an HP Elite Book AMD PRO A10, 10 Compute Cores 4 CPU + 6 GPU of 1.8 GHz, 12 GB of RAM was 21 minutes. Using the below-mentioned formula, classification accuracy can be calculated:

$$Accuracy = \frac{TPos+TNeg}{TPos+FPos+TNeg+FNeg} \quad (1)$$

Where TPos is the number of true positives, TN is the number of true negatives, FPos is the number of false positives and FNeg is the number of false negatives.

$$Precision = \frac{TPos}{TPos+FPos} \quad (2)$$

Precision is denoted in equation (2) to give the relationship between the true positive predicted values and total positive predicted values.

The Figure 11(a) shows the real-time results of the Crop Precision of wheat based on Humidity, Temperature, Soil Moisture, Soil PH Level, and NPK nutrients showing the soil contains a low quantity.The Figure 11(b) shows the real time result of Soil Classification where the system classify soil as Loamy Soil and Figure 11(c) represents classification results as Clayish Soil.The most important thing is that the real-time application is also developed and implemented and is very beneficial to predict land to grow the desirable crop.

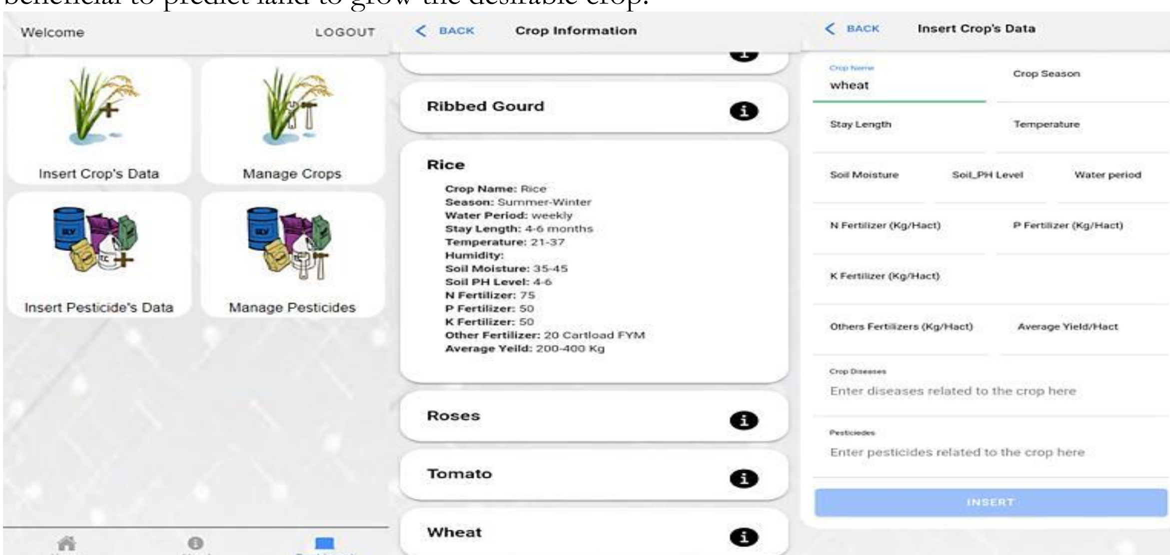


Figure 10. Android application – crop & pesticides management

According to Table 1, it is clearly that the more accurate results are obtained from the RF algorithm. We have obtained 96.5% accuracy from RF. Among the ANN, SVM, KNN, Logistic Regression, and RF algorithms, RF provides high accuracy. It can automatically balance datasets when a class is more infrequent than other classes in the data. The method also handles variables fast, making it suitable for complicated tasks. RF classifier accuracy is high because the RF classifier does not need feature scaling, and is more robust to the selection of training samples and noise in the training dataset. RF classifier is harder to interpret but easier to tune the hyperparameter [19]

As compared to ANN & SVM, RF is computationally less expensive and doesn't need GPU to get learning done. An RF can provide you with an alternate interpretation of a decision tree but with the best performance. RF technique preserves good precision even a big proportion of data is absent. RF requires less learning time. If there are more trees, RF won't allow over-fitting trees in the model. The comparative analysis demonstrates the excellent property of RF in terms of classification accuracy, stability, and robustness to features [20].For ANN [21], it requires a huge processing time for large neural networks. Learning ANN can be slow. Limitations of the SVM [22]are the functional speed of the machine in training and testing, slower convergence rate at the testing phase, choosing good quality kernel parameters, and large requirements of memory space to implement the model.

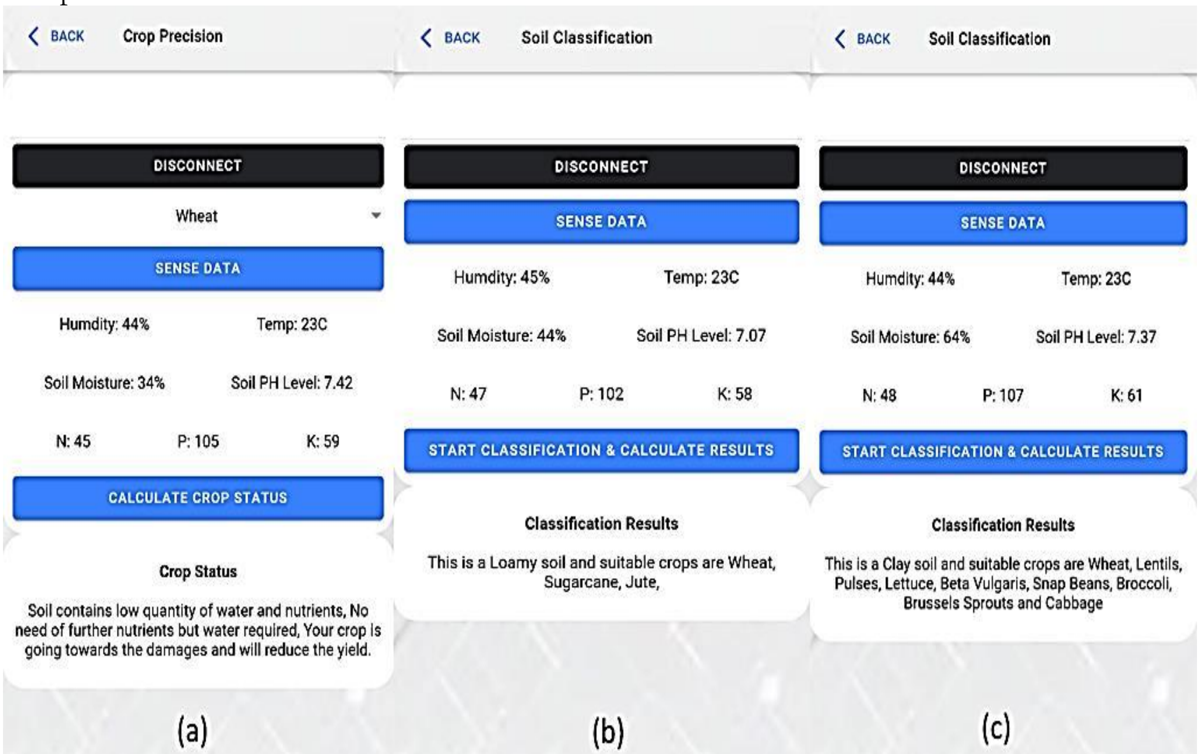


Figure 11. Android application – real-time results of crop precision & soil classification

Table 1. Performance of the model

Method	Accuracy	Precision
Artificial Neural Network (ANN)	90%	96.71%
Support Vector Machine (SVM)	91.7%	96.94%
K-Nearest Neighbor (KNN)	92.3%	96.6%
Logistic Regression	96.4%	95.5%
Random Forest (RF)	96.5%	98.31%

Conclusion

Major outcomes of the proposed system are that the proposed system recommends the crops on the basis of the soil properties as well as the number of fertilizers on the basis of the crops and Soil properties . The android application and websites have recommendation for pesticides against diseases. Furthermore, in our research, the real-time data will be captured through the different sensors from the different fields would be stored in the CMS database, after storing the real-time data in the CMS the next step is to process using Android Application as well as for the website and finally calculating the results that what is current crop condition and which is suitable crop according to the soil properties. Random Forest classification provides 6 different soils types as with accurate result to it has methods for balancing errors in data sets where classes are imbalanced. By using this system, farmers can improve crop production. In future work, suitable fertilizer will be suggested for soil type which will also increase the growth of the crop.

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