Decentralised and Predictive System for Efficient Agri-Transactions Through Blockchain Technology

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Abstract: Agriculture is an art, a craftsmanship and a scientific way of cultivation, growth and maintenance of edible crops and livestock. Majority of the current farming communities do not have prior knowledge of predicting the suitable crop for their soil and climatic conditions. Difficulty in raising the initial investment for crop cultivation is also one of the serious concerns of these communities. The difficulties faced by the civic agriculture, the insecure monetary transactions, along with the concerns related to the financial process have been identified and listed. The paper proposes a feasible solution by predicting the appropriate crops that could be grown in a specific scenario or environmental conditions using the machine-learning model of Support Vector Classifier and provides data related to quality yields using Fuzzy Decision Merkle Tree (FDMT) Regressor. Additionally, a transparent and secure fund transfer mechanism is provided using Ethereum blockchain-based technology. The proposed model implements a secured, translucent and tamper-resistant digital platform for the farming communities to host their products. A fortified consensus can be formed between the farmer and the investor bounded with a rating mechanism to build the credibility of both the farmer and the investor[7] based on the prior knowledge obtained in the Agri-market.

Keywords: Blockchain, Fuzzy, Agriculture, Machine learning, SVM.

1. Introduction

Agriculture is the backbone of many emerging countries around the world and contributes with a moderate percentage to the income of both the developed and the developing countries. Agricultural sector is the one which provides fodder for livestock and cattle, and the necessary products for people, which may be a sort of protective food. To maintain agriculture all over the nation, everyone should have an awareness of farming and its benefits. Blockchain technology can be used in agricultural sector to improve farming and to provide initial investment to the farmers without any intermediary interference. Food safety can be extended using blockchain and it allows for identity traceability across the food supply chain.

It encourages the usage and implementation of data-driven technologies for smart index-based agriculture insurance and smart farming by providing a secure means of storing and handling data. Machine Learning can also be used in agricultural sector to extend crop production and to educate the new farmers in the field by providing them better knowledge of crops, their yields and fertilizers. Machine Learning acts as a useful decision-making method for crop yield prediction and also for deciding what crops to plant and to process during the crop's growing season.

Support Vector Machine is categorized to be a popular Supervised Learning algorithm in Machine Learning, which is used for classification, as well as Regression based requirements. The core objective of SVM is to deliver an efficient decision scope that categorizes and segregates a multi-dimensional plane of data factors or space into different classes of data categories. Hyperplane is the aforesaid decision boundary created by the SVM algorithm. The algorithm, Support Vector Machine, closely classifies the acute points and vectors to create the hyperplane and those extreme cases are the resultant support vectors. A customized tree structure-based regressing and classification model, the Fuzzy Decision Merkle Tree (FDMT), is developed with the support of basic decision tree technique in Machine Learning platforms. The process consists in the decomposition of a huge set of data into multiple smaller sets and subsets by developing an associated decision tree in parallel. This is incremental in nature. The resultant set would be the decision node which represents the final decision factor on a numerical rate. This categorization is applicable to numerical and categorical data. The major contribution comes from the prominent algorithm ID3. Overcoming the issues faced by the aforesaid ID3, a customized version of decision-making algorithm, the Fuzzy Decision Merkle Tree (FDMT), has been proposed. It is a top-down approach with an additional strength of greedy search engine through the available variants of branches. This does not involve backtracking and it is an algorithm,

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which utilizes the concepts of standard deviation reduction in place of information gain for the regression problems.

The existing ID3 algorithm takes discrete data with minimal cardinality values. Actually, that is an advantage to the system since it improves the understandability of the persuaded knowledge, but, at the same time, it requires apriori partitioning. Apart from that, multi-valued bias problem exists while selecting attributes and the attributes which carry higher values are not always optimal. Another issue faced by this algorithm is that finding the information entropy through log-based algorithms will cost more time. At the same time, controlling the size of the tree is not a simple task, more classification rules are to be defined as the tree size grows. This is one of the major issues faced in this domain. The proposed algorithms sorts some of the issues faced above. In order to reduce the complexity faced by the apriori partitioning and resolve the multi-valued bias problem, the standard deviation ratio has been utilized instead of information gain. One of the improvisations made is the direct embedding of different weights in each attribute. This makes the selections of the attribute extremely optimal and comprehendible, by having a minimal runtime. Also, the proposed method controls the size of the decision tree and it builds a more precise and reasonable decision tree with minimal computational cost and complexity. The obtained results show that the proposed method has a better performance in comparison with the one of the existing methodologies.

Blockchain Technology provides a framework, which creates a network of data modules that are chained in a linear sequence, and is difficult or most of the times impossible to modify, delete or impersonate the data items. The technology hosts a digital ledger comprising of transactions, which is, in turn duplicated and distributed to the network of similar peer nodes or computer systems. Each entity of block in the total chain encapsulates a variety of data elements that depicts the content to be secured along with the transaction details. The records of these transactions are embedded to the user's ledger. On the contrary, the distributed ledger technology is a framework of decentralized database, which is administered by a group, or multiple users of the system. Blockchain is a variant of the Distributed Ledger Technology in which all the allowed transactions are recorded, logged and covered by an immutable cryptographic signature algorithm called Hash. The Emerging Blockchain technology has many advantages in this digital world, being:

- immensely secure – this system acquires the support of the digital signature thereby making it impossible to modify the information transferred;
- completely decentralized – even though the regulatory authorities of the bank play a vital role in providing approval, a secure, seamless, efficient transaction is made possible through this distributed and mutual consensus between the users of the network;
- capable of automating the system – the complete system is capable of being automated, it is easily programmable with lower resource costs, and disposes of event-based decision generation properties.

The Ethereum Blockchain supports the programmers and the developers to develop competent and resourceful program modules that can be deployed in its blockchain framework at ease. Components such as tokens are created to identify digital resources and properties along with the capability of tracing the ownership of the records within a stroke of simple and customizable programs.

The blockchain protocol is a specialized protocol that executes on the layer of P2P network of computing nodes. Every node in this network encapsulates the same copy of the ledger records or transactions. Thereby, this system enables the transaction without the involvement of an intermediary through a mutually accepted consensus mechanism. The peer-to-peer network of computing nodes makes the complete system free of any individual point of failure without leveraging the support of servers due to the concept of redundancy. The blockchain is in fact shared, publicly accessible and records all the transactions happening in the network right from the inception block. The distributed and mutual consensus through the game theory based economic consensus protocol in combination with the crypto systems enables the prospective validation of P2P transactions by default.

In recent times, many demotivating incidents including the farmer suicides and poor yield in farming has been reported. Nations like India are highly dependent on the land for building houses and uplifting technology through commercializing industrial areas. The lands are becoming infertile due to the widespread use of chemicals, so the yields should grow in quantity as well as in quality. Even though the demand increases day by day, the farmers are suffering from many issues like, rapidly increasing investment rates for field setup, uncompetitive prices for the cultivated products due to the involvement of mediators in the market, being void of the current crop requirements and market trends, and incompetency in predicting the market scenarios. The incompetent supply chain process and the redundant problems in storage and transportation lead to the deterioration of the farming processes.

Similarly, the investors in the market worried about quality of products. There is a lack of mechanisms for ensuring authenticity and integrity in various stages of cultivation. The biggest challenges in the agriculture sector are the disconnection between the farmers and the investors and the intermittent involvement of mediators due to lack of proper technology.

In the present paper, a Fuzzy decision merkle tree algorithm has been designed for decision making. This algorithm in combination with the Support Vector machine learning algorithm helps in crop and fertilizer prediction with yield estimation. This is done with the support of the dataset obtained from the government sources which gives information about the past history of crops and the yield obtained This system serves as an efficient model for the agricultural community to better understand what crops and fertilizers should be used and also to estimate the yield. This will help the farmers to get an idea about their return on investment. In order to make the transaction between the producers (farmers) and the consumers (customers/users) as transparent as possible, a blockchain based fund transfer mechanism has been implemented which helps to eradicate the middleman during the transaction process. The proposed system proves to be more efficient in comparison with the existing models serving the same purpose. Section 2 of the article presents the various literature studies made in order to understand the existing issues and developments made in the domain of discussion. Section 3 and 4 discuss the architecture of the system and the proposed algorithm, respectively, that are implemented in the present work. Section 5 gives a detailed review of the results and of the performance analysis of the proposed model and it is followed by the conclusions and the prospects for the development of the proposed research in a future work, discussed in section 6.

2. Literature Survey

Lin et al. (2020) have conducted a clear-cut survey on the various techniques, methodologies and the application recompenses of blockchain technology practiced especially in agricultural platforms. Initially, the technical components including data structures, security methodology depicting the cryptographic means and consensus mechanisms were explored. Then, the various categories of the existing agricultural blockchain applications were reviewed to demonstrate the advantages of using this blockchain technology. In addition to the above, the various popular smart contract platforms that were used in their architecture was also explained in a transparent manner. They have also identified the core challenges in many potential agricultural entities and discussed the efforts and prospective solutions to smartly handle these issues. The existing scenarios in the agricultural platforms were discussed in great depth, indicating the essential problems of recent days.

Pradeep et al. (2021) proposed a compact solution for blockchain-based Agriculture and with secure Supply Food chain. They have enlisted the key features of blockchain and smart contracts, deployed over the Ethereum blockchain network. The additional features of blockchain were clearly explained. Their model proposes a highly reliable system ensuring traceability and a straightforward trusted delivery mechanism in the agricultural supply chain process. The transactions written to the blockchain which ultimately uploads the data to Interplanetary File Storage System (IPFS) were also discussed. The data hash is returned and is ultimately stored on the blockchain which, in turn, ensures an efficient, effective, secure and a reliable solution. The model provides an error resistant smart contract combined with the respective algorithms to improvise the interaction of the entities in the system. Furthermore, they have simulated and evaluated the outcome of the smart contracts embedded with a proper analysis of the securities and vulnerabilities of the system.

The Future challenges of agriculture were discussed by Galvez, Mejuto & Simal-Gandara (2018) insisting the farming community to avoid facing the difficulties in future. The preventive measures and technology like blockchain can be used to tackle the future challenges. There are many works related to data algorithms in (Wu & Tsai, 2019).

Osmanoglu et al. (2020) proposed a blockchain integrated solution that carries out a specific yield estimation of various agricultural products. An efficient yield assurance system that enables the farmers to share their ideology, farming techniques and plans for the oncoming harvest term with the co-participants of the market was proposed in their model. They highly utilized the blockchain technology in order to design their working platform which provides a restriction and tamper proof, and a strongly immutable public collated ledger holding the time-stamped transactions. The yield estimation done by the reputation system was broadly discussed by Shahid et al. (2020). Although their proposed platform provides a secure and strong yield estimation mechanism, the efficiency can still be improvised better. The diversified role of blockchain technology in Internet of Things (IoT), its system and their applications were discussed in depth by Caro et al. (2018) and the concepts in by Awan et al. (2019).

Schmidhuber (2018) devised a model, Blockchained and IoT based Food Traceability System (BIFTS) that transparently integrates a novel deployment of blockchain, IoT technology, and a non biased fuzzy logic into a totally retraceable shelf-life product and food management system for ensuring food safety. There are many works related to data algorithms which are discussed in (Quinlan, 1986; Priya, Sannasy & Daisy, 2022).

The physical delivery of products was discussed by AlTawy et al., (2017) to ensure the proof of delivery. This system is light weighted, can vaporize the characteristics and trace the food life cycle through the deployed blockchain network. At the same time, an integrated consensus mechanism that contemplates transit time of the shipment, assessment of stakeholders, and the shipment capacity is implemented. Subsequently, integrating the shelf-life data that is accurate and reliable, to make core support decisions and quality decay level evaluation was done using the fuzzy logic architecture of their proposed model. One of the serious restrictions they had is, their model was purely based on the food traceability ideology instead of other supply chain applications. Authentication was never a part of their study which is again a matter of concern.

Nationwide effects on the economies of food safety and the standard support system through Blockchain associated to it were deeply discussed by Kshetri (2019). Food adulteration, contamination, mislabelling, and misbranding of the related products have levied an incredible economic and societal costs on a global scale. Study conducted by the respective author at the household level shows that food insecurity happens due to high need and demand for quality food supplies. In order to tackle the situation with a lifelong solution, the author proposed a food related blockchain mechanism which addresses many of the food safety challenges confronted by the community today. This technology can be utilized in the food industry and firms to enhance their reputation through modern ideas implementing technology to cater the essential needs of the society. But still, there were so many issues and challenges in food industry which leads to severe impacts on the environment.

Ali Syed et al. (2019) displayed a wide and well-organized comparative analysis of the blockchain architecture with its applications zones. Healthcare, IoT, custom vehicular industries, core financial verticals and business were identified to be the thrust zones where the blockchain technology could sort out the centralization issues and provide vibrant solutions. Moreover, result oriented analysis of the platforms, models of consensus mechanism and application areas were conducted. Finally, the key aspects required to adopt and implement blockchain technology were also identified and discussed in detail.

IPFS based agricultural product tracking and storage mechanism had been discussed by Hao, Sun & Luo (2018) to ensure safe and secure transactions that will be used for future projects of blockchain in an essential manner. Also, the blockchain based proof of delivery was discussed by Pradeep et al., (2021) to ensure a transparent and tamper-proof resilient system.

The Evaluation and Demonstration of Blockchain Applicability Framework (BAF) was done by Gourisetti, Mylrea & Patangia (2020). Their proposed model depicted a BAF that is designed to effectively evaluate an application, categorize the blockchain architecture involved, and identify the appropriate consensus mechanism required for the same. Adopting this framework on transitive systems proved the efficacy of this model. The proposed model was the initial version of the BAF, wherein further improvisations can certainly strengthen the controls, decision making factors and process, as well as to assess the consensus involved.

There are many works related to data algorithms discussed in Kim et al. (2018). The work elaborated on the usage of Blockchain in Management and Logistics. Their study focusses on the research in LSCM through BCT. The authors used a bibliometric analysis procedure to assimilate their results and present it in a comprehensible way. Network citation analysis and co-citation analysis were adopted for better presentation of the findings. Based on a co-citation analysis, Balakumar & Kavitha (2021) classified the existing architecture into different clusters of research that includes the core modelling of BCT applications, edging supply chain oriented BCT, concept-oriented testing of blockchain models and their specific roles in supply chains.

In all the specialized literature referred above, an exact and simplified crop prediction mechanism is not available for the farmers to rely on. At the same time, fertilizer prediction is always an area of concern. There is no any transparent fund transaction mechanism between the producers (farmers) and the consumers (end users/ intermediaries). These factors are addressed in the model proposed in this paper with an efficient Fuzzy decision making and Machine Learning System along with blockchain mechanism for distributed and transparent transaction.

3. Proposed System Architecture

Machine learning model is combined with the Blockchain technology to give a better knowledge to farmers and to fund them without any initial investment. Crop yield estimation and crop prediction are done using a machine learning model which provides a better understanding and knowledge to the new young farmers. Crop yield estimation is done using FDMT Regressor with an input of current month, current rainfall, current year and Wholesale Price Index. Along with the above functionality, the prediction of crops and fertilizers is done using support vector machine with an input of particular soil conditions. With this knowledge, a farmer can cultivate the suitable crop for his soil condition and he can raise the fund requested from the investor using Ethereum based blockchain technology. Based on the quality of the crop yield, the fund will be given to him by the investor without any intermediate interference. Thus, the blockchain technology provides a transparent and secured fund transfer mechanism for any distributed system.

Figure 1 depicts the architecture of the proposed system. The first module of Agri-system is sufficient for providing a better understanding

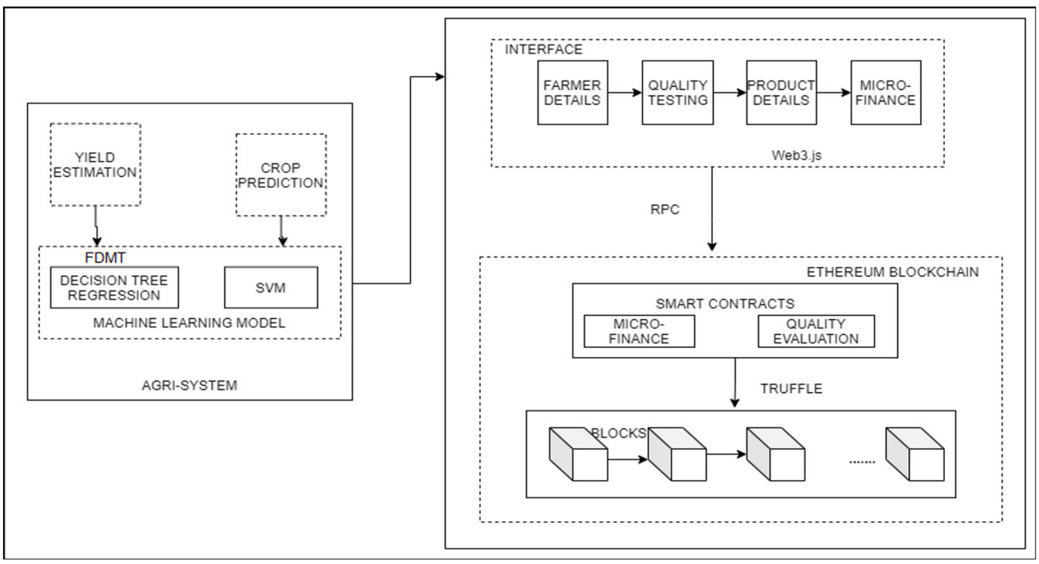

Figure 1. Overall System Architecture

to developing farmers using machine learning models. The initial component is yield estimation using the FDMT Regressor and the second is crop prediction using Support Vector Classifier. The predicted output will serve as the crop details input for the fund transfer mechanism using Blockchain Technology. The second module of fund transfer mechanism comprises of an interface which interacts with the Ethereum Blockchain. In its turn, the interface consists of farmer details, quality check factors and values related to them, product details and fund transfer properties. The deployed smart contracts of fund transfer and the quality check in blockchain are used to test the quality of the crop and to transfer the fund to the farmer. This is how the fund transfer mechanism is achieved.

The Dataset used for the experiment in this research is originally collected from the web portals such as (Ministry of Statistics and Programme Implementation, n.d.) and (Open Government Data, n.d.) that are given for public access. The aforesaid dataset includes features such as total rainfall in the specific areas, total irrigated area, name of the crops, various seasons, total production, and the final total yield, data which were collected for around 40 years until 2018. This study applies Support Vector Machine and regression methods in order to achieve a proper prediction of the total yield in India. Mean absolute error, root mean squared error and mean squared error methodologies are used to validate the system.

The crops that are taken into consideration from this dataset are cereals, barley, millets, ragi, maize, jowar, wheat and rice. Other varieties include pulses, groundnut, castor seed, sesamum, sunflower, soyabean, cotton, sugarcane, jute, potato, onion, tobacco, coconut and cashew. Since various sources are involved in the collection of these data, aspects like their quality, the format in which the data is presented and the feature availability are not considered and hence they should be properly managed before exactly using these data for research and other purposes. In this regard, data pre-processing has a vital role in reducing the noise present in the data and embedding the missing values with assisted values, handling inconsistent data and attributes of less relevancy or opposite relevancy. Some of the measures that could be taken to pre-process the data are aggregation of features, assessment of data quality, reduction in dimensionality and sampling features. The nature of the addressed problem decides if only a limited set of methods should be used or all these methods. Some methodologies simply eliminate the unwanted data rows while others replace them with existing duplicated values in order to attain certainty with appropriate assessment methods.

The Application Binary Interface (ABI) is a custom interface for encoding the data that are supposed to work with the smart contract environment in Ethereum. The core purpose of ABI is to cooperate with various contracts residing on the blockchain system from the external network and at the same time, the interface serves inter-contract interaction. Encoding data is dependent on its type and, therefore, it cannot be described in only one way. Solidity and ABI have similar type of data format - i.e., unsigned integer (8 bits and 256 bits), signed integer (8 bits and 256 bits), string, boolean, etc.

The ABI module provides complete support for the various specifications of ABI which include:

- overall implementation of Java that includes different types of ABI and conversion platforms from Java to its native code and vice versa;
- methods and event handling support;
- support or multiple versions of ABI;
- multiple testing platforms including unit and module testing.

Remote Procedure Call (RPC) is a protocol underlying Java platform in which a single threaded or multithreaded code can be used to request and respond from and to another code snippet present in another system through the local network without any information about the network itself. This request-response process happens within the remote zones of networked computing nodes. The RPC request is always initiated by the client by sending a request package to the remotely attached server node. When receiving the request, the server node responds accordingly. Ethereum is a platform which is based on Blockchain Technology, it is an open-source framework and hence a decentralized one which is frequently utilized for efficient and reliable transactions of their own digital currency, the ether. The framework enables the developers to build smart contract and closely distributed applications, DApps. These applications can be developed and implemented without any interruption, central control or interference from any third-party user or system.

4. Proposed Algorithm

This module is proposed to give a basic knowledge of crop yield every year with an input of current year, current month, current rainfall and wholesale price index. Decision Tree Regression is used to predict the best and worst yielding crops.

The yield value of every crop addressed in the present work is also available in the dataset obtained from the standard governmental body. Yet, a deep knowledge is required in order to properly estimate the crop yield. The accuracy of the estimation keeps increasing as the growth stage of the crops reaches its maturity. One of the methods undertaken here is easy to implement and achieves fast results compared to the other available methods.

Let 'X' be the average area in which the crop is grown. Let 'Y' represent the number of grains in crop heads. The grain weight which is obtained from the dataset is referred as 'Z'. Then, the yield in t/ha can be calculated as (X × Y × Z) / 10,000. For instance, in order to calculate a cotton yield, let's say the average heads per m^2 is 150 (X), and assume that the average grains per head is 12 (Y), 100 grains weight of wheat is 1.7g (per dataset) (Z), then the yield in t/ha = (150 × 12 × 1.7) / 10,000 = 0.31. The overall yield estimation accuracy is dependent on the number of times the measurement is taken in order to obtain the average value. Since loss of grain is an unavoidable factor, 5% to 10% loss could be accepted in the final calculation. It has been noticed that there is a quite increase in the yield of crops such as wheat, soya and maize worldwide in around 75% of their harvested areas. This contributes to around 80% of the global production. On the other hand, the remaining production occurs in areas of yield stagnation. This shows that for wheat and rice, stagnation in yield has a high-level implication on the capability of agriculture to reach the growing demands.

4.1 Criteria for Suitable Crop

Most of the soil types in India are categorised into alluvial soil, black soil, red and yellow soil, laterite soil, arid soil, mountain and forest soil, desert soil, alkaline and saline soil. The dataset obtained from the standard governmental body consists of variants of crops which are suitable for the above-mentioned different soil types. The selection of crops is dependent on the percentage of phosphate and potash (maintained fertilization is required here), lime, nitrogen, salt, calcium, organic matter, iron, magnesium, aluminium and porosity of the soil.

Table 1 describes the different categories of soil along with the suitable crops that can be grown in those soils. This selection is obtained with the help of the richness and absence of the minerals in the soil.

Scikit-learn: Sklearn is a commonly acquired library for machine learning entities in Python. It encompasses a rich set of selected tools which are efficient in terms of statistical modelling process, reduction of dimensions, classification, clustering and regression. This modelling is provided through a consistent user interface and is robustly built on NumPy, SciPy and Matplotlib.

Table 1. Category of soil and suitable crops

Category of Soil	Rich in	Poor in	Suitable Crops Variety
Alluvial	Organic matter, Phosphorous acid	Potassium, Nitrogen	Cotton, Wheat, Maize, Barley, Jute, Tobacco, Green/black gram, beans, vegetables
Black	Mg, Iron, Aluminum, Lime	Nitrogen, Phosp(P), Organic	Cotton, Sugarcane, Linseed, Sunflower
Red & Yellow	Iron oxide, Potassium	Nitrogen, Mg, Lime, Phosp(P), Organic	Groundnut, Potato, Maize/Corn, Ragi
Laterite	Iron	Organic matter, Calcium, Nitrogen, Phosphate	Cotton, Wheat/Rub, Tea/Coffee, Coconut, Cashews
Arid	Salt, Limited Nitrogen	Organic matter, Moisture	Barley, Maize, Wheat, Millets, Cotton, Pulses

Algorithm 1. Fuzzy Decision Merkle Tree Predictor

Input: Current Month, Year, Rainfall, Wholesale Price Index and other factors in the dataset
Output: The top 5 (best) and bottom 5 (worst) yielding crops along with their predicted price

Get the data set in any form which has the above given input.
Split the given dataset as train_data and test_data
Train the given input through FuzzyDecisionMerkleTree (FDMT)-Regressor Module.
Store the resultant as commodity list
For i in commodity list
    current_predict=getPredictedValue(current_month, current_year, current_rainfall)
    prev_predict=getPredictedValue(prev_month,current_year, prev_rainfall)
changesInpercent=(current_predict - prev_predict) * 100 /prev_predict
sorted_changesort(reverse=True)
Display the top and worst five yielding crops

Algorithm 2. Fuzzy Decision Merkle Tree (FDMT) Regressor Module

Input: Tdn, Ta, Att
  Tdn: Training data nodes with weightage
  Ta: Target Attribute
  Att: Descriptive Attribute set
Output: Att with High IG
Assign XRoot = W for all Tdn
For all unexpanded nodes, compute the counts
$P_k^N = \sum_{j=1}^{|E|} f2(X_j^N, \mu_{(V_k^c)}(y_j), P^N = \sum_{k=1}^{|Dc|} P_k^N$
Compute the standard information:
$SInfN = -\sum_{k=1}^{Dc} \frac{P_k^N}{p^N}.\log\frac{P_k^N}{p^N}$
The weighted information content for Vi is calculated as $I^{(S_{Vi}^N)}$.
Select the attribute Vi with low standard deviation ratio and weight.
Abstract the Merkle node Vi as
Let Vi = cur-node
cur-node = {}
For each c in data
  If cur-node[c] = null
    Cur-node[c] = {}
  cur-node = cur-node[c]
cur-node["data"] = data
Initiate the root node for the tree as Vi
If: all Tdn are +ve
    Return (Single Node - with +ve label)
If: all Tdn are -ve
    Return (Single Node - with -ve label)
If: empty Tdn
    Return (Single Node - with commonly Ta label)
Else:
    Begin:
    Let, Xinit = Best classified Att from the list Root(decision) = Xinit
    for each (val in Xinit) & val = Xinit
        Add branch to Root(decision)
        Let sub_val=subset{{Q},where Q is the set{val=Xinit}}
        If: sub_val is empty then
        Add leaf node (with commonly Ta label) to this Branch
        Else:
        Add a subtree to this Branch
        Recursively call-FDMT(Tdn, Ta, Att-{Xinit})
End
Return Root(decision)

Algorithm Explanation:

The algorithm ID3 is a binary classification algorithm, but, in the proposed model, the sets are fuzzy by nature, hence fuzzy sets and fuzzy logics have been deployed. The input of the system consists of the training data with weightages, the target attribute and the descriptive attribute set, whereas the output consists of the node with the highest possible gain and lowest standard deviation ratio.

Initially start the procedure with the data having 'W' weights and assign them to XRoot. For any unexpanded node N find the example count, i.e., X_j^N which is the membership of the data e_j in N, which is nothing else but the membership in the fuzzy set defined by the fuzzy sets of the restrictions found in FN, calculated with functions f0 and f1.

Then find $P_k^N = \sum_{j=1}^{|E|} f2(X_j^N, \mu_{(V_k^c)}(y_j)$ and $P^N = \sum_{k=1}^{|Dc|} P_k^N$, where function f2, the mean and the standard deviation ratio are defined. Hence compute the standard information using the formula: $SInfN = -\sum_{k=1}^{Dc} \frac{P_k^N}{p^N}.\log\frac{P_k^N}{p^N}$.

Then, at each node, the set of remaining attributes is searched to split the node. Calculate the weighted information content for V_i as $I^{(S_{Vi}^N)}$ and then select the attribute V_i such that the weighted information content is high and with low standard deviation ratio.

Once the perfect V_i is identified, the merkle tree is build based on the normalised procedure. Here the proposed procedure consists of three consecutive phases: the root creation, the generation of the output, and finally the verification phase. During the initial phase, the base root element of the required tree is generated. Along with this, the subtrees having roots at $(0:2_{ih})$, where the value of i ranges from 1 to L, are calculated and immediately stored. The second phase contains 2^H rounds and during the final round the j^{th} leaf and the corresponding authentication path are given as the output. The final phase is the regular verification identified in any data structure. If there is no child node with training data, then it will not be possible to contribute to the implication. Hence, all those children node are detached. That is the reason why some internal nodes end up by missing child nodes. The final predicted node value is sent as the final output of the proposed algorithm.

Fuzzy Decision Merkle Tree (FDMT) Predictor Regressor Module is an expert system which could act as a mathematically explored tool that can help in resolving uncertainty. The imprecise and coarseness nature of data (noise and unknown values) present in the data set plays a vital role in distressing the decision-making process. This can be resolved by fuzzy means constructed by the proposed algorithm. It is a fuzzy system which takes the soil factors such as N, P, K which are currently present in the soil as the input factors and predicts the levels of N, P and K values required for the better growth of crops as the output factors. The algorithm goes through the following phases. The fuzzifying module converts the sharp quantities into fuzzy variable quantities. The Rules database consists of the conditional fuzzy IF-THEN rules and the membership functions of the various fuzzy sets incorporated in these fuzzy rules are well-defined in the knowledge data base. Therefore, the decision-making unit performs action on the above defined rules. In return, the defuzzification module converts the fuzzy quantities into sharp quantities again.

Triangular based fuzzy membership functions were incorporated in the present system. The reference variables used for the input (current N, P, K) and the output (required N, P, K) fuzzy model are "Less (L)", "Moderate (M)" and "High (H)". The values for the membership functions for the currently available nutrients and the required nutrients will be the "start" and "end" values consecutively. The values are set in mg/kg and range from 0 to 100 for N and P, and from 0 to 500 for K.

For example, if the input current values for Nitrogen (N) range between 0 mg/kg and 30 mg/kg as starting and ending values, the output required level would be "Less Required" (LR), if the input current values for Nitrogen (N) range between 30.1 mg/kg starting and 70 mg/kg ending values, the output required level would be "Moderate Required" (MR), and if the input current values for Nitrogen (N) range between 70.1 mg/kg starting and 100 mg/kg ending values, the output required level would be "High Required" (HR). Some parts of the rules are mentioned in Table 2.

Algorithm 3. SVM Crop Predictor

```
Input: Soil conditions namely Nit, Pos, Kt, pH, temperature and price/hr
Output: Desirable crop and the respective fertilizers
Read the data available from the given input.
Split the given data as train_data and test_data
Train the soil conditions using Support vector classifier.
clf = SVC(kernel='linear', random_state=0)
clf.fit(x, y)
prediction1 = clf.predict(pred)
#similarly predict three different crops using predict function
For i in crops
    If(prediction==prev_predict)->print crop1
    Elseif (prediction==prev_predict [0])->print crop2
    #similarly, for all crops
    Display the best three crops for particular soil conditions given
    #similarly predict the fertilizer for the given soil condition
```

4.2 Crop and Fertilizer Prediction

This module predicts the suitable crop for the given input soil conditions of N, P, K, pH, temperature using the Support Vector Machine algorithm. SVM is also a core package rendered by the scikit-learn library. Prediction of the suitable crop and fertilizer is done by the data predictor of the same package. SVM was used instead of Naïve bayes, logistic regression, random forest and KNN, because SVM has more accuracy regarding this dataset when compared to other algorithms.

Table 2. Input NPK vs Output NPK required

Input (Current values of NPK)			Output (Required Values of NPK)		
Nitrogen (N)	Phosphorous (P)	Potassium (K)	Nitrogen (N)	Phosphorous (P)	Potassium (K)
L	L	L	HR	HR	HR
L	L	M	HR	HR	MR
H	H	H	LR	LR	LR
M	M	M	MR	MR	MR
M	H	M	MR	LR	LR
H	L	M	LR	HR	MR

The blockchain mechanism is used to make a distributed and transparent system to store the transaction data of the producer (farmer) and the funder end user (user who funds the farmers). The financial transactions will happen through the traditional money exchange method and hence cryptocurrencies are not utilised in the system. Presence of blockchain will help the users to have transparency in the transaction systems and eradicate the middleman or intermediaries who might have monetary gains through these transactions. This helps the funder identify the exact beneficiaries (farmers) of their funding and vice versa.

4.3 User Interface

Interface enables interaction between the user and the backend blockchain (Ethereum). User interface includes five main forms:

- farmer and crop details
- quality testing;
- product details;
- verification of farmer and product details;
- fund transfer

4.4 Farmer and Crop Details

The details include:

- farmer ID;
- farmer name;
- crop name;
- phone;
- quantity;
- expected price.

These details get stored as blocks in the blockchain.

4.5 Quality Testing

This module helps checking the credibility of the farmer in the overall system. Thus, it avoids the unauthorised usage of the system. The quality of the overall model depends on the strength of the blockchain to execute transactions in a seamless and secure way. Hence, farmer ID is given as input which returns the farmer details. The Get value button gives the value of the block from which the corresponding farmer details get stored. After returning the values, the approved details will approve the farmer to raise the fund.

4.6 Product Details

The details include:

- lot number of the product;
- farmer ID;
- expected quantity;
- duration;
- grade of the product.

These details get stored as blocks in the Ethereum blockchain to maintain the product details and help in fund raising.

4.7 Fund Transfer Form

Here, the given input consists of:

- farmer ID;
- lot number of the product;
- fund-raising amount.

After clicking the fund raise button, the amount raised will be detected from the actual one.

4.8 Smart Contracts

Smart contract is a compatible and self-executing code which includes the terms and policies established between the buyer and seller. This agreement code is transported and hosted in a decentralized blockchain network of nodes. Transactional execution is fully controlled by this code and all the transactions are traceable but at the same time they are irreversible. These smart contracts allow the various reliable transactions and code agreements to be implemented among incongruent and anonymous users, totally void of a central control or any external interference.

4.9 Fund Raising and Quality Check

The farmer details such as his ID, address, the cultivated crops, area of land owned by the farmer, the funds received till now, the amount of funds required in future and related information are stored in an appropriate data structure. These details are then tested for quality by verifying the transactions in the blockchain. Similarly, after testing, the product details are stored in another appropriate data structure followed by the approval of product details. There might be a handful of investors who are ready to fund the farmers in the specific region. The aim of the present work is to identify those investors and to connect them to appropriate farmers so that the financial lag for the farmers could be handled smoothly. This represents a mutual manner to help both the farmers and the investors. Therefore, it is important to check the availability of the investors and the funds. In order to simplify the overall process, the proposed system will check whether the investors are genuine or not by comparing their basic details with that of the details registered within the datasets of the standard authorities and bodies. By doing so, the modifier function checks for the credibility of the investor. Once the investors are found to be genuine and credible, then the investor balance is checked as per the request by the user (farmer). The entire amount is then transferred accordingly with digitally signed contracts.

Algorithm 4. Funding Smart Contract

```
Input: farmer and product details
Output: Fund transfer with Quality Checking
Contract storage
Farmer-details->struct{id, Name, crop name, quantity, price}
Function: send (address-receiver, amount, address-sender)
if (balances[sender]<amount) return false;
Else balances[sender]-=amount;
balances[receiver]+=amount; return true;
Product-details->struct{lot-no, farmer-id, grade, testdate,
expdate}
function getquality(bytes memory k)
   return(l1[k].lotno,l1[k].grade,l1[k].mrp,
         l1[k].testdate, ll[k].expdate);
End contract
```

The above algorithm is used to make transaction of funds between farmer and the investor. The details of the product and farmer are given as input to get corresponding quality of the product as output. The above smart contract plays a vital role in transaction mechanism.

5. Implementation Results and Discussions

In the present paper, the dataset is used for estimating the yield of the crops from different states of India. The features included in the dataset are: current year, current month, current rainfall, different states of India (along with some countries), Wholesale Price Index and other features discussed next.

5.1 Crop and Fertilizer Prediction Dataset

The dataset used here is for predicting the suitable crop for the given soil conditions. The features included in the dataset are Nitrogen, Potassium, Phosphorus, pH, temperature. The obtained output is given in the form of classes labelled as 1, 2, 3 etc. Those numbers indicate the different type of crops and different fertilizers.

5.2 Yield Estimation, Crop and Fertilizer Prediction

The way in which the plant grows depends on the basic nutrients that are present in minimal quantities and at the same time, the other nutrients need to be available in essential quantities. Therefore, it can be understood that, the nutrients present in the soil are minimally enough for a basic yield of any crop but not to the level of obtaining a top yield. From the available fertilizer recommendation methods, the method that focuses on the yield seems to be the best method since it provides not only the dosage of fertilisers required based on soil test, but it also gives the yield that could be obtained if best practices are taken in crop cultivation. The most important data needed for the fertilizer recommendation system in order to obtain the required target yield are a) the required nutrients of the grain/crop measured in kilogram q^{-1}, b) the amount (percentage) of contribution of the nutrients available in the soil and c) the amount (percentage) of contribution of the nutrients available in the fertilizers. With these inputs the parameters are calculated as follows:

N, P, K values required for production of grains:

Total kilograms of nutrients required per/q of the grain = Entire intake of the controlled area in kilograms ha-1.

The percentage of availability of soil nutrients (ConS%) = The test values of nutrients obtained from soil in the controlled area in kilograms ha-1 * 100.

The percentage of availability of nutrients from the fertilizer (ConF) = Entire intake of nutrients in the controlled area – (Soil test nutrient values in the fertilized areas * ConS%).

Required percentage of nutrients from Fertilizers (ConF %) = ConF * 100.

The required dosage of fertilizers = 'x' constant * targeted yield (q per ha) – 'y' constant × soil testing rate (kilograms per hectare).

This concept of target yield creates a unique stability between applying fertilizers to the crops and applying fertilizers to the soil. Hence this methodology gives a scientific standard approach for a stable fertilization and an equilibrium between the available soil nutrients and the nutrients applied to the soil and crop. In the proposed targeted yield technique, there always exists a linear connectivity between the crop yield and the intake of nutrients necessary for the crops for a respective yield. Hence a finite amount of nutrients is absorbed by the plants. If this required value is known for a given yield, then the estimation of the amount of fertilizer required can be easily done by considering the nutrients available from the soil. NPK values required in 100kg of products is denoted by NPKR, the contribution of NPK from soil is denoted by ConS, the contribution of NPK from fertiliser is denoted by ConF and the contribution of NPK from the organics is denoted by ConO.

The equation for the required fertilizer is given as

$$F = TR*(NPKR / ConF) - ConS*(STVA / ConF) - ConO*(OM / ConF)$$

where TR is the yield target in q ha-1, NPKR, ConS, ConF and ConO are defined earlier, STVA represents the available nutrients from soil analysis results and OM is the nutrient available in organic matter.

The variation in the N/P/K Content is identified from the soil taken for consideration and the required N/P/K contents are calculated based on the formula discussed earlier. This formula is taken as a standard attribute to identify the type and quantity of the fertilizer to be suggested for the respective crops in order to maintain or enhance the growth.

The top five and the bottom five crops are listed based on the crop name, estimated yield and the price percentage change from base price, which are also listed in this implemented module. The recommended crops are calculated using the FDMT Regressor. The system shows the top three crops suitable for cultivation based on the given soil condition using KNN and it provides the accuracy of 75 percent for the given dataset. Then, the system shows the top three crops suitable for cultivation based on the given soil condition using Naïve Bayes and it provides the accuracy of 67 percent for the given dataset. Then, the system shows the top three crops suitable for cultivation based on the given soil condition using Random Forest and it provides the accuracy of 70 percent for the given dataset. Finally, the system shows the top three crops suitable for cultivation based on the given soil condition using SVM and it provides the accuracy of 85 percent for the given dataset. Therefore, the SVM algorithm has been used for crop and fertilizer prediction to give a better knowledge to farmers.

5.3 Blockchain Module

In this module, Truffle configuration file has been linked to Ganache to deploy the contracts to the blockchain. This is how the blockchain network is connected to the interface. The proposed model explains about the first contract deployment to Ganache. The deployed contract shows transaction hash, block number, block timestamp and the price of gas used. The transaction hash is a unique value generated for each and every successful transaction. Apart from that, every chain transaction has its own unique transaction id that can be witnessed in the transaction details. The contract address actually points to the location of the address of the real contract token that manages the logic for the token and it does not mean the address that keeps the personal contract tokens. Gas limit refers to the constrained limit of gas that can be utilised for a particular transaction in Ethereum. Higher gas limit refers to high resource usage for transaction execution through smart contracts using ETH.

5.4 Block Timestamp

There can be many transactions in a block, all have the same timestamp, and all are the same timestamp as blocks. Block Timestamp is the value what miner decides to publish there when he or she finds a block.

Apart from the second contract deployment to Ganache, implementation is shifted to the deployed contracts in Ethereum blockchain. It displays name, address of the contracts, whereas the details of farmer ID, farmer name, crop name, quantity and expected price are to be given as inputs to the system. The value of the block from where the details are stored is displayed. Then, the system acquires the input of lot number, grade, quantity, expiration date. Once the investor gets lot number and farmer ID as input, they can verify the farmer and product details. The smart contract is called each time, from and to contract addresses. Then, the total gas value used is given after each transaction. The system shows the time and number of events occurred during each contract and blocks creation.

Table 3 shows a package of six datasets used in order to test the crop prediction and to list the accuracy using the proposed FDMT algorithm. The results were supportive for the present implementation which proved to have a good performance for each and every transaction made in the system.

Table 3. Crop Prediction Accuracy Comparison (with FDMT)

Transaction Cycle No./Data Set No.	Crop Prediction Accuracy (in %)	
	Without FDMT	With FDMT
TC1/DS1	68	73
TC2/DS2	78	83
TC3/DS3	82	86
TC4/DS4	86	90
TC5/DS5	88	90
TC6/DS6	88	91

From Figure 2, it can be seen that the classical Naïve Bayes algorithm gives a crop prediction accuracy of 62%. The Random Forest algorithm gives a crop prediction accuracy of 72%. The Logistic Regression gives a crop prediction accuracy of 75%, whereas the outperforming KNN gives a crop prediction accuracy of 65%. The model implemented in the proposed system, the SVM gives the highest crop prediction accuracy of 80%, respectively.

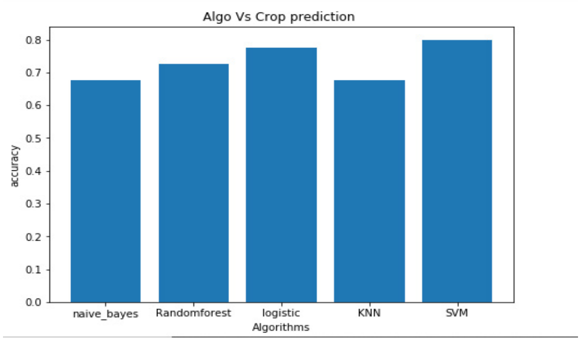

Figure 2. Different Algorithm Vs Crop Prediction Accuracy

Table 4 shows a collection of six datasets used in order to test the crop prediction and to list the accuracy using the proposed SVM algorithm. The results were supportive for the present implementation which proved to have a good performance for each and every transaction made in the system.

Table 4. Crop Prediction Accuracy Comparison (with SVM)

Transaction Cycle No./Data Set No.	Crop Prediction Accuracy (in %)	
	Without SVM	With SVM
TC1/DS1	61	64
TC2/DS2	65	69
TC3/DS3	72	77
TC4/DS4	83	88
TC5/DS5	81	87
TC6/DS6	85	90

From Figure 3, it can be seen that the classical Naïve Bayes algorithm gives a fertilizer prediction accuracy of 50%. The Random Forest algorithm gives a fertilizer prediction accuracy of 50%.

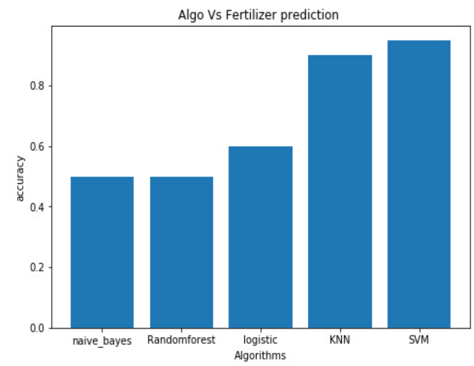

Figure 3. Different Algorithm Vs Fertilizer Prediction Accuracy

The Logistic Regression gave a fertilizer prediction accuracy of 65%, whereas the outperforming KNN gives a fertilizer prediction accuracy of 85%. The model implemented in the proposed system, the SVM gives the highest fertilizer prediction accuracy of 90%, respectively.

Figure 4 shows the accuracy of both crop and fertilizer prediction for different algorithms. Since SVM provides the highest accuracy when compared to other machine learning model, this algorithm has been used for prediction. The results are shown as graph.

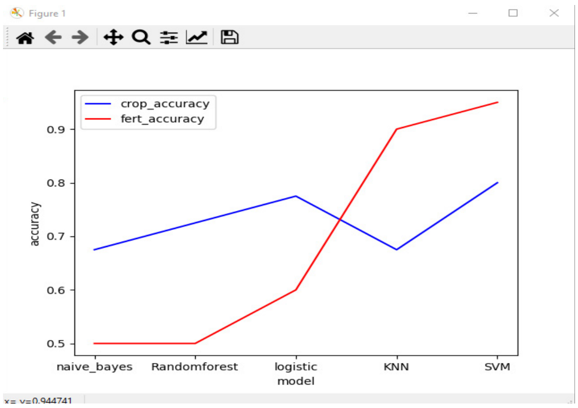

Figure 4. ML Model Vs Accuracy

Figure 5 shows the amount of gas used for each transaction in storage contract.

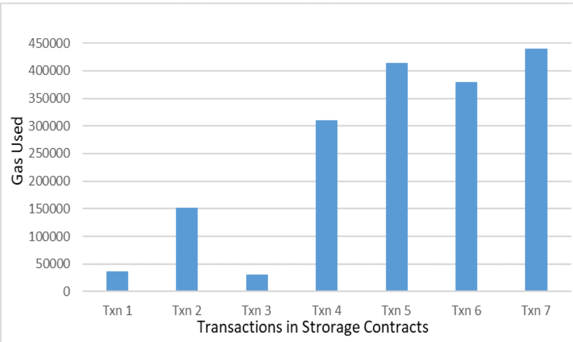

Figure 5. Gas Usage of Different Transactions

The Transaction includes the details entered to the blockchain and the amount of gas used is employed for storing the details in the Ethereum blockchain.

5.5 Comparison with Existing Models

The present learning model SVM has been compared with other similar approaches like Logistic Regression, Random Forest algorithm, Naïve Bayes and the K-Nearest Neighbour (KNN). The main advantage of using SVM in the present model is that SVM actually works well with those unstructured and partially structured data elements whereas other algorithms like Random Forest, Logistic Regression and KNN works well with previously recognised independent variables. SVM is based on the geometrical properties of various data elements, whereas other approaches, as Logistic Regression, are based on various statistical methods. The compact risk due to the process of overfitting is comparatively minimal in SVM, while the other approaches are widely vulnerable to overfitting. The outcomes of using the other models in comparison with the selected SVM methodology is shown in Table 2 where the used model achieves an accuracy of nearly more than 90%. The differences of accuracy with respect to other models are depicted in Figure 4.

Other classical models which are independent of Machine Learning require additional resources and involve higher implementation costs. Since the proposed model is already trained and could be readily implemented in decision making scenarios, it is considered feasible compared to the traditional methods of crop and fertilizer predictions.

5.6 Limitations of the Model

The major limitations of the model are the external factors affecting the growth of the crop like the presence of pests, the quality of the fertilizers and other influencing factors that are not taken into consideration. The proposed prediction model focuses on the factors available in the dataset, assuming that the standard quality of fertilizers has been supplied to the end user.

6. Conclusion and Future Work

In the proposed work, a farmer funding mechanism for yield estimation and crop prediction has been designed using blockchain technology along with the proposed machine learning models FDMT and SVM. SVM gives the highest accuracy of 80 percent and 95 percent in predicting crop and fertilizer respectively. This may give a better knowledge to the young farmers regarding crops, fertilizer and their yields. This blockchain system provides a secure and transparent transfer mechanism to the farmers. By this system, the farmers obtain the funds easily without any intermediary interference. Since the system is a distributed peer-to-peer one, there is no single point of failure, thus it remains a safe system for fund transferring. The result of different algorithms like KNN, Naïve Bayes, and Random Forest have been shown and compared with the results of SVM which gives the highest accuracy of prediction. Simulations are performed and the amount of gas for deploying and executing smart contracts is shown. Moreover, the system also maintains the immutability and integrity of the transactions as these transactions are based on blockchain. The proposed system provides these advantages with help of Machine Learning model and Blockchain Technology.

However, blockchain based systems still face challenges related to their practical implementation. In future, refund and return mechanisms can be developed and security analyses can be performed against those processes of refund and return mechanisms to make the system more advanced and efficient.

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