Chapter 8
An Effective Big Data and Blockchain (BD-BC) Based Decision Support Model for Sustainable Agriculture System

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8.1 Introduction

Agriculture has a major share in the economy of developing countries. India being a developing country, over 58% of the rural households depends on agriculture as their principal means of livelihood, and agriculture is one of the largest contributors to the GDP of the country [1]. But the agricultural system in the developing countries is lagging ineffective use of advanced technologies available, and hence facing many hurdles. According to National Crime Records Bureau's latest farmer suicides data, over 6867 farmers had committed suicide across the country India in 2015–16 [2]. This is primarily due to the failure to pay back loans raised from banks and microfinance institutions [3, 4].

There is a myth in the agriculture that more yields give more profit in crop business. Everyone is working towards improving the yield and production of the crop without bothering about the actual demand for the same. With the lack of actual demand information and the other farmer's choices, if the farmers produce more goods in the verge of making more profit, there will be more supply than demand resulting in losses. Conversely, if there is less supply in the market, then the consumer suffers from the high prices.

This is mainly because of the lack of management between supply and demand for various food produces in the agricultural system. This gap can be minimized by developing an efficient demand-supply management service system. This service system maintains the demand and supply for all the food produces and guides the farmers in making a wise decision in selecting appropriate crop for cultivation, con-

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A. Haldorai et al. (eds.), *EAI International Conference on Big Data Innovation for Sustainable Cognitive Computing*, EAI/Springer Innovations in Communication and Computing, https://doi.org/10.1007/978-3-030-19562-5_8

sidering the actual desires of the society and hence decreasing the demand-supply miss match which may lead to unexpected variations in the market conditions. Hence, it is imperative for farmers to adopt technology-based management service system, make critical decisions thereby getting better yields and profits.

Upon the production of needy harvest the farmer problem will not end. The big problem is supply chain management. In most of the developing countries, the supply chain of food commodities is inefficient due to information asymmetry which is also a main reason for low farmer income. The current food supply chain is a complex network, as it involves various characters between farmers to consumers range from brokers, distributers, processors, retailers, regulators, etc. There is no transparency in any phase of this supply chain and avoiding a middleman in each phase is a headache. There are certain bodies which will hold the supply of some commodities for a certain time period to create a demand in the market with the intention of making a profit. All these limitations make the farmers suffers in their farm business or consumers for their daily usage.

The integration of Big Data [5], Cloud [6], and Blockchain [7] technology in agriculture will bring revolutionary changes. This paper proposed a Big Data, Blockchain, and Cloud based efficient crop management system achieving effective demand-based decision support and simplified, transparent, and secure supply chain system aiming to provide technological solutions for the present problems of agricultural sectors.

The Blockchain technology is revolutionizing the different domains of the society such as financial services [8, 9], health care [10], Supply chain management [11], and the land ownership registration [12]. Blockchain technology is also transforming other domains of the society like education, entertainment, government, protection of rights, human resource management, retail industry, business and the list goes on.

Agriculture is a field which also requires a face shift from traditional farming methods to modern technological methods. There is a need of a forum or a system which could assist the farmers' right from the crop selection till they receive their proper shares for their harvest from the market. This avoids the middleman's interruption in all stages of crop farming. Blockchain and Big data are such kinds of technologies which can bring the radical changes in the field of agriculture to make our farmers happy in their farm business. The main contributions of this work are as follows.

- The proposed system synchronizes the demand and supply, thereby reducing the gap between supply and demand. Hence it reduces the loss for the farmers and also the price inflation for food crops making consumers happy.
- A Blockchain-based crop-trading platform is proposed to trade the yields in different phases like village, Taluks, and District levels to avoid the middleman intervention. The proposed system will manage the supply at various levels based on the demand.

The remaining portion of the paper is organized as follows: Sect. 8.2 illustrates the proposed crop management system with different modules. Section 8.3 discusses the implementation and results, Sect. 8.4 concludes the work.

8.2 An Effective BD-BC-Based Crop Management System

In order to match the supply of the food commodity from the farmers as per the need of the consumer, the demand-based crop selecting system is proposed. The proposed decision support system predicts the demand and assists the farmers in cultivating the proper crops required to match the demand, thereby maintaining the equilibrium in the market conditions.

8.2.1 Demand-Based Efficient Decision Support System for Suitable Crop Selection

The proposed system maintains various data like farmer's land-related information, soil moisture data, weather and environmental data, harvest and yield data, and demand and supply data in a cloud-based framework as shown in Fig. 8.1. These data helps the data analytics module of the system to suggest the best suitable crop for the farmer to harvest for which there will be a demand. Keeping track of the list of crops with the corresponding demand and also the total amount of yield expected for each crop in the list by various farmers avoids the overabundance by impeding farmers not to select the crop which has already been matched with the predicted demand.

The system architecture of the proposed crop selection system is shown in Fig. 8.2. A farmer can avail the services provided by this system by registering

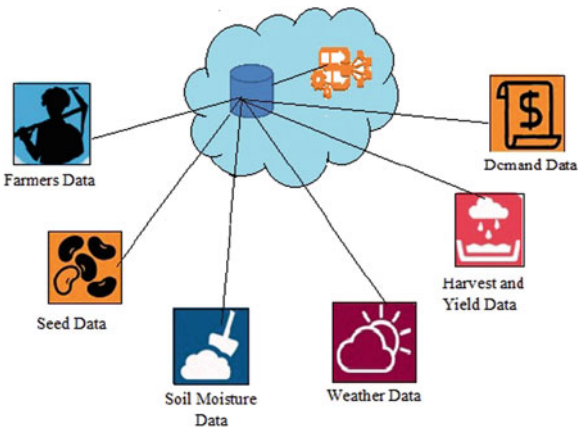

Fig. 8.1 Cloud-based framework to assimilate the land-related information in cloud

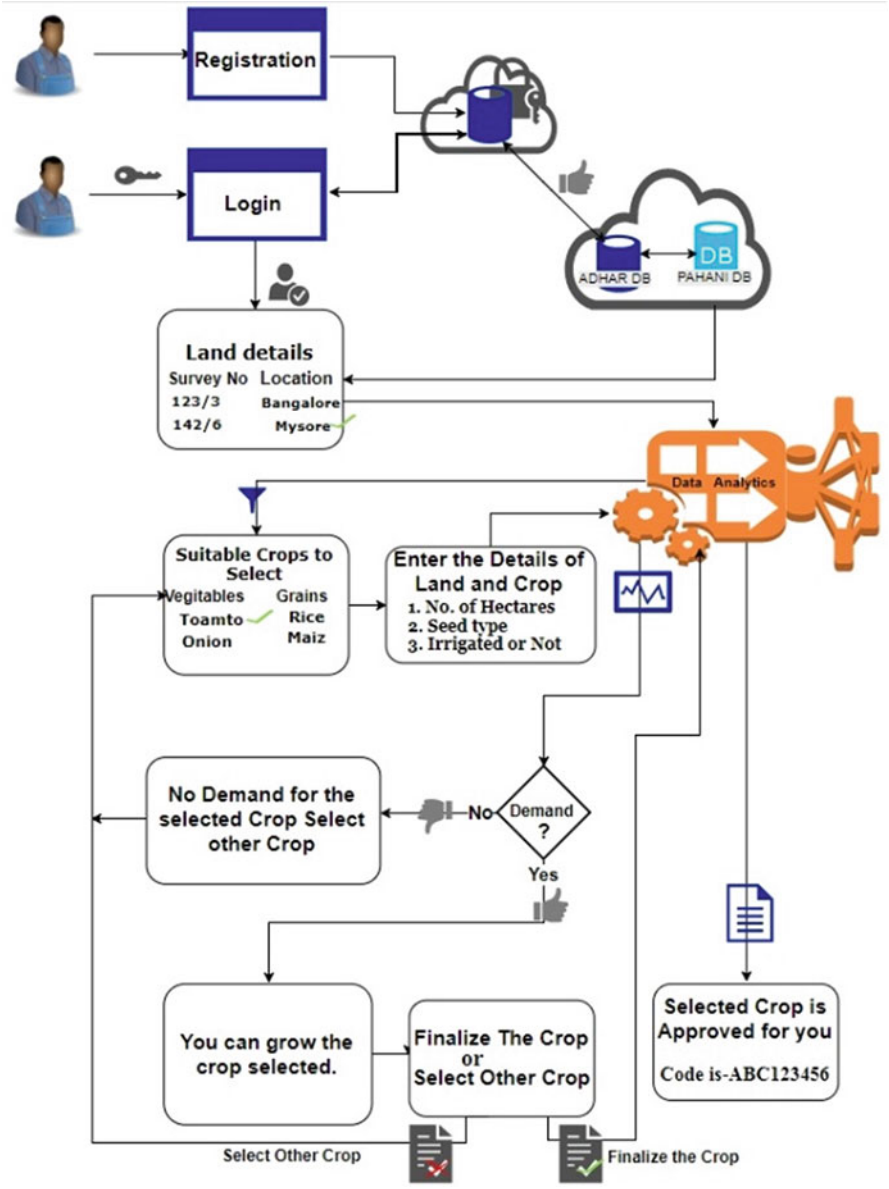

Fig. 8.2 System Architecture of the proposed crop selection model

with the system furnishing "Aadhaar" details, thus allowing only legitimate users and avoiding the unauthorized access to the system. Once the user gets registered with the system, a user ID and password are sent to their registered mobile number.

The registered user can utilize the crop suggestion system to select the crop suitable for his land specifications which will have a demand in future.

When the user logs into the system, the system displays the list of various lands owned by the user. The land details are obtained through the Pahani (Pahani or RTC is an important land record that contains details of land) database, where the Aadhaar data is integrated with Pahani records to get the user-specific land details. The user has to select the land from the list displayed in which the crop is planned to grow.

Based on the land selected and other related parameters like soil type, rainfall details, the season of the year, and the sources of irrigation, the data analytics module of crop suggestion system render a list of suitable crops for the selected land. In the displayed list of suitable crops, the user has to specify one or more crops of his interest and enter the number of acres in which he wishes to grow. Once these details are specified, analytics module will evaluate the expected yield for the selected crop. Analytics module also estimates the harvesting period required to get the yield and forecasts the demand for the selected crop considering the estimated harvesting period. Once the quantity of yield and the harvesting period has been estimated, the estimated quantity of yield is equated with the forecasted demand for the expected period of the harvesting. If the estimated quantity of yield is less than the forecasted demand, the system will recommend the user to go with the crop he had opted to grow. If the estimated quantity of yield is greater than the forecasted demand, the system will alert him and he can adopt another crop from the displayed list of suitable crops and the process repeats.

Once the crop has been finalized by the user for cultivation, the demand for that crop is updated by subtracting the estimated quantity of yield of the same which will be used for the next demand comparison. At the end of the inquiry, the user will get a unique code for the successful selection of the crop which is added to ledger of Blockchain.

Even after a valid registration and crop selection process, if the farmer fails to meet the projected yield, then careful appraisal for the possible reasons of failure in production of an estimated quantity of yield is done. If the reason is due to natural calamities or disasters, then the farmers in that area could be considered for compensation from the Government. This system could also be instrumental in helping the Government for identifying the farmer's plight and make necessary policy interpretations tailored to the needs for smart agriculture.

8.2.2 Blockchain-Based Crop Management System

The proposed food crop supply chain management system implemented using Blockchain technology is shown in Fig. 8.3. The proposed system builds the chain of all different bodies involved in food supply chain ranging from farmer to consumer connected through Blockchain. Each participant in the supply chain requires certification. Certification is performed by accredited agencies. After a

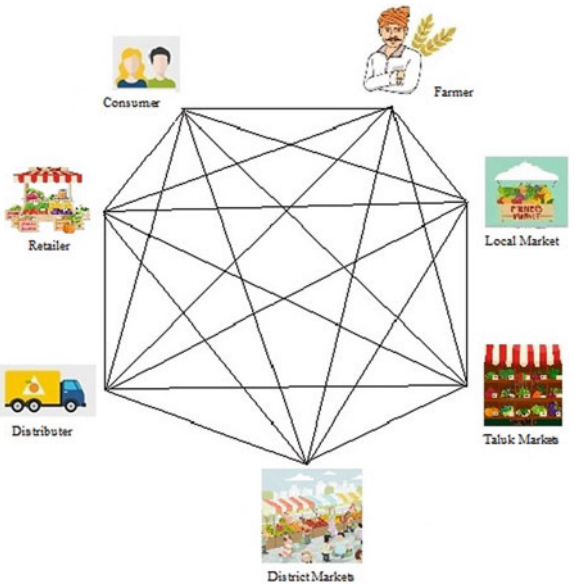

Fig. 8.3 Blockchain-based food supply chain management system

successful audit, the certification body uploads the audit report to cloud. Every transaction at each phase is registered in ledger which brings the transparency and also the food crop supply can be identified at each phase which gives food security and avoids middleman each phase.

When the Farmers get the yield, the same could be delivered at the Government supported local market in the village. The Manager at the market takes the yield after verifying the farmer with the unique transaction code and the volume of yield estimated for his land using the ledger data with data analytics module. When the farmer makes the trade, corresponding transaction will be added to ledger. After the verifier acknowledges the transaction, farmer account is credited with the rate fixed. After all farmers submitted their harvest, the village market manager sends the collected harvests into Taluk market.

Each Taluk market receives the harvest of different crops from different villages and the same is recorded in a ledger through Blockchain. The Blockchain technology allows the retailers and distributers to purchase the selected yields directly from the farmers and ensures the appropriate and immediate payment for farmers by avoiding brokers and be fraudulent from any illegal sources. The remaining yields will be transported to District level Markets for the distribution and then to state level. As the data about the demand is pre-estimated and the supply data can also be estimated on the number of farmers registered to grow, the export can also be planned earlier to avoid price variation in market.

Blockchain will maintain a traceability in supply chains of agriculture, as the Blockchain ledger could record and update the status of harvest from each and every market. The upside for large operations is a secure, immutable ledger that ensures the never lose a supply. The status of all the crops is available in real time. The

BD-BC-based decision support model manage the food crop wastage in case of excess supply, crop scarcity in case of less supply and middleman's intrusion very efficiently.

8.3 Implementation

The data set about the demand and supply for certain crops for the state Karnataka has been gathered from the authorized government websites [13, 14] to analyze the scenario of demand and supply for the year 2016–17. The data values are tabulated as shown in Table 8.1, and the table shows the excess supply and scarcity for the different food crops for the state Karnataka during the year 2016–17. Excess supply for crops like wheat, sugarcane, etc., and results in wastage of food crops and hence farmers will not get an expected profit. In contrary, when there is less supply for any food crops like Rice, Maze, etc., it creates a scarcity for food crops and consumers suffer with the high price.

The main aim of BD-BC system is to reduce the gap among the supply and demand of food produces and to bring the transparency in trading of the same. The proposed system has been implemented using Java, which consists of a Web server and client browser. The Web server was implemented using PHP. The client browser was implemented using JavaScript. The Blockchain is designed to record information about crop selection, estimated supply, crop trading, and crop transportation data along with the time stamp. A Web server is accountable for collecting and storing land-related data, demand data, crops data, all transaction data, block-related data, crops supply data, and supply transportation data. The client browser is an interface for farmers to interact with the system for crop selection and allocation as shown in Fig. 8.4.

Datasets used in the process of crop suggestion like land details, rainfall pattern, crops suitable for different land conditions, harvesting durations of different crops are taken from "Profile of agriculture statistics Karnataka state, department of agriculture Bengaluru." The yield for different crops at different regions is taken from the government website [15]. Data sets used for Demand forecasting are

Table 8.1 Demand supply gap for different food crops for the state Karnataka for the year 2016–17

Crops	Demand	Supply	Gap	Result
Rice	110	102	−8	Scarcity
Wheat	89	108	18	Excess
Maize	19	12	−7	Scarcity
Cereals	235	245	10	Excess
Pulses	22	40	18	Scarcity
Food grains	257	365	108	Excess
Oilseeds	59	26	−33	Scarcity
Sugarcane	279	380	101	Excess

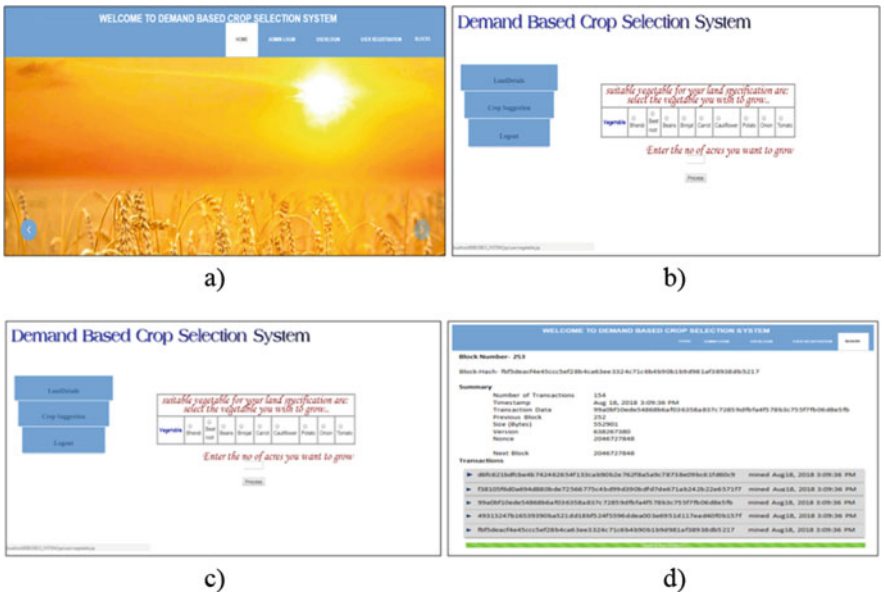

Fig. 8.4 (**a**) Welcome page. (**b**) Crop suggestion phase. (**c**) Crop selection phase. (**d**) Block information page

Table 8.2 Expected reduced gap for the food crops using the proposed methodology

Crops	Demand	Supply	Gap
Rice	110	112	2
Wheat	89	90	1
Maize	19	18	−1
Cereals	235	237	2
Pulses	22	24	2
Food grains	257	260	3
Oilseeds	59	60	1
Sugarcane	279	280	1

considered from government website [16, 17]. For evaluating this model, 15 different vegetables, 20 different cereal crops have been considered. 50 farmers are made to register to the system also demand and supply data of previous 10 years have been considered. Blockchain technology has been used to eliminate the brokerage system and has been implemented using python with a group of 4 farmers, 3 distributers, retailers, consumers and Bank at 2 Taluks and one District level.

The proposed system could successfully map the supply and demand of food crops by efficiently assisting the farmers and regulating the supply according to the demand, thereby reduce the chances of either food wastage or scarcity due to more supply or less supply as shown in Table 8.2.

Table 8.3 Price inflation through halting the supply

Month	Demand	Supply	Wholesale price	Retail price
Jan	467123.3	3934	15.25	20.32
Feb	421917.9	2295	16.54	20.73
Mar	467123.3	2798	16.78	22.85
Apr	452054.9	2908	13.04	20.47
May	467123.3	3826	16.65	24.34
Jun	452054.9	4258	15.98	23.86
Jul	467123.3	3770	14.27	22.49

Table 8.4 Regulated demand supply by the proposed system

Demand	Supply	Price
17	15	9
18	17	10
15	17	8
18	14	11
18	16	8
17	18	8

The proposed system could avoid the middleman's intervention and improve the returns for farmers. Table 8.3 shows the scenario of price inflation due to the intrusion of middleman even when the supply and demand were almost inline. Brokers may supply the yields illicitly in the market with the intention of making the profit. From Table 8.3 it can be observed that when the supply is more than the demand, the wholesale price which the farmer gets is less. When the supply is less than the demand, there is a hike in price and consumers suffers with high price. It can also be observed in that table that, in the month of June and October even when the supply is almost equal to the demand, the retail price is high; this may be due to holding the supply to create a demand.

The proposed system could provide the transparency and traceability at each step of supply chain. This avoids the middleman's interruption and illegal holding of food supply, thereby reduces the uneven price inflations in the market and also improves the return for farmers.

Table 8.4 shows the reduced demand supply gap and reduced price inflation which is a result of using the proposed BD-BC system. This helps farmers from the loss and also the consumers from high price from food crops.

8.4 Conclusion

The Big Data, Blockchain, and Cloud technologies brings revolutionary changes in agriculture system. By making use of technologies available, this proposed model effectively improved the quality of the agricultural system by effectively achieving 90% to 92% match in demand and supply of food crops required by the society from the farmer's end, thus avoiding the loss for farmers and catering the needs

of consumers. This leads to a gainful crop business for farmers and satisfactory fulfillment of the societal needs. Thus, a judicious mix of extensive physical outreach and interactive methods of information technology could be used for sustainable and better agricultural practices. BD-BC-based decision support model proposed in this work effectively facilitated real-time monitoring of supply chain bringing total transparency and security to agricultural transactions also eliminating the nuisance created by middlemen and curbing the wastage of agricultural produce. In future, an entire network of all the stake holders including farmers, regulatory bodies, processing units, etc. could be build, in the Blockchain. All this will be possible with the help of regulation and consensus system known as smart contracts leading to very less scope for corruption.

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