Novel Framework for Quality Crop Predictions Using Data Mining and Soft Computing Techniques

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2023 International Conference on Artificial Intelligence and Smart Communication (AISC) | 979-8-3503-2230-9/23/$31.00 ©2023 IEEE | DOI: 10.1109/AISC56616.2023.10085117

***Abstract*—Data mining (DM) and Soft Computing (SC) are a vital computational approach that offers good competence of flexible agricultural data processing systems to solve farmer's problems. Recently, soft computing has emerged as a powerful technique for solving and analyzing complex real-world problems. This article suggests an approach of smart crop predictions is presented through DM &SC in the field of agricultural quality crop prediction. A five-level framework is proposed namely 1) Collection of data from different repositories, 2) Pre-processing of data, 3) Appropriate Classifier Selection, 4) Prediction and Estimation 5) Draw AUC & ROC curve. Method proposed here focuses on analyzing agricultural yield, soil for crop, rainfall required based on chemical property of soil. Agricultural data analysis and cataloging is one of the best applications of new computing tools such as soft Computing, Machine Learning (ML) approach, became a burning area for the reason that of the massive development of farming data. DM& SC approaches for accomplishing applied research will give effective answers for this type of problem. ML is a working tool to study multiple learners and combine their assessments for accomplishing greater forecasting accurateness. In this investigation, we had recapitulated ML methods which can be applied as an essential tool by the farmer and agriculture scientist for timely prediction of crop production.**

Keywords— Agriculture, Crop Prediction, Economy, Soft Computing, Data Mining, Machine Learning, Neural Networks

I. Background

Farming is a very important area of Indian economy because it contributes nearly 17% to the total GDP and offers pay to over 60% of the population. Agriculture sectors are the regions with the highest degree of yield uncertainty. In the agriculture sector , yield fluctuation and agribusinesses entirely depend on several components such as climate, geography, economics and agricultural policies of the country. Economy of a developing country like India is mostly driven by cultivation and this sector provides a lot of opportunities to boost the financial system higher than other sectors. There has been a tremendous slowdown in crop production in the last three decades. Today, we need an ever-growing and incremental agriculture model that can boost the Indian economy [1]-[2].Climate and meteorological conditions are crop development and production defining factors since the fluctuations in weather and variability in climate affect productivity and crucial aspects of crop production system [3]-[4].Prediction of weather conditions provides the concerning statistics about the weather likely over the coming times. While it's typically impossible to forecast these daily changes in detail after about a week to come, one might say about the likely conditions averaged over the coming months. A periodic prediction is trying to give the necessary information on possible weather for several months or forthcoming days [5].The demand of quality crops is ever-growing to boost the Indian economy. Many uncertainty folds in the agriculture sector have caused natural problems in predicting quality crop production [6]-[7].There are many factors on which crop production depends such as temperature, amount of rain, soil characteristics, choice of crops etc. These are some of the important reasons that have created uncertainty among the farmers and therefore prediction of crop productions has become a natural problem[8].The farming sector is demanding an effective, systematic, and well-defined model that employs a methodological approach for predicting quality crop production with its yields. This model will help the farmers in selecting quality crops for better productions and a significant improvement in the revenue [9]-[10]. Agriculture is one of the important sources of livelihood for all organisms. New farming technologies that improve the influencing factor of agriculture play an important role in the Indian economy [11].

II. Availability of Online Agricultural Data for Study

There are various online repositories that maintain different types of data related to agriculture that encompass details of agro products like the daily price, varieties, production statistics, land use statistics, observation studies, agro surveys, geospatial data, and learning resources. These repositories help the researchers, data analysts, and scientists carry out their studies in different agricultural domains and produce some novel results for the problems identified. A few online agricultural repositories are shown in Table 1.

TABLE I. Repository and Their Description.

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S. N	Name of Repository	Description About Repository
1	https://data.gov.in	The purpose of this portal is to allow the Ministries and Departments of the GOI to use their datasets to publish district- and season-wise crop production statistics for scientists and researchers. The following information can be found in this repository • Estimates of agricultural production • Current daily price of various commodities • Import of Chemical Fertilizers • Export of Horticulture Produce in India • Field Crop varieties released
2	http://raitamitra.kar.nic.in	The following information can be found in this repository • Population statistics • Geographical Area Karnataka. • Trend of Cultivable and Irrigated Area • Rainfall • Land Use Statistics • Operational Land Holdings • Trends in Land Holdings • Agro-climatic Zones in the State • Consumption of Fertilizers in Karnataka
3	https://krishi.icar.gov.in/	ICAR designed a Central Data Repository System(CDRS) that generated agricultural data through the following sources: • Experiments • Agricultural Surveys • Observational studies • Geo-spatial data • Publications • Geo-spatial data • Learning Resources
4	http://www.ksndmc.org	Centre of Natural Disaster Monitoring (Karnataka State)
5	http://agropedia.iitk.ac.in	This website provides agricultural statistics that are widely used by farmers. • Agriculture Research Institutes in India • Agricultural Economists • The Agriculture Sector in India

III. Literature Survey

Real world problems such as agricultural problems typically have large data sets known as raw data. DM is composed of powerful techniques for extracting precise, important, and useful information [1][12].DM algorithms employ a descriptive and predictive approach. The general properties of data from generalized databases are extracted with the use of descriptive techniques whereas explicit values based on patterns obtained by using predictive DM and soft computing methods. Predictive DM approach has been widely applied for solving predictions of crop production problems, yield analysis, predicting weather, required number of pesticides and fertilizers, amount of revenues to earn and so on. Large data sets are processed by DM approaches in order to discover new patterns or precise information from existing historical data [13].

The main aims of soft computing and DM approach are to process raw data into the computer and human understandable form so that it can be processed further to extract in precise form and apply to solve agricultural problems. There are no restrictions on the types of data that DM techniques can process. It can be used to analyze data which may be from a database, relational database, text or simply a log file. Here, we briefly introduce some of the DM techniques to understand their effectiveness in solving some related problems. DM approach is broadly classified into association analysis, Classification, Clustering and Regression analysis. Association rule mining has been applied to detect some relevant patterns when the data set is huge. It is used to find relationships among different attributes in a transactional database. Methods are familiar with discovering items that coincide repetitively inside a dataset that has many independent selections of items.. It has been used extensively in Market Basket Analysis (MBA), Catalog design, customer segmentation, telecommunication alarm forecast and store layout [4][14]. Data mining provides extensive association rule mining algorithms such as, Priory Algorithm (AA), Dynamic Hashing and Pruning[5][15].DM techniques are essential techniques for achieving effective and useful ways out for farming issues. Variation in soil ecological conditions, commodity costs, and input levels has made the whole thing more relevant for agriculturalists and utilize information and be assisted to make critical agribusiness resolutions. Experimental study and analysis of the agricultural data, soil, climate statistics and discovery prime parameters to increase the yield via data mining and soft computing practices [16].

IV. DM Approaches

DM algorithms and statistical approaches are widely used for solving classification and prediction problems. The algorithmic model is capable of learning for the purpose of forecasting a class label from a training data set and then it can be used to determine different class labels from the newest cases. The accuracy of classification or prediction depends on the chosen algorithms. These procedures follow three types of ML algorithms:

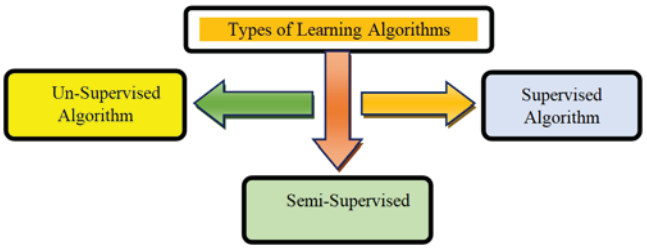

Fig. 1: Types of ML Algorithms

There are many classification algorithms and statistical methods available, such as rule-based classifiers, NB, KNN, DT, GA, ANN, RS, FL, SVM, Markov chain model, and time series analysis, for solving classification or pattern discovery problems [6][17][43].The numbers of abbreviations used for data science techniques are shown in Table-2. Clustering is a technique to divide datasets into different clusters such that they differ from one another according to some distance. It is a method for creating partitions among datasets so that similar instances are grouped together. However, the objective of clustering is to recognize a class whose characteristics are shared among other groups. Some useful clustering methods are DBM, PM, GBM, MBCM, HM, soft computing methods [18]-[20].A learning based function that maps out items of data to an existing prediction variable

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known as regression. The most essential technique for solving many forecasting problems. In this technique, a Machine Learning (ML) model is trained to forecast some desired target. It is used to perform classification with grading or quantitative labels and further classified as linear and non-linear regression [21][46].

TABLE II. TYPES OF DATA SCIENCE TECHNIQUES AND THEIR ABBREVIATION

Abbreviation	Approaches/Techniques
CART	Classification and Regression Trees
GA	Genetic Algorithm
FL	Fuzzy Logic
NBC	Naïve Bayes Classifier
ANNs	Artificial Neural Networks
CNN	Convolutional Neural Network
SVM	Support Vector Machine
DT	Decision Tree
DL	Deep Learning
XGBoost	Gradient Boosting
AdaBoost	Adaptive Boosting
GBM	Grid-based Methods
LightGBM	LightGrid-based Method
KNN	K-Nearest Neighbor
DBM	Density-based Methods
MBCM	Model-based Clustering Methods
PM	Partitioning Method
AA	Apriori Algorithm
HM	Hierarchical Methods
RS	Rough Sets
AUC Curve	Area under the ROC Curve
ROC	Receiver Operating Characteristic Curve
TPR	True Positive Rate
FPR	False Positive Rate
NFM	Neuro Fuzzy Modeling
FINkNN	Fuzzy Interval Number k-Nearest Neighbor
ANFIS	Adaptive Neuro-Fuzzy Inference System

Clustering is a technique to divide datasets into different clusters such that they differ with one another according to some distance. It is a method for creating partitions among datasets so that similar instances are grouped together. However, the objective of clustering is to recognize a class whose characteristics are shared among other groups. Some useful clustering methods are DBM, PM, GBM, MBCM, HM, Soft-computing Methods [18]-[19].A learning based function that mapping out items of a data to an existent prediction variable known as regression. Most essential technique for solving many forecasting problems. In this technique, a Machine Learning (ML) model is trained to forecast some desired target. It is used to perform classification with grading or quantitative labels and further classified as linear and non-linear regression [21] [42][43].

V. IMPORTANCE OF SOFT COMPUTING AND DATA MINING ALGORITHM BASED MODEL

DM and SC algorithm-based models that systematically employ an effective and well-defined methodological approach for solving quality crop prediction problems. Soft computing and DM tools have been successfully and widely used in recent years to solve the problem of agricultural crop prediction. SC is a group of practices that work synergistically to provide solutions for complex real-world problems. Soft computing is composed of GA, FL, ANNs working in synergy to solve complex problems whose solutions could not be possible with the use of repetitive mathematical models [22]-[23]

VI. PROPOSED PREDICTION SYSTEM

In this approach, our aim to combine the effectiveness of DM and SC inspired frameworks and DM algorithms to solve quality crop prediction problems. We propose a framework to re-process and extract the features from the agriculture databases based on ML such as NBC, SVM, KNN, ANN, and CNN to predict the quality of soil for quality crop prediction for smart farming, as shown in Fig. 2. Major steps of proposed frame work are as follows.

A. Collection of data from different repositories

There are many good Indian repositories that maintain agricultural data for study and future prediction. A list of repositories where data can be collected, as shown in Fig. 2.

B. Pre-processing of data

For preprocessing, we have suggested various techniques like data cleaning, data reduction, data discretization, and data integration. These techniques improve the accuracy of the data used in experiments.

C. Appropriate Classifier Selection

After reviewing different research articles, we have identified a few classifiers for our research framework that are more suitable for our proposed model. There are a few parameters that we have taken into consideration for the proposed framework.

D. Classification of Agricultural Data

In the suggested framework, we have used the following classification models for the classification of crop data on the basis of their crop properties: The classification models are NBC, SVM, CNN, and ANN. The classification of agricultural data can be done on the basis of the following properties: yield, soil for crops, and rainfall required based on the chemical properties of the soil.

E. Prediction and Estimation

In the field of agricultural crop prediction, there are numerous tasks that are challenging, for example, the prediction and estimation of crop patterns to avoid and control the quality. To execute the proposed task, a few algorithms are suggested in the proposed framework, like NBC, SVM, CNN, ANN, etc.

F. Draw AUC & ROC curve

This curve plots the performance of different classification models on the agricultural dataset at all

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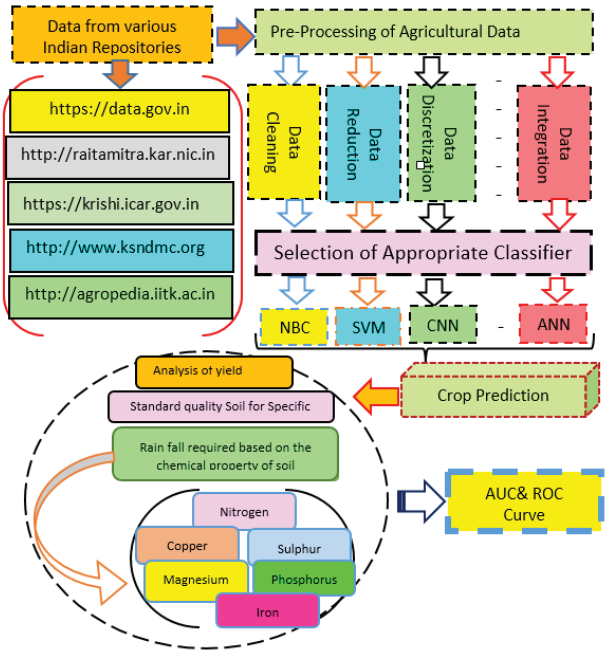
classification thresholds as shown in proposed framework on the basis of two parameters, TPR and FPR.

Fig. 2: Quality Crop Prediction Model



VII. ML Techniques Used for Study of Agricultural Data

Applications of soft computing and DM techniques are necessary approaches in agricultural dataset problems. ML for quality crop, categorization of agricultural land, soils classification from huge soil datasets and their tests conducted to check the diverse characteristics inside the dataset to decide efficiencies when correlates using the right statistical method[20][47].

Table 3. Details of SC and ML techniques used in agriculture

Year	*Authors*	*Techniques*	*Description*	*References*
1993	Shibayama M	Remote Sensing	Yield Prediction of Rice	[24]
1994	Stathakis et al.	ANFIS	Yield Prediction Wheat	[25]
2003	Petridis and Kaburlasos	FINkNN	Yield prediction of Sugarcane	[26]
2005	Kaul and Robert	ANN	Performance analysis of ANN models in typical climatic conditions to forecast soybean and corn yields and relate the forecast proficiencies of models at different levels like regional, state, and national	[27]
2006	Chen and Mcnairn	ANN	Rice yields were estimated using the ANNs method and results are compared with government statistics, found prediction accuracy of 94%.	[28]
2006	Khamis et al.	ANN	A study of palm oil using ANN.	[29]
2007	Henry and Boosarawongse.	Statistical Techniques and ANNs	Compares the performances of ANNs with ARIMA and exponential smoothing models in prediction rice exports from Thailand rice.	[30]
2009	Bhargavi and Jyothi	NBC, J48	NBC, J48 Classifier applied on the soil data set and found 100% prediction classification accuracy.	[31]
2011	Megala and Hemalatha	Clustering Algorithms	The agricultural productivity of rice and land utilization have been examined using data mining approaches.	[32]
2012	Ornella et al.	Machine Learning	studies a number of articles that use Machine Learning in maize breeding	[33]
2012		Fuzzy Modelling	On the basis of rainfall patterns and soil composition, design a fuzzy based approach for crop selection in agriculture.	[34]
2013	Prasad and Begum	ANN	A literature review of comparative studies on ANNs and traditional methods used for agricultural crop estimates	[35]
2013	Papageorgiou et al.	FCM	The key resolution of this research was to categorize apple harvest using Fuzzy Cognitive Maps learning approach.	[36]
2014	Khoshnevisan et al.	ANN	This article presents a model of greenhouse gas emissions and energy consumption using an ANN classifier in the production of wheat.	[37]
2015	Ashaary et al.	ANN	A study of ANN classifiers is being used for the forecasting of a number of water resource variables, including, flow, rainfall, water level, etc.	[38]

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Year	*Authors*	*Techniques*	*Description*	*References*
2016	Kuwata and Shibasaki	ML	Predicting the US corn harvest with ML approaches.	[39]
2017	Mullainathan and Spiess	ML	Presented a new way of thinking about ML that gives it its own place in econometric software. ML not only offers novel tools; it also resolves different agricultural problems.	[40]
2018	Chlingaryan et al.	ML	Fast developments in ML methods and sensing tools and will offer economic solutions for improved environment and crop estimation.	[41]
2019	Klompenburg et al.	CNN	Presented a study of climate impact on crop	[42]
2020	Mehrjardi et al.	ML	Land suitability assessment using machine learning	[43]
2021	Ben Ayed Hanana,	ANN	A study to improve the food quality.	[44]
2022	Jagtap et al.	ML	Role of various ML techniques in agriculture.	[45]

After carefully reviewing literatures, it has been observed that the DM approaches are suitable for pre-processing of raw agricultural datasets and soft computing framework will definitely help to obtain optimal solutions.

VIII. Conclusion

The rate of rapid population growth and the scarcity of natural resources are putting pressure on existing farmers to meet the rising demand for food. The proposed framework for agricultural crop prediction and estimation based on practical data mining and soft computing approaches in recent years will undoubtedly automate the current farming and irrigation systems.

There is a critical need for focused machine learning approaches in the development of a new framework for agricultural crop prediction and estimation. This kind of framework relates to the various factors that are responsible for healthy soil and quality crop prediction using data mining and soft computing.

The use of efficient classifiers based on AI and ML methodologies such as SVM, KNN, ANN, CNN, and BNC to extract features from agricultural databases for quality crop prediction based on amount of rainwater required, soil quality, and agricultural yields improves the current farming process significantly.

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