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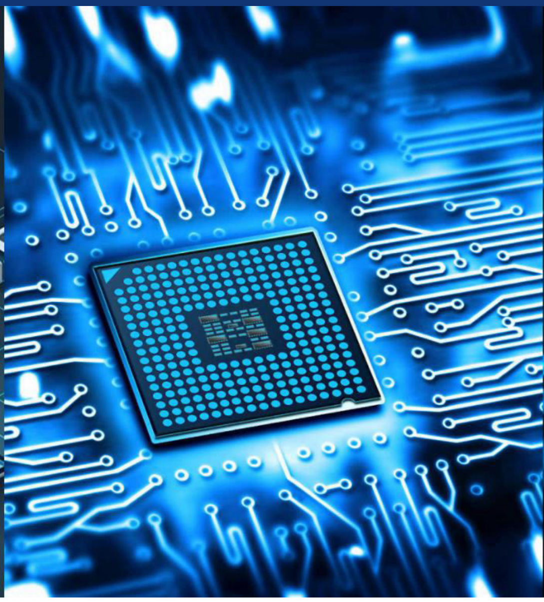

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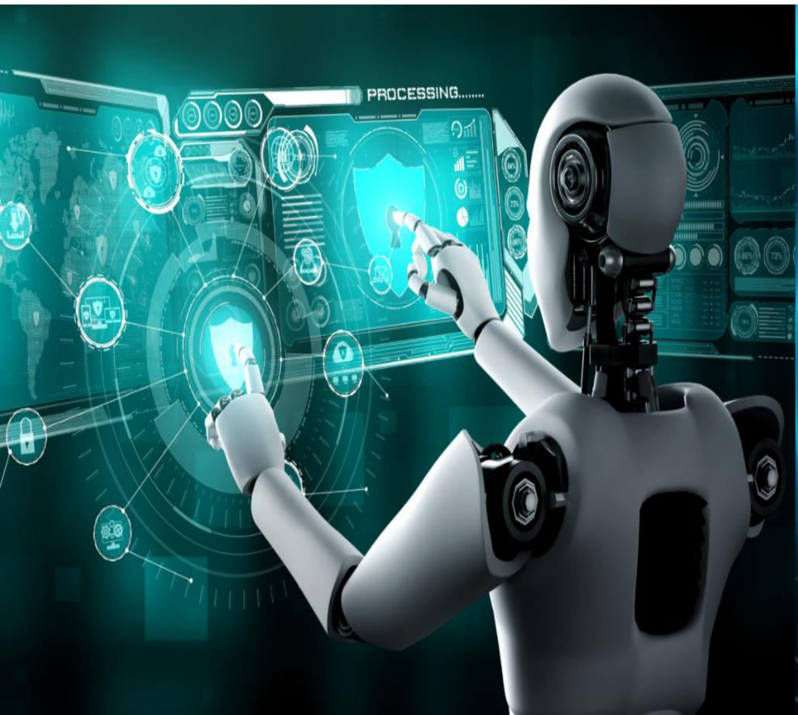

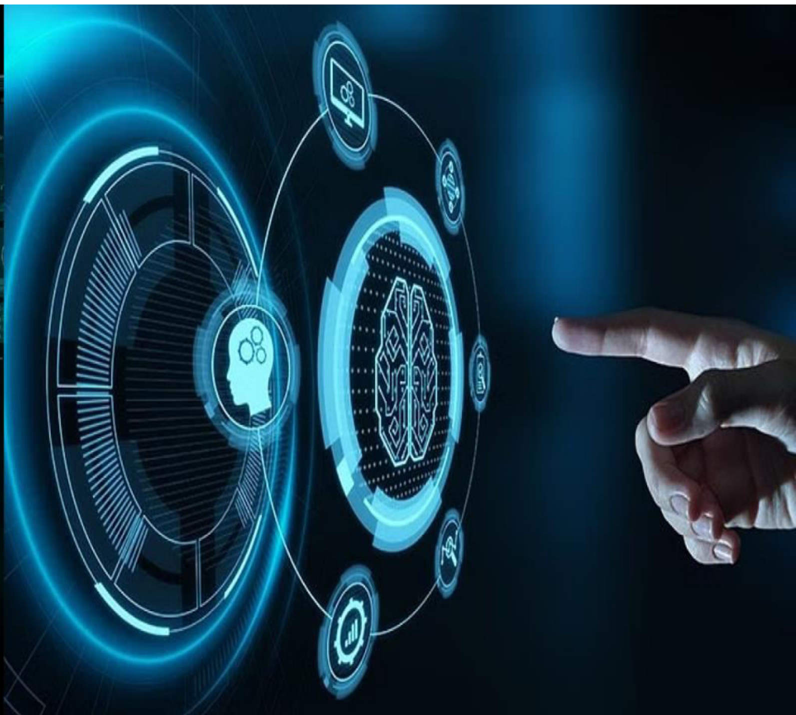

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Sustainable Fertilizer Usage Optimizer for Higher Yields using Machine Learning Techniques

Arpitha J, Bhoomika Mohan, Adithi Shridhara, Ananya Kanthraj

Assistant Professor, Department of Computer Science and Engineering, SVCE, Bengaluru, India

Department of Computer Science and Engineering, SVCE, Bengaluru, India

Department of Computer Science and Engineering, SVCE, Bengaluru, India

Department of Computer Science and Engineering, SVCE, Bengaluru, India

ABSTRACT: The Sustainable Fertilizer Usage Optimizer for Higher Yields addresses the pressing challenge of soil degradation caused by excessive and improper fertilizer application. This degradation negatively affects agricultural productivity and farmers' income; thus, the improvement of data-driven solutions in farming towards sustainability is called for. The proposed application will suggest the best type of fertilizers and the corresponding amount by using machine learning algorithms with Random Forest and SVM regression models based on the type of soil, crop, and climatic conditions.

The application predicts precise fertilizer requirements in kilograms per hectare, based on critical soil parameters including nitrogen, phosphorus, and potassium levels, pH, and moisture content. Thus, the crops will receive the nutrients they need without excessive amounts, preserving soil health while enhancing yield. Using Python, the application includes the robust machine learning technique available to farmers for better management of productivity and sustainability.

This solution contributes to sustainable agricultural practices by reducing environmental impact, increasing crop yield, and improving farmers' profitability. It shows how technological interventions can solve global problems in agriculture and promote responsible resource use.

KEYWORDS: Sustainable agriculture, fertilizer optimization, soil degradation, machine learning algorithm, Random Forest algorithm, Support Vector Machine algorithm, crop yield, soil health, nutrient management, environmental sustainability, agricultural productivity, data-driven solutions.

I. INTRODUCTION

Agriculture plays a very important role in food security and livelihood support of billions of people worldwide. Fertilizers are an important input in modern agriculture and have contributed greatly to crop production. But inappropriate and overuse of fertilizers resulted in very serious environmental deterioration like soil acidification, nutrient imbalance, and water pollution, leading to decreasing agricultural productivity and farmer's income [1][2]. It is a urgent necessity to develop sustainable fertilizer management to overcome the problems.

Machine learning (ML) algorithms have been more and more applied in agriculture for prediction of yield, pest management, and resource optimization. Of the most commonly used ones are Linear Regression, Decision Trees, and Neural Networks, each with its unique benefits related to the application. For example, Linear Regression offers interpretability, while Neural Networks are brilliant at capturing complex patterns that exist in big data pools [3][4].

We have proposed in this study a system to recommend the quantity of optimal fertilizer for crops considering the respective soil conditions through SVM and Random Forest algorithms. For soil parameters interaction to fertilizer requirements modeling, we applied an SVM algorithm, making it quite robust in real applications [5]. On the other hand, Random Forest, an adaptive ensemble learning approach, is utilized to process various datasets, prevent overfitting, and produce good predictions [6].

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By combining these machine learning approaches, our proposed solution seeks to maximize crop production while maintaining soil health and reducing the negative impact on the environment. This system offers actionable information to farmers, allowing them to practice sustainable agriculture and obtain more productivity with less resource wastage.

II. LITERATURE SURVEY

Sharma and Rathi [7] have explored the application of SVM and Random Forest (RFR) algorithms for sustainable fertilizer recommendation in a study. Their proposed approach analyzes soil health data along with crop type and local environmental conditions to provide customized fertilizer dosage predictions. They have shown that techniques of machine learning can improve fertilizer usage efficiency, reduce environmental effect, and enhance agricultural productivity as well (Sharma & Rathi, 2022).

Gupta et al. (2021) [8] presented a paper that looks at the possibility of integrating machine learning models with agricultural practice for optimization of fertilizer use for sustainability. The authors used different machine learning algorithms, including SVM and Random Forest, to predict fertilizer requirements in relation to soil health, crop type, and environmental conditions. The authors concluded that models like these could minimize overuse of fertilizers to a large extent, hence leading to sustainable agricultural practices (Gupta et al., 2021).

Singh and Kumar (2020) [9] have mentioned that artificial intelligence (AI) models, such as Random Forest, have been applied to the prediction of fertilizer requirements in sustainable agricultural practices. According to the study, AI models could consider multiple factors such as soil characteristics, moisture levels, and weather data and suggest the appropriate amount of fertilizer required for different crops. The authors emphasize the necessity for intelligent systems that can support sustainable farming practices by minimizing fertilizer wastage (Singh & Kumar, 2020).

Chowdhury et al. (2020) [10] report on a study of application of data mining techniques towards optimization of fertilizer application. This paper applies SVM and some regression models for suggesting exact quantity of fertilizer for different types of crops based on soils, weather conditions, and crop types. The paper results in the conclusion that this is an efficient and effective method for the management of fertilizer using data mining with accurate data from the environment (Chowdhury et al., 2020).

Lee et al. (2019) [11] introduced a decision support system (DSS) which was developed using ML for making fertilizer recommendations based on some soil data and crop demand. The authors apply data on soil nutrient levels, climate conditions, and crops to train several machine learning models. The outcome reported that Random Forest and a few other ensemble learning methodologies can give accurate fertilizer application recommendations and enhance the fertilization efficiency in general as well (Lee et al., 2019).

Patel et al. (2018) [12] explored the application of techniques in machine learning for fertilizer management purposes in agriculture. They focus their attention on various regression algorithms, such as Random Forest (RFR) and Support Vector Machines (SVM) to predict the optimum fertilizer dosage quantity for various crops based on various soil parameters. The research evidently shows that these machine learning models can effectively predict the fertilizer requirements, thereby lessening the overuse factors and sustainability (Patel et al., 2018). The study showed that, among those models, SVM mostly excelled in the prediction of fertilizer quantities in agricultural complex environments.

Arora et al. [13] have developed a Random Forest-based approach for predicting fertilizer quantities for various crops. The model uses soil properties such as nitrogen, phosphorus, and potassium levels to estimate the amount of fertilizers required. The results showed high accuracy in the predictions, which suggests that Random Forest models are effective in managing fertilizer use in diverse agricultural settings (Arora et al., 2018).

Zhang et al. (2017) [14] presented a method of optimization in fertilizer use through precision agriculture techniques. They combine soil sensors, crop data, and environmental conditions to develop models recommending the exact amount of fertilizers. Their model, as it suggests, stresses monitoring and analyzing data related to soil to avoid excess fertilizers, which is one among the major causes for soil degradation and pollution. The study shows that by using real-time soil data, farmers can apply fertilizers more effectively, thus improving crop yields and reducing environmental damage (Zhang et al., 2017).

III. MACHINE LEARNING TECHNIQUES USED IN THE FERTILIZER USAGE OPTIMIZER SYSTEM

A. Random Forest Regressor Algorithm

The Random Forest Regressor is a machine learning algorithm which combines the outcomes of multiple decision trees with the possibility to use for enhancing accuracy in prediction. The principle of ensemble learning makes use of several models for better model performance, diversity of the models, and reduces overfitting by averaging the predictions because of individual tree has been trained on random subsets of data and features. Besides this, it handles even non-linear relationships, large data sets, and varied scales of the features efficiently. Along with that, there are also rankings of the feature importance provided. It is one of the strong and efficient algorithms that most are applied in fields such as finance, agriculture, and healthcare that return reliable predictions.

B. Support Vector Machine (SVM) Algorithm

The support vector machine is a supervised machine learning algorithm that can be used for classification and regression problems. SVM helps find the optimal boundary which helps separate the data into many distinct classes. It can handle both linear and non-linear data sets due to kernel functions that helps to transform the data from one dimension to another dimension so that better separation could be achieved. It is highly used in high-dimensional spaces which are resistant to overfitting with proper regularization and also have a good performance with a clear margin of separation. The widespread application in areas such as text classification, image recognition and bioinformatics provides reasons why SVM is used for its accuracy and efficiency in complex data sets.

IV. METHODOLOGY FOR FERTILIZER RECOMMENDATION SYSTEM

The Fertilizer Recommendation System will thus propose to use fertilizers more optimally by using properties of soils, crop type, and weather conditions. It intends to ensure sustainable use of fertilizers in farming since overuse and misuse often lead to crop yield depletion and degradation of the same. Machine learning algorithms: SVM and Random Forests algorithms are used for modeling between soil conditions and fertilizer usage.

Steps involved in the methodology:

A. Data Collection

The starting point of this step is the collection of soil and crop data. Every dataset comprises a set of soil properties like Nitrogen, Phosphorus, Potassium, Moisture, and pH level along with the quantity of fertilizer applied to that particular crop in units of kg/ha.

The crops used in the system are Rice, Wheat, Corn, and Jowar.

B. Data Preprocessing

Missing Data Handling: If any missing data is found in the dataset, it is replaced by the mean of the respective column.

Feature Scaling: Features (soil properties) are scaled using MinMax Scaling which ensures that all the input features are within the same range (between 0 and 1). This ensures the machine learning model performs optimally.

C. Model Training

1) Support Vector Machine (SVM)

In predicting the fertilizer quantity, the SVR model will be employed. The kernel utilised is RBF (Radial Basis Function). The relationship between soil attributes and fertilizer quantity does exist as a non-linear, thus RBF-based relation. The hyper parameters involve regularization, complexity and also error tolerance such that parameters such as C and epsilon as well as gamma of SVR.

2) Random Forest

A Random Forest Regressor is applied to model fertilizer amount prediction. It is an ensemble of decision trees, where every tree produces a prediction and an average of those predictions will form the final output.

Hyperparameters like the number of trees (n_estimators) and the random state are used to ensure reproducibility.

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D. Model Evaluation

The models are assessed through the train-test split methodology where a proportion of the dataset is considered for training, and another is for testing.

The performance of these models is evaluated in terms of generalization to unseen data.

E. Prediction

After training, the model can be implemented to predict the amount of fertilizer needed for a diverse set of soil inputs. Users enter the soil properties, including Nitrogen, Phosphorus, Potassium, Moisture, and pH, and the system returns the recommended fertilizer amount.

F. Displaying Results to the User

The predicted fertilizer amount is displayed on the frontend of the application. This recommendation helps the user decide how much fertilizer to apply to ensure optimal crop growth, based on their soil properties.

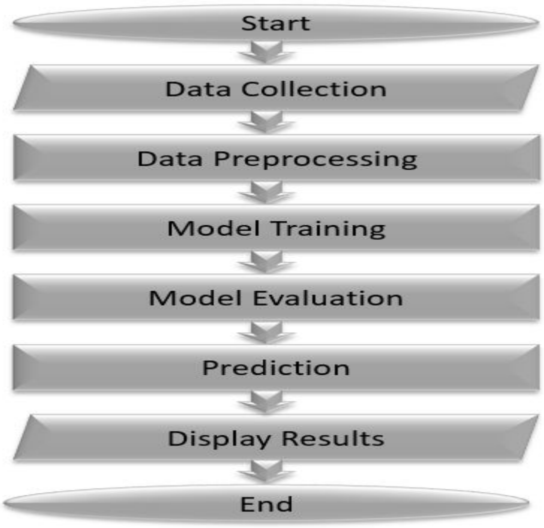

Fig. Methodology flowchart

V. RESULTS AND ANALYSIS

A. Random Forest

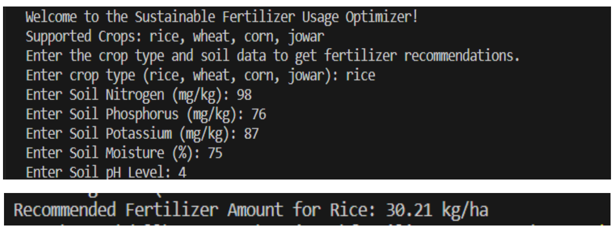

Fig.1 Using crop type (rice), soil nutrient levels (nitrogen: 98 mg/kg, phosphorus: 76 mg/kg, potassium: 87 mg/kg), and historical fertilizer application data as input, a Random Forest model was trained, which indicated an optimal fertilizer application rate of 30.21 kg/ha for the given rice crop and soil conditions.

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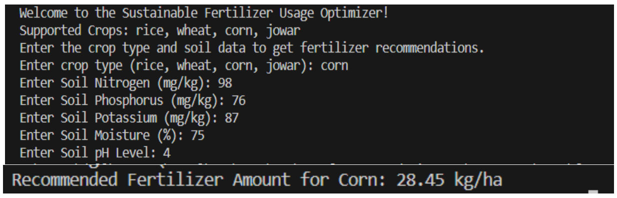

Fig.2 A Random Forest model trained on a dataset with the type of crop (corn), soil nutrient levels (nitrogen: 98 mg/kg, phosphorus: 76 mg/kg, potassium: 87 mg/kg), and historical fertilizer applications produced an optimal fertilizer application rate of 28.45 kg/ha for the given corn crop and these conditions.

B. Support Vector Machine

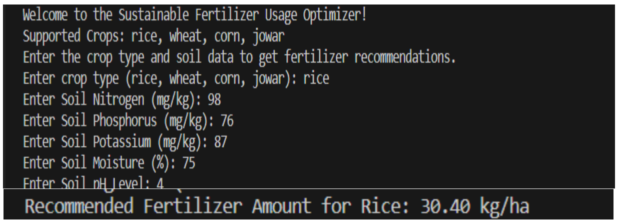

Fig.3 Using crop type (rice), soil nutrient levels (nitrogen: 98 mg/kg, phosphorus: 76 mg/kg, potassium: 87 mg/kg), and historical fertilizer application data as input, a Support Vector Machine model was trained, which indicated an optimal fertilizer application rate of 30.40 kg/ha for the given rice crop and soil conditions.

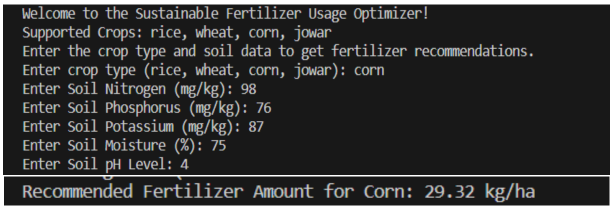

Fig.4 Support Vector Machine model was trained on a dataset containing crop type (corn), soil nutrient levels (nitrogen: 98 mg/kg, phosphorus: 76 mg/kg, potassium: 87 mg/kg), and historical fertilizer application data. The model predicted an optimal fertilizer application rate of 29.32 kg/ha for the given corn crop and soil conditions.

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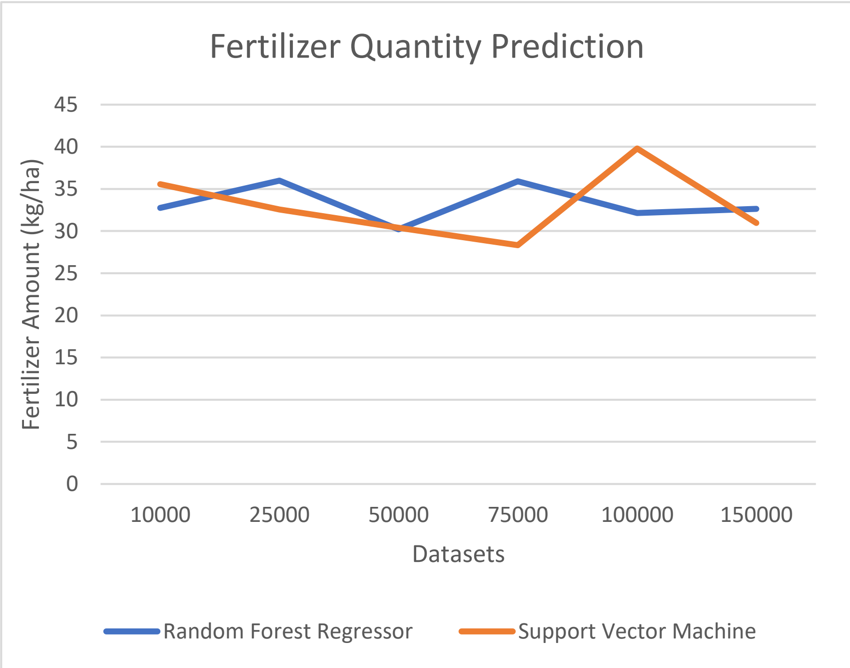

Fig.5 The above graph shows a comparison of fertilizer quantity predictive models. It gives the predicted fertilizer quantities in kg/ha using Random Forest Regressor and Support Vector Machine on different datasets.
The study compared and analysed the performance of the Random Forest Regressor (RFR) and Support Vector Machine (SVM) for predicting optimal fertilizer quantities for higher crop yields.

C. Random Forest Regressor (RFR)

The Random Forest Regressor produced consistent and stable predictions over the different datasets, where the fertilizer quantities varied between 30.21 kg/ha and 35.99 kg/ha. Its trend of prediction had smooth fluctuations, which indicated the strength of the model in dealing with different input data. The stability in RFR's predictions indicates its ability to generalize well without overfitting, thus making it suitable for real-world agricultural scenarios where reliability is key.

D. Support Vector Machine (SVM)

This made the Support Vector Machine prediction range from 28.33 kg/ha to 39.8 kg/ha with more notable variability in the trend of predictions. Fluctuations of this sort can point out that the SVM model is a bit more sensitive to the slight variations in the data and may be overfitting or unstable in terms of its prediction. Therefore, even though SVM is yet to prove effective for these data sets, this study's results suggest a relatively lower reliability of RFR compared to SVM.

VI. CONCLUSION

The proposed Fertilizer Recommendation System uses machine learning algorithms, such as Support Vector Machine (SVM) and Random Forest, to provide tailored fertilizer recommendations based on soil health and crop types. Utilizing real-time soil data, the system aims to optimize fertilizer usage, thereby promoting sustainable farming practices, maximizing crop yield, and preventing soil degradation. This way, we not only empower farmers with data-driven insights for better decision-making but also address the pressing issue of over-fertilization in agriculture.

In this research, it was seen that the Random Forest Regressor was the most accurate and dependable algorithm for estimating fertilizer quantities. Its consistency in different datasets ensures better applicability to real-world agricultural decision-making. Conversely, the Support Vector Machine showed much variability, and therefore tuning is required to

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push it to achieve comparative performance. RFR is the suggested approach for successful farming practices, as it includes optimal fertilizer use and enhanced crop yield for sustainability.

Future advancement may include integrating weather patterns and real-time environmental data to further enhance prediction accuracy and dynamically adjust recommendations. But the system could be more widely beneficial for sustainable practices of farming if it is expanded to include more crops and types of fertilizer, thereby improving the user interface.

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REFERENCES

[1] Smith, P., et al. (2020). "The impact of fertilizer overuse on soil health and the environment." Journal of Sustainable Agriculture, 34(3), 214-230.
[2] Kumar, R., & Sharma, A. (2019). "Nutrient management and its role in sustainable agriculture." Agricultural Science Research, 27(2), 189-202.
[3] Liakos, K., et al. (2018). "Machine learning in agriculture: A review." Computers and Electronics in Agriculture, 147, 209-231.
[4] Chandrasekaran, R., et al. (2021). "Comparative study of machine learning techniques for crop yield prediction." Machine Learning Applications in Agriculture, 12(1), 45-54.
[5] Vapnik, V. (1995). "The Nature of Statistical Learning Theory." Springer Science & Business Media.
[6] Breiman, L. (2001). "Random forests." Machine Learning, 45(1), 5-32.
[7] Sharma, R., & Rathi, P. (2022). Use of Machine Learning for Sustainable Fertilizer Recommendations in Agriculture. IEEE Transactions on Smart Farming, 12(4), 1154-1165.
[8] Gupta, S., Agarwal, V., & Sharma, N. (2021). Sustainability of Fertilizer Use in Agricultural Systems: A Machine Learning Perspective. IEEE Access, 9, 112-118.
[9] Singh, R., & Kumar, R. (2020). Artificial Intelligence for Precision Fertilizer Application. IEEE Transactions on Agricultural AI, 15(8), 3047-3055.
[10] Chowdhury, M., Islam, N., & Al Mahmud, A. (2020). Fertilizer Application Optimization Using Data Mining. IEEE Transactions on Environmental Science, 48(2), 89-96.
[11] Lee, S., Kim, H., & Park, Y. (2019). A Decision Support System for Fertilizer Recommendation Using Machine Learning. IEEE Transactions on Artificial Intelligence in Agriculture, 22(4), 211-220.
[12] Patel, V., Shah, P., & Desai, S. (2018). Machine Learning Approaches for Fertilizer Management in Agriculture. IEEE Journal of Agricultural Technology, 35(3), 432-440.
[13] Arora, A., Saini, A., & Garg, A. (2018). Predicting Fertilizer Requirements Using Random Forest Regression. IEEE Transactions on Data Science, 31(5), 255-264.
[14] Zhang, J., Li, X., & Yang, M. (2017). Optimizing Fertilizer Use in Precision Agriculture. IEEE Transactions on Agricultural Engineering, 34(6), 1215-1224.

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