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Multidisciplinary Model for Smart Agriculture using Internet-of-Things (IoT), Sensors, Cloud-Computing, Mobile-Computing & Big-Data Analysis

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Abstract

Although precision agriculture has been adopted in few countries; the agriculture industry in India still needs to be modernized with the involvement of technologies for better production, distribution and cost control.

In this paper we proposed a multidisciplinary model for smart agriculture based on the key technologies: Internet-of-Things (IoT), Sensors, Cloud-Computing, Mobile-Computing, Big-Data analysis. Farmers, Agro-Marketing agencies and Agro-Vendors need to be registered to the AgroCloud module through MobileApp module. AgroCloud storage is used to store the details of farmers, periodic soil properties of farmlands, agro-vendors and agro-marketing agencies, Agro e-governance schemes and current environmental conditions. Soil and environment properties are sensed and periodically sent to AgroCloud through IoT (Beagle Black Bone). Bigdata analysis on AgroCloud data is done for fertilizer requirements, best crop sequences analysis, total production, and current stock and market requirements. Proposed model is beneficial for increase in agricultural production and for cost control of Agro-products.

Keywords: *Internet-of-Things, Cloud Computing, Big-Data Analysis, Mobile Computing, Sensor, Smart Agriculture*

1. Introduction

Internet-of-Things and Big-Data analysis are recent technologies from last few years and applications are being developed in various domains using these as key technologies. Sensor technology has also been advanced and many types of sensors like environmental sensors, gas sensors are developed and used in applications as per the need. Cloud-Computing and Mobile-Computing are mature technologies and applications exists in almost every field using those technologies. Uses of these technologies in the field of agriculture are also introduced and are used for improvement in this sector.

1.1 Internet of Things (IoT), Wireless Sensor Networks and Sensors

Internet of Things is a technology which tends to connects all the objects in the world to the Internet. It involves the use of RFID, wireless and other sensors with Internet stack inbuilt into the device. Applications are developed based on IoT enabled devices for monitoring and control in various domains including industrial processes, home appliances, health monitoring applications, smart homes, smart cities [4,5,11,16,30,33]. In agriculture domain few researchers have proposed architectures based on IoT to monitor supply chain management of agricultural products [6,7].

Wireless Sensor Networks is said to be mature technology and lot of work has been done for agriculture domain [35, 44]. Sensors are available for sensing and analysing the various parameters that are required in agriculture domain. Many applications are in use which utilizes sensors in agriculture [13,15,20,21,22,23,24,25,26,27,28,29, 35,49]. WSN architectures were proposed, implemented and tested for monitoring the soil properties.

1.2 Mobile Computing

Mobile computing has affected lots in number in our day to day life due to its availability and has a cheaper cost of communication. It is in use in almost every field including agriculture sector. System based on mobile computing has been proposed for sending daily, seasonal messages to farmers regarding the product information and weather information in [53].

1.3 Big-data and Big-Data Analytics

Big-data is a massive amount of data collected from different sources and for longer period like sensor data, social networking data, and business data. The major challenge is capture, storage, analysis, search [54]. It is in use for business data processing along with big-data analytics to search for hidden patterns in the data. Big-data in agriculture domain [10] is used for supply chain management of agro products, to minimize the production cost.

1.4 Data Mining, Analysis and Knowledge Building

Data mining is process of analysing data to find some patterns hidden in the data. Data mining for agriculture sector have been the topic of research for many years **[9, 38, 39, 41, 42, 45, 46, 47, and 48**]. Data mining have been used for analysing the soil types and properties to classify them. Also soil data mining is useful for crop prediction and deciding the better crop sequence based on previous crop sequences in the same farmland with the current soil nutrient information.

1.5 Cloud Computing

Cloud computing provides sharing of resources with cheap cost [54]. Cloud computing service provider offers services like Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) with cheap cost. Cloud computing has been used for storage of agriculture data [8, 37]. It has been used in agriculture sector along with IoT [2, 3].

1.6 Agriculture Industry in India:

Agriculture is the major source of income for the largest population in India and is major contributor to Indian economy. However technological involvement and its usability still have to be grown and cultivated for agro sector in India. Although few initiatives have also been taken by the Indian Government for providing online and mobile messaging services to farmers related to agricultural queries, agro vendor's information to farmers [53], it provides static data related to soil quality at each region. The system which utilizes real time data of soil quality based on its current properties for decision making has not been implemented. Soil properties determine the quality of soil. The soil pH value and amount of properties like Nitrate, Phosphate and Potassium in the soil is an important factor which determines the soil quality and type of crop production. Real time monitoring of these properties helps to maintain soil health intact by applying only required amount of fertilizers. Soil moisture analysis helps to apply the water whenever necessary avoiding wastage of water. Also environmental conditions such as temperature and moisture also affect the crop production and crop diseases. In this respect we need a dynamic model which collects such real time data. In support to this; all agriculture entities need to be connected to have decision making system to increase the production and ease the distribution of agricultural products from farmers to marketing agencies and from vendors to farmers. Such system will also be responsible for controlling other parameters like agro product rates.

Smart mobile phones are available now days to many users including in the rural areas. Beagle black bone is a cheap IoT device which can be interfaced to soil and environmental sensors to collect soil properties and current environmental conditions. This motivates to develop a cost effective and portable sensor kit for sensing the soil properties for current requirements of fertilizers. The soil data from farmlands needs to be collected through sensor kit and sent to AgroCloud storage for further processing. The collected big-data then

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can be analysed for the required actions for production.

2. Related Work

Researchers have proposed different models for agriculture sector with one or multiple technologies mentioned above.

Use of IoT has been proposed in agriculture domain in [1, 6, and 7]. In [1] authors have described FMS architecture which utilizes Future Internet characteristics. The farmers will get Easy access to information and advice through this architecture. In [6, 7] IoT has been used for product supply chain business process. In [2, 3] IoT and Cloud computing have been used for agriculture sector. In [2] authors have explained this in the context of service providers and supply chain for cost effective services for farmers. In [3] authors have described controlled architecture of smart agriculture based on IoT and Cloud Computing. Use of cloud computing for agriculture sector for storing details of agriculture information has been explained in [37]. Cloud storage stores work history information, fertilizers distribution, cultivation images through camera and environment information collected through sensors, collection and recording information. Authors have analysed the collected data for correlation between environment, work and yield for standard work model construction. Monitoring for adverse signs and fault detection. In [8] authors have used image processing on crop images for crop disease detection and image data is stored on the Cloud.

In [9] an approach is proposed based on artificial neural networks to predict crop yield by sensing soil properties and atmospheric parameters. Big-data technology in agriculture domain and how it will affect the cost reduction and benefits is explained in [10]. Challenges in agriculture sector and remote sensing applications are discussed in [13] which include crop estimation and cropland mapping. In [15] authors have designed and implemented a wsn based on soil temperature, humidity monitoring system for agriculture using ZigBee and GPS technologies for the operation. In [24] authors have proposed development of rice cropping monitoring system for real time monitoring to increase rice production. This system makes use motes with external sensors for leaf wetness, soil moisture, soil pH, atmospheric pressure sensors attached to it. PH values are sent to the farmer from base station via GSM modem in the SMS form. Using the pH values farmer can decide the amount of fertilizers to be used. IoT with data mining is discussed in [32], the data generated from IoT and applying various data mining techniques on this data. Authors have also discussed changes required for data mining in IoT perspective along with issues and future trends.

WSN based greenhouse environment monitoring system is explained in [35] which makes use of temperature, humidity, CO2 and light detection modules. This combined wsn technology and greenhouse control technology provides automatic adjustment of greenhouse.

Bigdata applications in data mining are explained in [36]. In [38] authors have surveyed data mining techniques to find most effective techniques to extract new knowledge and information from existing soil profile data contained within soil data set. They have described data-mining techniques suitable for different prediction in agriculture. Crop yield estimation using existing data through data mining is proposed in [39]. For this they have utilized four attributes namely year, rainfall, area of sowing and production. In [41] authors have analysed data mining algorithms to predict crop yield with more accuracy and generality using existing data. E-agriculture information system for farmers to provide information of current schemes for agribusiness and information regarding the plantation is proposed in [43]. In [44] authors have reviewed WSN technology and applications in agriculture domain. Authors have also discussed existing frameworks in agriculture domain. The application of WEKA-based data mining and analysis model is discussed in [45]. Authors have discussed use of machine learning algorithms through a case study in agricultural domain for mushroom grading process. In [47] authors have explained the use of spatial data mining in agricultural domain. They have used K-means algorithm along with optimization method progressive refinement for spatial association analysis. Temperature and rainfall is given as initial spatial data and analysing it for the improving the crop yield and to reduce the crop losses.

Although researchers have proposed few models in agriculture domain using one or more of the technologies mentioned; the dynamic model is needed that provides an integrated approach to:

1. Monitor various soil properties from each farmland and environmental conditions periodically through portable cost effective IoT device and usable by multiple users, enquires about crop production details to the farmers after crop harvesting and stores these details at the central place as in the cloud storage. This in result producing Big-data over the time and will be analysed for fertilizer requirements for current crop, mapping of crop production to soil properties

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at that time, next crop to be cultivated etc. This will be helpful for increase in production.

2. Connect all agricultural entities together including farmers, agro marketing agencies, agro product vendors and Ministry of agriculture and AgroBanks. This will facilitate distribution of products from farmers to buyers and from agro vendors to farmers. Through the Ministry of agriculture farmers will be able to get notifications about new schemes announced by the government for agriculture sector.

3. Proposed multidisciplinary model for Smart Agriculture

The proposed architecture of multidisciplinary model as shown in figure 1 consists of the five modules:

1) SensorKit Module.

2) MobileApp Module.

3) AgroCloud Module.

4) Big-Data Mining, Analysis and Knowledge Building Engine Module.

5) Government & AgroBanks UI

SensorKit module is portable IoT device with soil and environment sensors. MobileApp module provides interface to the users. AgroCloud Module consists of storage, Big-Data mining, analysis and knowledge building engine and application module to communicate with the users. Government and AgroBanks user interface is an web interface for information related to agricultural schemes and loans.

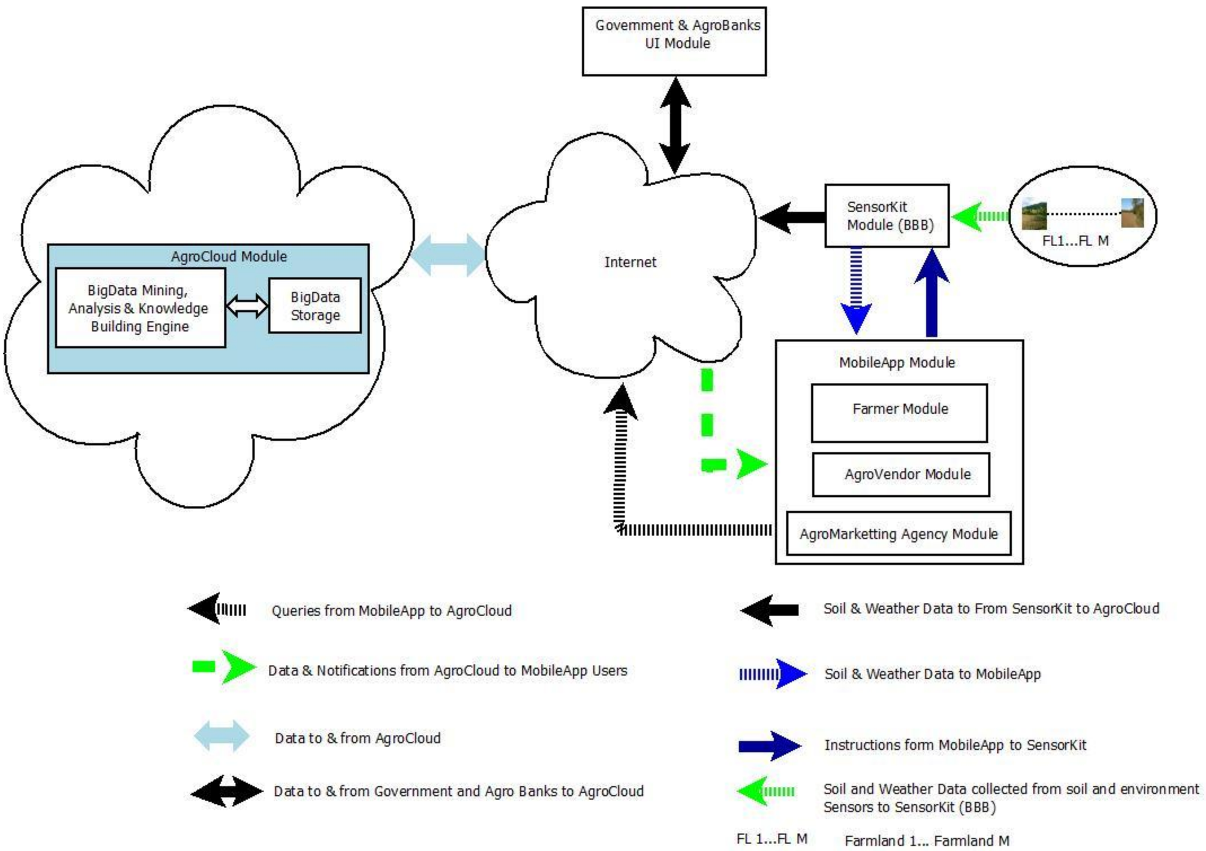

Figure 1: Proposed Architecture for Multidisciplinary model for Smart Agriculture

3.1 SensorKit Module

This module is an important part of this architecture and is responsible for soil sampling at periodic intervals to get soil property values.

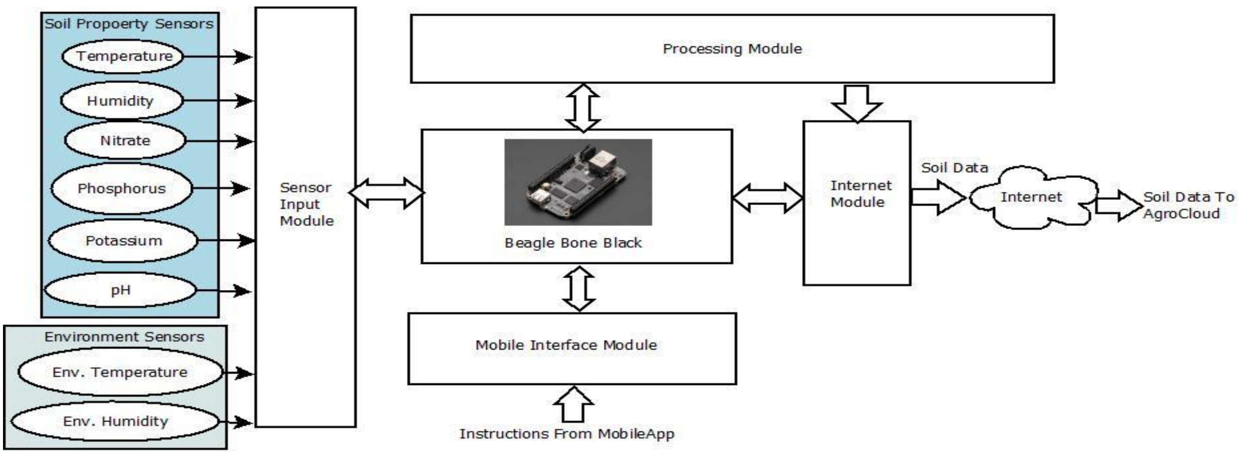

Figure 2: SensorKit Module.

Figure 2 shows SensorKit module. SensorKit is a cost effective and portable kit in which we have considered the use of beagle black bone which is IoT enabled device with memory and processing capability, GPS sensor to detect the positional information. The major components of this kit are soil nutrient sensor devices connected to it. Soil attributes sensors we have considered for this model are soil pH sensor, soil moisture sensor, Phosphorus (P), Potassium (K), Nitrate (N) sensors which are interfaced to the IoT device.

3.2 MobileApp Module:

Mobile applications need to be installed on the end users mobile phone. It has three parts

a. UI for farmer
b. UI for agro marketing agency
c. UI for agro vendors including fertilizer, pesticide providers and seed providers.

Initially the end user has to register to the mobile app with few credentials including identity information, user type, address, geographical locations and other necessary details. If end user is farmer then has to send few credentials regarding the farmland information consisting of approximate location and total area for each farmland. The soil information per farmland is gathered through SensorKit. SensorKit gets the required instructions from MobileApp. The information will be sent and stored on AgroCloud Big-Data storage. SensorKit also collects and sends the soil information to cloud storage when the crop cultivation is in progress. Through these app farmers get suggestions regarding the fertilizers required and its amount for better crop results and cost savings. This app is also used for sending the notifications to the users. When the crop is harvested, the total production information for each crop will be sent to the cloud storage from the farmer along with current soil characteristics after cultivation of that crop. This information is stored in the cloud storage along with the time-stamp details.

Agro marketing agencies responsible for purchasing harvested crops from farmers has to send the periodic updates related to changes in cost and their purchase requirements. Agro product vendors are responsible for selling fertilizer, seed, and pesticide and agricultural equipment's. Agro vendors have to send updates related to products and cost changes periodically. Mobile application module is shown in figure 3.

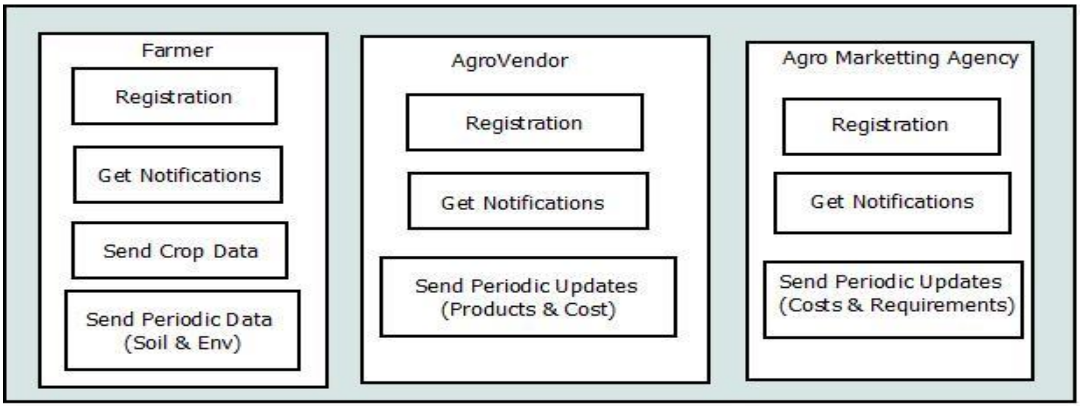

Figure 3: MobileApp Module.

3.3 AgroCloud Module

All the users of agriculture sector needs to be registered to AgroCloud through MobileApp. AgroCloud storage consisting of Big-Data storage will store all the details of farmer, agro marketing agent details, and agro vendors and service providers (fertilizer/pesticide/seed and agro equipment providers) details and government schemes for agriculture sector including bank loans for farmers and concessions given on seed and/or fertilizers.

This module also stores periodic data collected through soil and environment sampling. As larger and larger number of end users gets connected to this service and the data size grows rapidly over the time resulting into the Big-Data. The AgroCloud module with Big-Data storage, Big-Data Mining, Analysis and Knowledge Building Engine and application module is shown in figure 4.

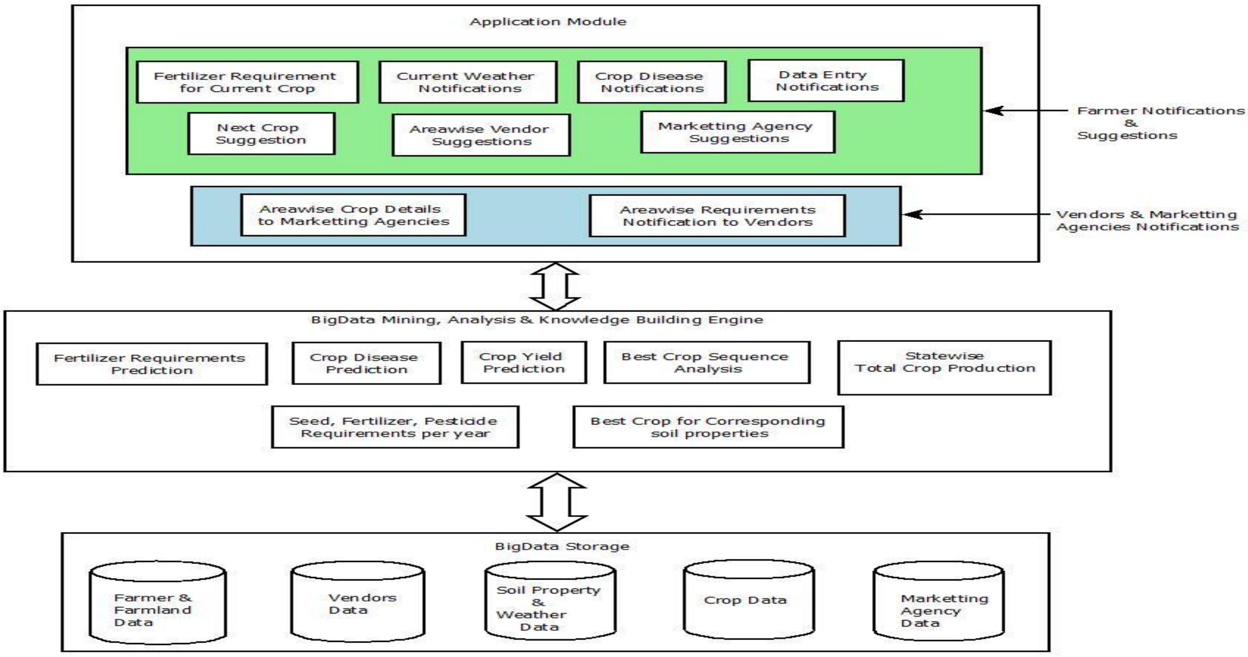

Figure 4: AgroCloud Module.

3.4 Big-Data Mining, Analysis and Knowledge Building Engine

This module resides at AgroCloud and as shown in figure 4 plays important role in decision making for the fertilizer requirements for current crop based on current soil properties for better yields, crop disease prediction based on current soil properties and current weather conditions, crop yield prediction, best crop sequence analysis from the data collected over the period, best crop for corresponding soil properties, watering required based on soil moisture level. This database also provides information of region wise crop production details for each crop, total crop production for each crop in the state, based on this and current requirements for the consumers will be helpful to control the costs for each agro product.

As this database collects information over the years for soil properties and crop information details with its production amount for each farmland, inference results with data mining can be calculated for better crop sequences to be carried for best production and to preserve good soil health. As well as this database can provide suggestions to the farmers for crops to be taken on the farmland with peculiar soil properties based on previous stock of agro products and current requirements in the market. Bigdata analysis can be carried out to estimate future production of each product based on previous knowledge base.

Application module at the cloud storage is used for sending the notifications to the users, suggestions based on analysis, crop disease notifications based on current weather conditions and previous knowledgebase.

3.5 Government and AgroBanks UI

Through the user interface of this this module ministry of agriculture will be able to provide the details of recent schemes and subsidies for farmers and agriculture sector. Agricultural banks also provide the details of loan schemes through the UI. All these details will be stored on the AgroCloud storage and farmers and other beneficiaries who are registered on the AgroCloud storage will get this information through notifications when the schemes and subsidies are announced without physically visiting and enquiring to the government offices.

4. Conclusion and Future Work

In this paper we have proposed a multidisciplinary approach for smart agriculture using five key technologies: Internet of Things, Sensors, Cloud Computing, Mobile Computing and Big-Data Analysis. Through real time sampling of soil farmer will be able to get current fertilizer requirements for the crop. This is an essential requirement towards agriculture sector in India to get improved crop production with reduction in cost of fertilizer requirements keeping soil health intact. As the data is collected over the years for crop details and soil conditions, this model provides Big-Data analysis for best crop sequence, next crop to be cultivated for better production, total crop production in the area of interest, total fertilizer requirements, and other data of interest can be analysed. As all the agriculture related entities are connected together, this will also facilitate the distribution of harvested crops to the agro marketing agencies and farmers will also be able to get required agriculture products and services from agro vendors. This model also facilitates the estimates of total production per crop region wise and state wise, total fertilizer requirements. This will be helpful to keep the cost of agricultural products in control. Through notifications farmers will also informed about current schemes for agriculture.

Our future work will be focussing on interfacing different soil nutrient sensors with beagle black bone and analysing the results to get correct and better results, implementing this model and collecting data from various farmlands, analysing data mining algorithms suitable for agricultural Big-Data analysis for getting the desired outcome.

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