Sustainable Food Development Based on Ensemble Machine Learning Assisted Crop and Fertilizer Recommendation System

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Article Info
Journal of Machine and Computing (http://anapub.co.ke/journals/jmc/jmc.html)
Doi: https://doi.org/10.53759/7669/jmc202404030
Received 02 August 2023; Revised from 27 December 2023; Accepted 08 January 2024.
Available online 05 April 2024.

Abstract – Agriculture is the most vital sector for the global food supply, and it also provides raw materials for other types of industries. A crop recommendation system is essential for farmers who want to get the most out of their crop-choosing decisions. Over the last several decades, the world's ability to produce food has grown substantially owing to the extensive usage of fertilizers. Therefore, there has to be a more eco-friendly and effective way to utilize fertilizers that include nitrogen (N), phosphorous (P), and potassium (K) to ensure food security. For the reason, this study proposes an ensemble machine learning–assisted crop and fertilizer recommendation system (EML–CFRS) to maximize agricultural output while ensuring the correct use of mineral resources. The research used a dataset obtained from the Kaggle repository like that people can assess several distinct ML algorithms. The databases include data on three climate variables—temperature, rainfall, and humidity—and information on NPK and soil pH. The yields agricultural crops were used to train these models, including Decision Tree, KNN, XGBoost, Support Vector Machine, and Random Forest. Depending on the current weather and soil conditions, the trained model may then recommend the optimal fertiliser for a certain crop. Predicting the ideal kind and quantity of fertilizer for different crops was accomplished with a 96.5% accuracy rate by our suggested strategy.

Keywords – Agriculture, Ensemble Machine Learning, NPK Fertilizer, Food Security.

I. INTRODUCTION

Background

Producing food, fibre, and other essentials, agriculture plays an important role in economies across the globe. The agricultural sector faces challenges in meeting global food demand due to population growth, changing climate, and the importance of soil and fertilisers for crop yields and soil health [1,2]. The recommended CFRS has the ability to solve difficulties encountered with smallholder farmers and nations with food insecurity, like owing to poor productivity, depleting soil organic matter, and harsh elevation [3]. However, smallholder farmers have challenges that diminish their crop production, despite their significant contribution to the agricultural sector. The problems include subsumed conditions that induce frequent crop failures, acidic soils, reductions in soil organic matter owing to high human density, and the country's terrain, that renders agricultural systems vulnerable [4,5]. Manual work in agriculture has been substituted to a large amount, thus improving overall quality and efficiency, and enabling more people to engage in agriculture for their daily life [6]. There is an opportunity for academics and research and development organisations to create innovative methods to boost quality harvest while using less resources, ultimately overcoming long-term problems [7]. The EML-powered crop recommendation technology helps farmers make informed decisions on the crops to harvest, saving waste and leading to increased yields and quality harvests on time [8].

Motivation

Soil is an essential natural resource for producing food, fibre, and timber. Soil is essential for civilization's survival and growth. The industry is crucial to human livelihoods. Soil performs several purposes, including productivity, filtration, habitat, raw materials, and ecological and genetic storage [9,10]. EML techniques consider crop production agricultural an implicit function of input parameters, that can be complex and nonlinear, like weather and soil conditions. People employed random forest and multiple linear regressions to forecast wheat, maize, and potato yields [11]. The system recommends crops using the random forest technique, which works effectively on large datasets and can accommodate missing information. The paper demonstrates that this method segmentation can be used to forecast the appropriate fertiliser for a crop given the available NPK level in the soil [12,13]. The recommended CFRS has a transformational effect since it integrates crop and fertiliser recommendations. The strategy has the potential to transform the nation's agricultural sector with optimising crop decisions for specific land, increasing yields, decreasing fertiliser waste, and supporting sustainable practices [14,15]. Sustainable agricultural practices, social inclusion, and economic growth are the cornerstones of sustainable agriculture and crop production, that aims to include social and economic equality, a healthy environment, and financial profitability into the production process [16].

The Main Objective of the Paper

- Improving the crop diversity that can be cultivated seasonally is the primary goal. To maximise production while minimising challenges, the recommended strategy can aid farmers in selecting crops.
- Accurate and exact crop output predictions are provided using the system's model, and takes into account the land's atmospheric and soil factors to determine the optimal fertiliser ratio. The problem, in the process, increases crop yield and, resulting in farmer income.
- A sustainable food system ensures that people obtains has access to nutritious food without jeopardising the societal, financial, or ecological elements that pave the way for generations to maintain the identical.

The remainder of the portions for a study are as follows: **section 2** explores into the operation of present approaches, **section 3** proposes the EML-CFRS method, **section 4** assesses the results of the experiments, and **section 5** discusses the consequences of the research.

II. LITERATURE SURVEY

Usman Ahmed et al. (2021) discussed the suitable nutrients for different crops and provide nutrients recommendations with analysing the crop fertility and yield production, the proposes nutrient recommendations through an Improved Genetic Algorithm (IGA) that uses time-series sensor data and recommends various crop settings [17]. Fertilisers rich in nitrogen, phosphorus, and potassium are widely used by crops to ensure they get enough nutrients and maintain high levels of output. Soil fertility performance may be enhanced with the help of the suggested approach, which also provides nutrient recommendations for the best possible crop growth circumstances. The approach may shed light on nutrient suitability evaluations pertaining to certain crops in a world where the climate is changing and assist pinpoint the area to evaluate crop adaptability under particular nutrient levels.

Tanmay Thorat et al. (2023) detailed the dual operator, transition probability function, and Convolution Neural Network (CNN) are used to analyse the pest's image discretely and continuously for spraying the prescribed pesticide [18]. Soil NPK sensors are used in nutrient analysis to provide fertiliser recommendations according to the measured nutrient levels. Farmers use soil fertilisers and insecticides to increase crop yields. A few farmers are ignorant of the negative consequences of spraying likewise few pesticides on plants and applying excessive several fertilisers to the environment with evaluating the soil's condition.

Harsuminder Kaur Gill et al. (2021) illustrated the data collection proposes a Long Short-Term Memory (LSTM)-based framework that considers various parameters and predicts crop factors unique to a crop [19]. Agriculture has long been regarded for a few of the world's strongest vital industries, due to agriculture is essential to food security and human existence. With the expansion a variety of sensors that are readily available and the internet of things, people can gather data on several aspects, that can be analysed in a timely and efficient manner to be able to reach appropriate judgements. The proposed method extracts significant crop characteristics as input and output, and then employs an LSTM neural network to predict crop variables.

Kanaga Suba Raja S et al. (2023) examined the aims to investigate the methods used to extract bodies of water using satellite Remote Sensing (RS) [20]. Research into the prediction of agricultural yield using variables like soil, crop traits, and water has been an encouraging field of research. Among the main factors that contribute to enhanced crop output in agriculture are weather, rainfall, fertiliser, pesticides, and the condition of the soil. The collected data is then transformed into information useful for weather forecasting and classification in the manner. Collecting temperature and humidity data prior to using a clustering technique that uncover concealing patterns in massive datasets is the provided operate ultimate motive.

Pruthviraj et al. (2021) prepared the filtering the datasets of soil tests using the Support Vector Machine (SVM) method into several varieties highly fertile, moderately fertile, and lowly fertile soil [21]. In nations like India, farming is a main source of income. Farming provides a living income for more individuals worldwide. As a result, farmers are primarily focused on obtaining a high yield from their crops. The proficiency in recommends fertilisers to improve soil fertility and makes crop predictions based on the soil sample's classification. Farmers can utilise the suggested approach to determine the optimal NPK fertiliser ratio for their soil variety prior to decide the crops to cultivate.

Raghu Garg et al. (2019) introduced the performance of a stochastic gradient descent artificial neural network (ANN) in the Hadoop environment [22]. Society can achieve sustainability goals by making the most of data, information, and knowledge in light of the limited availability of natural resources. Through converting light energy into chemical energy, plants undergo photosynthesis. All life on Earth owes their existence to this process, and soil is the main element that determines if plants thrive development like that contains water, air, and all of the nutrients required for plant nutrition. However, owing to overexposure, soil degrades, hence fertiliser is a necessary component to maintain soil quality. In this context, soil analysis is an appropriate approach for determining soil quality.

Anuj Kuma et al. (2023) determined the Multi-criteria Decision-Making (MCDM) strategies may give the best answer and have been shown to be effective in a variety of complicated real-world decision-making situations, including agriculture-related decision-making difficulties [23]. To make agriculture sustainable, all elements of science, including mathematics and statistics, needs to be combined with agricultural practice. The application of agriculture-related issues, the models utilised, the data sources used, and the total accuracy achieved utilising the various performance criteria in the past decade. Agriculture has long been seen as the foundation of both emerging and wealthy nations' economies.

Yen-Cheng Chen et al. (2022) the examined the current research employs the Analytic Hierarchy Process (AHP) as the primary research object, focuses on rural Taiwanese cuisine, and constructs an index model for the inheritance, sustainable innovation, and development of local cuisine culture based on agricultural experts' opinions [24]. As a result, bolstering rural food production and fostering long-term economic growth may be achieved via food security, livelihoods, and productive activities. An indicator model for the transmission and preservation of Taiwanese rural culinary traditions is created in this research.

A few disadvantages of Efficient Crop and Fertiliser Recommendation System for Sustainable Food Development Utilising Ensemble Machine Learning in the modern day. Reduced likelihood of soil deterioration and improved crop health are two benefits of this approach. This system makes use of a variety of sensors to track several soil parameters, including temperature, humidity, soil moisture, pH, and NPK nutrients. IGA can solve the disadvantages of CNN, LSTM and RS if compared to the proposed approach EML–CFRS.

III. PROPOSED METHOD

As a promote system for sustainable farming practices and precision agriculture, the CFRS is being considered. Building a strong and efficient CFRS for the country's farming system calls for the right dataset, that can include details on crops, soil characteristics, and nutrients. Nevertheless, the benchmark dataset for creating CFRS is readily accessible at this time. The model seems to be well-suited to the data and shows promise for accurate prediction, like seen with the excellent training and validation accuracy. Fertilisation suggestion models that rely on a set of predetermined criteria can struggle to respond rapidly to fresh information. Updating the regulations for an excessive several of crops can likewise develop challenging. The association guarantees that farmers have access to the most up-to-date information and instruments to increase their work's productivity and longevity.

Crop Recommendation

The soil, climate, and agricultural output of different parts of India are all unique. To determine which crops, provide the highest yield in a given location, it is helpful to have data on the kinds of crops harvested and their yields in that area. Information base including data on agricultural yields for the purpose of recommending the best crop for the field. The information was gathered from the government's department of agriculture. Agriculture has a significant role in India's economy. In agriculture, conventional methods of suggestion remain in execute. Soil Nitrogen, Phosphorus, and Potassium (NPK) concentration and ontology-stored research data from prior decades are used to provide fertiliser recommendations. In addition to fertiliser recommendations, the algorithm also gives advice on certain crops can perform effectively in a certain area.

Fertilizer Recommendation System

To help farmers determine appropriate quantities of fertiliser for their crops, a specialised instrument called a fertiliser recommendation system is available. The goal of the approach is to reduce the adverse impacts on the environment while increasing agricultural output. The present nutrient levels in the soil can be unknown to many farmers. Identifying nutrient deficiencies, excesses, and optimal levels may be difficult without soil testing. The cost of professional soil testing is out of reach for many small-scale farmers, especially in developing countries. There can be enough systems in place to understand and use the results regardless of cases if inexpensive testing is accessible.

Fig 1 shown in Data collection from various sources is the job of the highest level of the system's architecture. A final crop dataset is constructed by analysing and mapping this data in the succeeding layer. Analysing the data via exploratory and correlational methods is the next stage. learn about the data and find out what kinds of pre-processing steps are necessary to make sure the dataset is full. To ensure the dataset is acceptable for training the learning model for crop prediction, this method is critical. The input data and task at hand dictated the configuration and optimisation of the neural network model. The testing dataset, which included several soil properties, was then used to verify the trained model. A fertiliser recommendation system based on rules is then integrated into the next section of the proposed system. Using the crop recommendation system's pre-processed information, this step initially conducts soil profiling before constructing a database that is based on solid research and the knowledge of industry professionals. The guiding principle of the suggested approach is the belief that domain-specific, expert-driven rules are indisputable valuable, even if many activities may benefit from machine learning's predictive capabilities. Every crop and soil mix have unique nutrient needs, and this idea forms the basis of the fertiliser suggestion system that proposes to use rules. That approach is based on proven agricultural wisdom makes it both clear and accessible. Through providing them with the rationale behind the advice, that helps farmers to believe them, that in turn increases crop yields and promotes sustainable agricultural methods. The system's rules and suggestions may be improved and updated over time with the aid of a feedback loop mechanism. The recommended research delves into the system's theoretical framework, highlighting potential practical uses and cloud deployment viability.

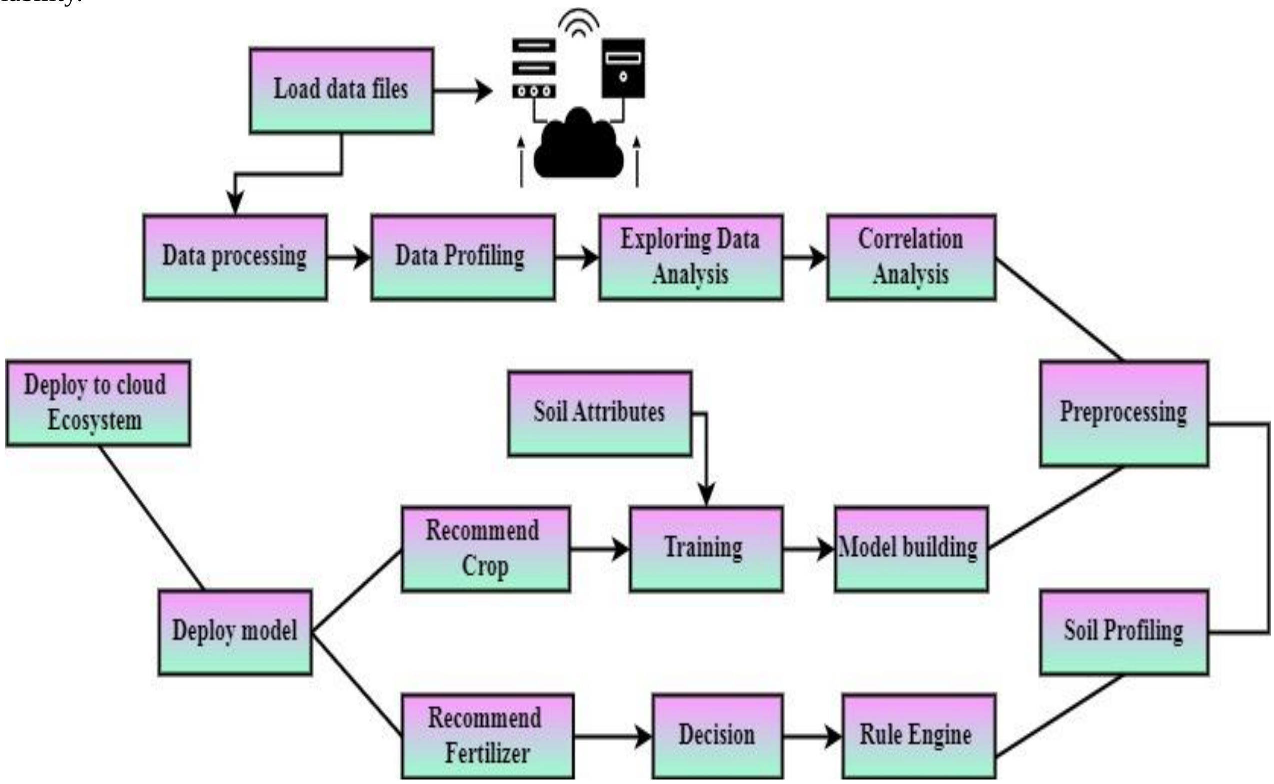

Fig 1. The Proposed CRFS has a Schematic Architecture

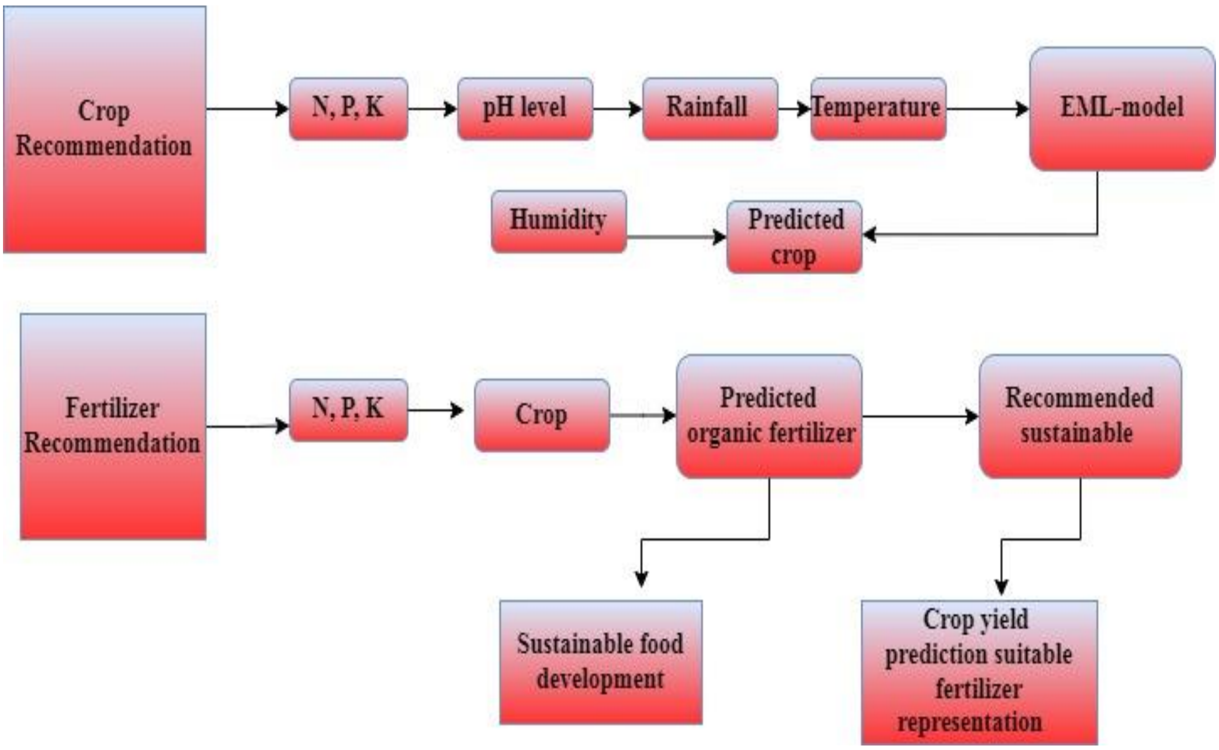

Fig 2. Overview of EML–CFRS

Fig 2 shown in the assist farmers in cultivating crops for improved yield, the suggested method is being developed. Based on essential crops from the given place, this work selects certain crops. The crops that have been chosen include sunflowers, jowar, wheat, cotton, sugarcane, onions, rice, cotton, soybeans, tobacco, and dried chilli. Soil nutrient data may be used for soil classification purposes. Soil classification uses two ML algorithms: Random Forest and Support Vector Machine. In terms of output, the different algorithms may classify and display a confusion matrix, recall, average values, f1-score, and accuracy proportionally. Data on crop yields, nutrients, and geographical locations may all be used to make predictions about future crop yields. According to the current inputs, the algorithms will predict the crop. It uses third-party apps to display weather, temperature, humidity, atmospheric pressure, and general description data. In order to create a more accurate prediction model, ensemble learning involves connecting several types of algorithms or repeatedly using the same approach. The optimal crop yields and recommended amounts of fertiliser are detailed in the fertiliser recommendation. Equally important is the fact that it prioritises showing the weather for the chosen location. To aid farmers, a mobile app can be developed that allows users to upload images of their farms. Disease detection in crops through image processing, with pesticides provided to users based on disease images. With the goal to increase crop yields, farmers need use smart irrigation systems.

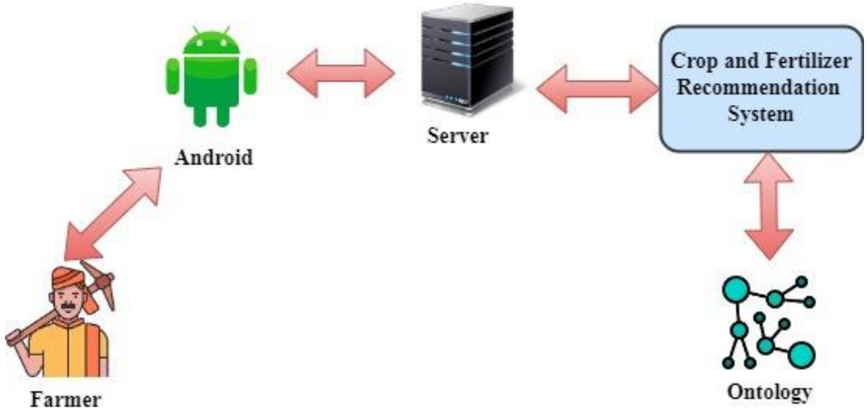

Fig 3. System Architecture

Fig 3 shown in A server-connected Android app with ontological knowledge powers the recommendation engine. The farmer is unable get to the system unless they sign up for an account and uses the Android app. For crop prediction, people utilise a random forest method, and for fertiliser recommendation, people use a k-means algorithm. Input values that the farmer supplies act as test data for these outcomes. The ontology is used to store the learnt data in an attempt to construct a machine learning model for crop prediction. As the server end, all these operations are executed, and the farmer's android smartphone displays the result. Fertiliser recommendations are derived on soil tests that assess nitrogen, phosphorus, and potassium. The pigmentation of leaves is caused by nitrogen present in the soil. Plants possess rather yellowish leaves when the soil nitrogen content is low, and greener leaves with the nitrogen content is moderate or high. The plant's reproductive system is influenced by the phosphorus concentration of the soil. The soil's general growth is dictated with the potassium concentration. The value dictates the plant's total growth rate and predicts the strength of the roots. For implementing an algorithm, there are mainly main processes. The algorithm begins with determining the quantity of fertiliser needed, illustrated that follows.

$$\boldsymbol{R_a = S_a - M_{ta}} \quad \textbf{(1)}$$

$\boldsymbol{R_a}$ = Required NPK for crop
$\boldsymbol{S_a}$ = Standard NPK crop
$\boldsymbol{M_{ta}}$ = Measured NPK crop

The equation (1) subsequent stage is for the method to use the metric distance to group neighbouring fertilisers into clusters. The discrepancy between the NPK levels. That is advised that farmers apply fertiliser in clusters with a minimum space between areas.

$$\boldsymbol{Los\ (A) = EL\ (y, A(X))} \quad \textbf{(2)}$$

where (X, y) is a subset of the training data S and (X) is a continuous loss function. Improving crop production and sustainability is the A goal of the study paper's crop suggested system. L, that aims to provide agricultural stakeholders, including farmers, with the knowledge and resources necessary to make well-informed choices.

$$\boldsymbol{Z = \frac{(x-\mu)}{\sigma}} \quad \textbf{(3)}$$

where the variables x, μ, and σ to identify and eliminate extreme values from the data set, people established a threshold. There found that procedure reduced the number of examples in the dataset when compared to the initial set of instances. the relationship between the characteristics of the dataset used for crop recommendations. For us to get numerical values out of the fertiliser prediction dataset, and categorical properties.

$$\boldsymbol{Y = A + Bx + e} \quad \textbf{(4)}$$

In the equation (4) Y that pertains environmental factors, including temperature, rainfall, and A agricultural production. Farmers B can profit from accurate crop production rate estimates, e is a statistical approach for predictive analysis.

$$\boldsymbol{C_{t2} = \sum \frac{Ob_t - E_{xt}}{E_{xt}}} \quad \textbf{(5)}$$

The equation (5) C_{t2} is a validate the proposed fertiliser recommendation system using characteristics, including nitrogen (N), potassium (K), phosphorus (P), temperature, humidity, soil type, crop kind, and soil moisture. People can $\frac{Ob_t - E_{xt}}{E_{xt}}$assess feature independence, detect patterns and linkages, and draw educated inferences regarding data associations.

$$\boldsymbol{\{t(x, \varphi_m), m = 1, \dots\dots.\}} \quad \textbf{(6)}$$

In equation (6) t uses an ensemble of decision trees designed to reduce overfitting and improve prediction accuracy. That helps comprehend φ_m the elements that impact fertiliser recommendations m through emphasising the relevance of certain features. The system provides farmers with real-time warnings and notifications for essential circumstances including water stress, nutritional deficits, disease outbreaks, and poor weather, and has extensive data visualisation and analytics capabilities. Farmers can utilise simple graphs and charts to evaluate sensor data and identify patterns in soil health, crop yield, and food quality.

Algorithm 1: Ensemble Machine Learning for CROP Recommendation

Input: x_{train} Training data (N, P, K, pH) y_{train} labels (crop)
Number of predictors η, number of unique crop classes k,
Learning rate α, number of epochs e, Batch size s, Adam
hyperparameter $\beta_1, \beta_2, \epsilon$
Output: Ensemble Machine Learning model
Procedure:
1. Initialization:
Define input layer with η
2. Initialize: of hidden layer W_1 and W_2
3. Training: For epoch = 1to e:
4. Toss the training data around
5. Divide x_{train} and y_{train} into the batch size s,
For each batch:
Compute: $Z_1 = W_1 + W_2$
Compute: Loss L
Analyse the manner in which the model performs on the test set to estimate its generalization performance
Pass a fresh output through the trained EML model to get the pesticide recommendation
Model validation using testing dataset
End

Explanation: Neurons in the input layer are equal to the predictor count, denoted as 'n'. This may be mathematically expressed asx_{train} and y_{train} represents N, P, K, and pH comprise the training data. Each iteration uses the gradients obtained from a single batch of the training dataset to update the model's weights and biases. $Z_1 = W_1 + W_2$ is one way to calculate the output layer. The final output probabilities for each class are obtained by applying the SoftMax activation function to the weighted aggregate. Optimisation algorithms EML and Adam are used to update weights and biases. The η technique is used to train the model, which takes the training data into account. Separate subsets for training and validation are created from the training data. Through the identification of latent characteristics and complex patterns in the training instance, the system optimises crop recommendation. The goal of this investigation is to inform farmers regarding certain fertilisers are best for certain crops through creating a rule-based fertiliser recommendation system. The scientific concepts of soil chemistry and plant biology form the basis of the system. In an effort to fill in the gaps in our understanding, the system takes soil pH into account when recommending fertiliser to plants, as various crops have varying nutritional requirements. According to a number of factors, including soil quality, the fertiliser recommendation system.

IV. EXPERIMENTAL ANALYSIS

To ensure a high-quality crop harvesting, that's crucial to invest in agriculture, even if the rule is a limited expenditure. There is important to ensure that the crop picked is appropriate for the soil and environment. The portion provides to evaluation of the proposed approach for predicting crop recommendations. Prediction accuracy was assessed using a number of metrics, including as F1-score, recall, precision, and accuracy. The accuracy and reliability of the ideas provided are ensured by many factors that provide a comprehensive view of the model's performance. The proportion of correct predictions relative to the whole number of forecasts is the accuracy performance metric.

*Dataset Description***:** Agriculture comprises several of the world's most helpful industries. The Crop and Fertiliser Recommendation System enables farms to generate safer in their decisions. The main objective of the collection is to construct a mechanism for recommending crops and fertilisers. A predictive prototype that takes into account a number of factors to determine the crops that would be most suitable for a certain farm. The dataset was created by enhancing existing datasets of snowfall, temperature, and fertiliser data for India. Precision agriculture comprises a few of the available trends. The prediction assists farmers in growing aware associated with that is farming process [25].

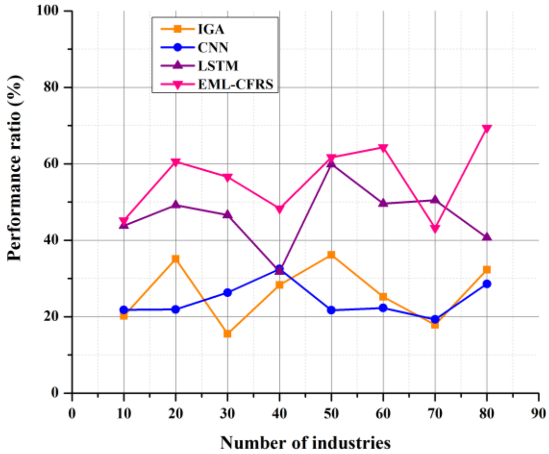

Fig 4. Performance Evaluation of Crop and Fertilizer Recommendation System

Fig 4 shown in farmers assist in evaluating the performance and correctness of implemented algorithms. Accuracy is calculated using the standard precision measure. Effectiveness is a measure of the quantity of food-related information received. The design features markings to assess correctness and exactness. The accuracy of forecasted crops and fertilisers is compared to the actual values provided with experts for those fields and crop sets for each farmer. If the crops indicated by the algorithm are in the expert's recommendation sets, then there are relevant crops. Considering these key crops, the accuracy of the recommendation system is determined. Performance indicators used to assess a model's ability to forecast crop selections and fertiliser recommendations. A fertiliser suggestion is a research-based set of rules, or management techniques, for applying fertiliser to a crop in order to accomplish yield and quality objectives while minimising nutrient losses to the environment.

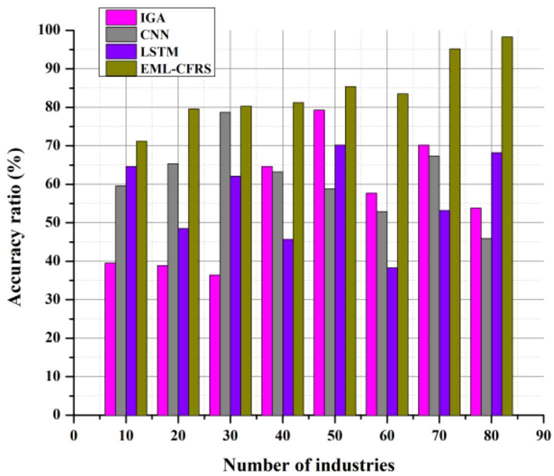

Fig 5. Accuracy of Sustainable Food Development

Fig 5 shows the accuracy of sustainable food development. A sustainable food system ensures food security and nourishment for all people. The system includes various aspects of food production, packaging, and transportation to consumers. Consumption relates to the physical availability of food, both in quantity and quality. Indicators of food availability include: Per capita dietary energy supply. Crop yield Food Price Index. Engaging in sustainable food practices guarantees that the industries and household has minimal environmental effect. Sustainable food seeks to minimise harming or waste natural resources. It reduces the contribution to climate change since sustainability frequently entails consuming more local food that is not transported far. The exhibited accuracy percentages were 91.73% and 85.17 percent, subsequently The effort focused on smart farming, including an intelligent pesticide and fertiliser recommendation system.

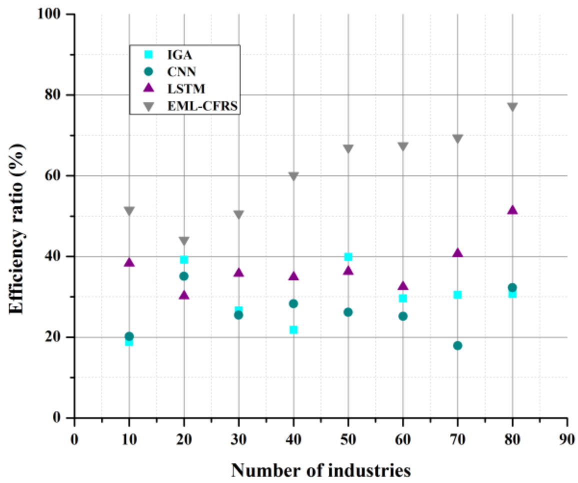

Fig 6. Efficiency of EML-CFRS

Fig 6 shown in the improve forecast accuracy in a crop recommendation system, a comprehensive strategy is required. Begin by gathering high-quality and diversified data on soil types, weather conditions, prior crop yields, and local agricultural methods, ensuring that the information is clean and reliable. Fertiliser usage efficiency is a measurement of an applied fertilizer's ability to boost productivity and nutrient utilisation in the soil and plant system. A regrowth indicator is primarily used to evaluate the efficiency NPK fertilisation. Efficient crop production is the process of increasing crop yield while reducing the use of resources such as water, fertilisers, and energy [26]. An efficient agricultural system is one with low income fluctuation and high earnings.

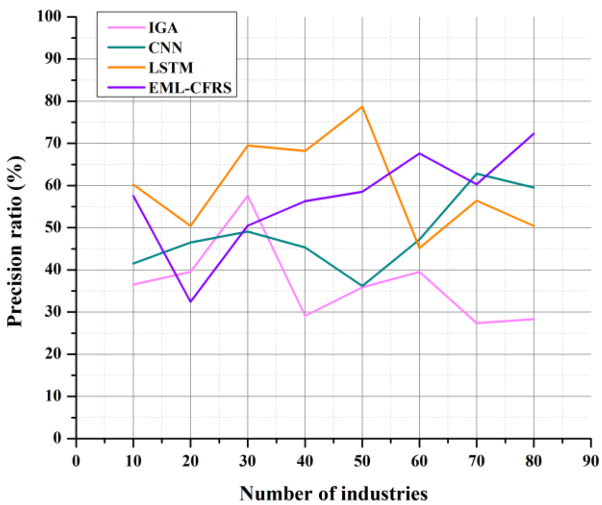

Fig 7. Precision of Sustainable Food Development

Fig 7 shown in Precision agriculture can help manage agricultural production inputs in an ecologically sustainable manner. Precision agriculture can utilise site-specific information to tailor fertiliser, seed, and chemical rates based on soil and other circumstances. Precision agriculture substitutes information and expertise for physical inputs.

Precision agriculture preserves ecosystems and increases agricultural sustainability while likewise preserving excellent water quality, soil biodiversity, soil organic carbon management, and avoiding land loss. Precision agriculture technology and techniques assist farmers in reducing the quantity of inputs they use, potentially lowering the risk of environmental damage. Precision agriculture technology can assist farmers monitor and manage their crops more successfully, lowering the risk of pests and diseases and improving soil quality.

Table 1. Statistical summary of Crop and Fertilizer Recommendation System

Methods	Nitrogen (N)	Phosphorous (P)	Potassium (k)	Air temperature	Air Humidity	Soil pH	Rainfall
IGA	50.55	2200	48.14	25.61	71.48	6.47	2200
CNN	36.91	32.98	50.64	5.06	22.26	0.77	20.21
LSTM	140.00	5.00	5.00	8.82	14.25	3.50	54.68
EML-CFRS	2200	145.00	205.00	43.67	99.98	9.93	298.56

Table 1 denotes fertiliser can provide macro-nutrients, with varied N, P, and K concentrations suitable for various crops. Crops need high levels of N, P, and K to flourish, and well-fed plants are more productive. Farmers that do not utilise fertiliser may experience insufficient soil nutrients for optimal development. Understanding the NPK ratios required by crops can assist farmers manage fertilisation for maximum plant growth and production. Fertiliser replenishes resources that the environment needs. People researched the nitrogen, phosphorus, and potassium requirements for many crop types in experimental. The results of our study show that fruits and crops need higher levels of potassium than comparable crops. In crop recommendation, people penetrate data that includes rainfall, temperature, N, P, and K levels, and the system then predicts the crop that can be grown. Soil data and kind of crop are supplied through people into the fertiliser suggestion system.

V. CONCLUSION

The Crop and Fertiliser Recommendation System (CFRS) developed for the nation's unique farming conditions. To help farmers in making accurate possibilities on crop selection and fertiliser usage, the system utilises data analysis and ensemble machine learning (EML). Their maintained precision, balance, and competence with outperforming several well-known machine learning models in thorough comparison tests. The research indicates farmers need to be issued ideas for ideal crops to grow in the field and fertilisers to use based on recorded data, as the data is crucial for farmers to develop informed agricultural decisions. The performance evaluation showed that the manufactured system's accuracy is quite high. This strategy has the ability to enhance agricultural goods and quality while promoting cost-effective farming techniques and reducing the environmental impact. Estimating soil pH, for example, by using soil moisture and sunshine. As a result, the sensors would cost less to install and maintain. However, the system can execute into Explore adding additional environmental and geographical components, and the data modelling and feature extraction techniques can be constrained. Future research might concentrate on incorporating more meteorological and regional parameters into the system, like rainfall, temperature, humidity, and altitude. A Farmers can utilise a smartphone application to submit photographs of their land. Crop diseases are recognised via image processing, and pesticides are sent to customers based on disease pictures. Implement a Smart Farming Systems on agriculture to boost output.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

Funding
No funding agency is associated with this research.

Competing Interests
There are no competing interests.

Reference:
[1]. M. A. Hossain and M. N. A. Siddique, "Online Fertilizer Recommendation System (OFRS): A Step Towards Precision Agriculture And Optimized Fertilizer Usage By Smallholder Farmers In Bangladesh," European Journal of Environment and Earth Sciences, vol. 1, no. 4, Aug. 2020, doi: 10.24018/ejgeo.2020.1.4.47.
[2]. U. Ahmed, J. C.-W. Lin, G. Srivastava, and Y. Djenouri, "A nutrient recommendation system for soil fertilization based on evolutionary computation," Computers and Electronics in Agriculture, vol. 189, p. 106407, Oct. 2021, doi: 10.1016/j.compag.2021.106407.
[3]. C. Musanase, A. Vodacek, D. Hanyurwimfura, A. Uwitonze, and I. Kabandana, "Data-Driven Analysis and Machine Learning-Based Crop and Fertilizer Recommendation System for Revolutionizing Farming Practices," Agriculture, vol. 13, no. 11, p. 2141, Nov. 2023, doi: 10.3390/agriculture13112141.
[4]. Aishwarya Karandikar, Chaitali Kannurkar, Amey Patil, Bhavesh Jagtap, and Varsha Sontakke, "Review of Crop and Fertilizer Recommendation Systems", Vidhyayana, vol. 8, no. si7, pp. 197 – 210, May 2023.
[5]. N. Panwar, "Designing an Intelligent Fertilizer Recommendation System for Small-scale Farmers," Mathematical Statistician and Engineering Applications, vol. 70, no. 2, pp. 1393–1399, Feb. 2021, doi: 10.17762/msea.v70i2.2331.
[6]. S. Singh, S. Mohanty, and P. K. Pattnaik, "Agriculture Fertilizer Recommendation System," Proceedings of 2nd International Conference on Smart Computing and Cyber Security, pp. 156–172, 2022, doi: 10.1007/978-981-16-9480-6_15.

[7]. P. He., "Ensuring future agricultural sustainability in China utilizing an observationally validated nutrient recommendation approach," European Journal of Agronomy, vol. 132, p. 126409, Jan. 2022, doi: 10.1016/j.eja.2021.126409.
[8]. P. Dey, "Soil Health Card Scheme of Government of India for balanced fertilizer application and on-line fertilizer recommendation system," In SAARC Training Manual on Integrated Nutrient Management for Improving Soil Health and Crop Productivity (P. Dey et al., Eds.) ICAR-Indian Institute of Soil Science. Bhopal, India, 91-98, 2018.
[9]. U. Sarkar, G. Banerjee, and I. Ghosh, "A Machine Learning Based Fertilizer Recommendation System for Paddy and Wheat in West Bengal," Computational Intelligence in Communications and Business Analytics, pp. 163–174, 2021, doi: 10.1007/978-3-030-75529-4_13.
[10]. R. Thendral and M. Vinothini, "Crop And Fertilizer Recommendation to Improve Crop Yield using Deep Learning," 2023 Second International Conference on Electronics and Renewable Systems (ICEARS), Mar. 2023, doi: 10.1109/icears56392.2023.10085054.
[11]. S. Iniyan, M. S. Raja, R. Srinivasan, C. Santhanakrishnan, and A. Srinivasan, "Crop and Fertilizer Recommendation System Applying Machine Learning Classifiers," 2023 International Conference on Emerging Research in Computational Science (ICERCS), Dec. 2023, doi: 10.1109/icercs57948.2023.10433972.
[12]. U. I. Udoumoh, E. G. Ikrang, and P. O. Ehiomogue, "Precision Farming and Fertilizer Recommendation Using Geographic Information System (GIS): A Review," International Journal of Agriculture and Earth Science., 7(2), 1-8, 2021.
[13]. W. Jiang, Y. Xing, X. Wang, X. Liu, and Z. Cui, "Developing a Sustainable Management Strategy for Quantitative Estimation of Optimum Nitrogen Fertilizer Recommendation Rates for Maize in Northeast China," Sustainability, vol. 12, no. 7, p. 2607, Mar. 2020, doi: 10.3390/su12072607.
[14]. S. Chavan, P. Saswade, Y. Pokale, A. Kadu, and H. Puranik, "Vegetable Plant Disease Detection And Fertilizer Recommender System," International Journal Of Current Science, 13(2), 634-638, 2023.
[15]. R. S and S. R, "Sustainable Fertilizers in Coffee Plantation: Hybrid Recommendation for Agricultural Producers," 2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA), Aug. 2023, doi: 10.1109/icirca57980.2023.10220825.
[16]. S. Zarei, O. Bozorg-Haddad, V. P. Singh, and H. A. Loáiciga, "Developing water, energy, and food sustainability performance indicators for agricultural systems," Scientific Reports, vol. 11, no. 1, Nov. 2021, doi: 10.1038/s41598-021-02147-9.
[17]. U. Ahmed, J. C.-W. Lin, G. Srivastava, and Y. Djenouri, "A nutrient recommendation system for soil fertilization based on evolutionary computation," Computers and Electronics in Agriculture, vol. 189, p. 106407, Oct. 2021, doi: 10.1016/j.compag.2021.106407.
[18]. T. Thorat, B. K. Patle, and S. K. Kashyap, "Intelligent insecticide and fertilizer recommendation system based on TPF-CNN for smart farming," Smart Agricultural Technology, vol. 3, p. 100114, Feb. 2023, doi: 10.1016/j.atech.2022.100114.
[19]. H. K. Gill, V. K. Sehgal, and A. K. Verma, "A Context Aware Recommender System for Predicting Crop Factors using LSTM," 2021 Asian Conference on Innovation in Technology (ASIANCON), Aug. 2021, doi: 10.1109/asiancon51346.2021.9544692.
[20]. K. Kamaraj, B. Lanitha, S. Karthic, P. N. Senthil Prakash, and R. Mahaveerakannan, "A Hybridized Artificial Neural Network for Automated Software Test Oracle," Computer Systems Science and Engineering, vol. 45, no. 2, pp. 1837–1850, 2023, doi: 10.32604/csse.2023.029703.
[21]. Pruthviraj, G. C. Akshatha, K. A. Shastry, Nagaraj, and Nikhil, "Crop and Fertilizer Recommendation System Based on Soil Classification," Recent Advances in Artificial Intelligence and Data Engineering, pp. 29–40, Nov. 2021, doi: 10.1007/978-981-16-3342-3_3.
[22]. R. Garg, H. Aggarwal, P. Centobelli, and R. Cerchione, "Extracting Knowledge from Big Data for Sustainability: A Comparison of Machine Learning Techniques," Sustainability, vol. 11, no. 23, p. 6669, Nov. 2019, doi: 10.3390/su11236669.
[23]. R. Jain et al., "Internet of Things-based smart vehicles design of bio-inspired algorithms using artificial intelligence charging system," Nonlinear Engineering, vol. 11, no. 1, pp. 582–589, Jan. 2022, doi: 10.1515/nleng-2022-0242.
[24]. Y.-C. Chen, C.-S. Lee, P.-L. Tsui, and M.-C. Chiang, "The Application of the Analytic Hierarchy Process Approach to the Inheritance of Local Delicious Food Culture and Development of Sustainable Innovations," Agronomy, vol. 12, no. 3, p. 660, Mar. 2022, doi: 10.3390/agronomy12030660.
[25]. https://www.kaggle.com/datasets/sanchitagholap/crop-and-fertilizer-dataset-for-westernmaharashtra
[26]. K. K. Devi and J. P. Kumar, "An efficient data collection tool for crop recommendations model using Robotic Process Automation," 2023 14th International Conference on Computing Communication and Networking Technologies (ICCCNT), Jul. 2023, doi: 10.1109/icccnt56998.2023.10308274.