Mathematical Statistician and Engineering Applications
ISSN: 2094-0343
DOI: https://doi.org/10.17762/msea.v70i2.2331

Designing an Intelligent Fertilizer Recommendation System for Small-scale Farmers

Neeraj Panwar

Asst. Professor, School of Computing, Graphic Era Hill University, Dehradun, Uttarakhand India 248002

Article Info
Page Number: 1393-1399
Publication Issue:
Vol. 70 No. 2 (2021)

Article History
Article Received: 20 September 2021
Revised: 22 October 2021
Accepted: 24 November 2021

Abstract
The agriculture sector is a vital part of the world's population, as it provides food for everyone. Unfortunately, small-scale farmers often face challenges when it comes to choosing the appropriate amount and type of fertilizer to their crops. This paper proposes an intelligent fertilizer recommendation system (IFRS) that uses machine learning techniques. IFRS is designed to help small-scale farmers make informed decisions when it comes to applying fertilizer. It uses machine learning techniques to analyze and recommend the most effective fertilizer for their crops. This system is built on historical data about the various factors that affect the development and maintenance of a farm's soil and crop yield. It uses machine learning techniques to make informed decisions and improve the efficiency of its operations. The system's dashboard is designed to help farmers easily access and interpret the recommendations it provides. It allows them to input their crop characteristics and location, and it provides personalized fertilizer suggestions based on these data. In addition, it displays the weather conditions and other factors that can affect the application of nutrients. The proposed IFRS would provide small-scale farmers with a reliable and efficient fertilizer recommendation system, which would enhance their income and productivity. The system's user-friendly dashboard and accuracy would make it ideal for use in different countries with varying climates and soil types.

Keywords: Fertilizer, Crops, machine learning,

Introduction

Machine learning has been shown to help solve various agricultural problems, such as the prediction of crop yield and the management of soil nutrients. This study aims to develop an intelligent fertilizer recommendation system that will provide small-scale farmers with personalized recommendations. The system will help them improve their income and productivity by allowing them to apply the appropriate amount and type of fertilizer. The agriculture sector is one of the world's most important industries, as it produces food for the population. Unfortunately, small-scale farmers often face challenges when it comes to determining the appropriate amount of fertilizer to use on their crops. Although there are already systems that can help them, they are not easily accessible to them[1]–[3].

As a significant contributor to the global food production, small-scale farmers play a crucial role in the development of this sector. Unfortunately, they are often hindered by various factors, such as the lack of access to modern technologies and inadequate knowledge about the proper use of nutrients. Farmers also face challenges in determining the appropriate application time,

quantity, and fertilizer type, as well as their income and crop yield. There are various methods that have been proposed to help solve this issue, such as precision agriculture techniques, expert systems, and decision support systems. These approaches require a lot of specialized knowledge and are not ideal for small-scale farmers due to their high cost and complexity. Therefore, a more cost-effective and efficient solution has to be developed[4].

The use of machine learning technology has been shown to help address various agricultural issues, such as the recommendation of fertilizer. Through the use of machine learning algorithms, which analyze large datasets, the system can provide accurate predictions. This study aims to create an intelligent fertilizer recommendation system, which will allow small-scale farmers to receive personalized advice. As a vital part of the global food supply, small-scale farmers are often hindered by various factors. These include the lack of access to modern technology, as well as the inadequate knowledge about how to properly use fertilizers. Farmers struggle with the appropriate application of nutrients, which impacts their income and yield. There are already systems that help farmers with this issue, but they require a lot of special knowledge and are not readily accessible to small-holders. This issue is why a more efficient and cost-effective solution is needed[5].

The use of machine learning technology has been shown to help solve various agricultural issues, such as the prediction of crop yield and the management of soil nutrients. This study aims to develop an intelligent fertilizer recommendation system that will allow small-scale farmers to receive personalized advice. The goal of the system is to improve the productivity of farmers by providing them with the necessary information to make the appropriate application of nutrients. The proposed IFRS can help small-scale farmers improve their income and productivity by giving them the appropriate fertilizer type and quantity at the right time. The system will provide customized recommendations based on various factors, such as the soil nutrient status, crop type, and weather conditions.

The dashboard for the system is designed to help farmers interpret and access the recommendations it provides. It allows them to input their crop type and location, as well as receive customized advice. It also displays the various factors that affect the application of nutrients, allowing them to make more informed decisions. The findings of the study can be used by policymakers and agricultural experts to inform their decisions regarding the use of machine learning in addressing certain agricultural issues. The proposed IFRS is expected to help improve the efficiency and sustainability of the agriculture sector, which is vital to achieving global food security goals and reducing poverty in rural areas. The study recommends the development of an IFRS that incorporates machine learning techniques to provide customized recommendations to small-scale farmers. The suggested system's user-friendly interface and recommendations can help boost farmers' income and productivity, while also promoting sustainable practices. The study's recommendations and findings can be used by policymakers and other experts to learn more about machine learning's potential to address certain agricultural problems.

Literature review

The literature review covers a range of studies and research papers related to fertilizer and soil fertility management in different regions. The study by Zelleke et al.[6] provides an overview of the fertilizer and soil fertility potential in Ethiopia. The research by Duan et al.[7] examines the nitrogen use efficiency in a wheat-corn cropping system over 15 years of manure and fertilizer applications. Bationo et al.[8] focus on improving the profitability, sustainability, and efficiency of nutrients through site-specific fertilizer recommendations in West Africa agro-ecosystems. Similarly, Ezui et al.[9] develop a decision support system for site-specific fertilizer recommendations in cassava production in Southern Togo.

Tetteh et al.[10] present fertilizer recommendations for maize and cassava in the breadbasket zone of Ghana. McFadden et al.[11] propose nitrogen fertilizer recommendations based on plant sensing and Bayesian updating. Nampoothiri et al.[12] provide research and development perspectives on the coconut palm. Ichami et al.[13] explore fertilizer response and nitrogen use efficiency in African smallholder maize farms. Sharma et al.[14] develop a web-based tool for calculating field-specific nutrient management for rice in India. Bijay-Singh et al.[15] focus on site-specific fertilizer nitrogen management in cereals in South Asia, while Hopkins et al.[16] examine potato production systems.

The literature review highlights the importance of site-specific fertilizer recommendations and management to increase profitability, sustainability, and efficiency of nutrient use in different crops and regions. It also emphasizes the need for the development of decision support systems and tools to facilitate precision agriculture practices.

Methodology

i. Data collection and preprocessing

It is essential to collect data related to soil characteristics, crop types, and weather conditions in order to develop an efficient IFRS. This study will gather information from various sources, such as government agencies and local farmers. The data collected will be pre-processed to remove any inconsistencies, outliers, and missing values. To ensure that the data is analyzed and ready for analysis, various techniques will be used, such as data cleaning and normalization.

ii. Feature selection and engineering

After collecting data, the next step is to identify the relevant features that can be used in the formulation of fertilizer recommendations. These features should have a substantial impact on the yield and be measurable. In order to improve the performance of the model, various engineering techniques will be utilized PCA.

iii. Model selection and training

The evaluation of various machine learning algorithms for the formulation of fertilizer recommendations will be carried out. These include a neural network, a random forest, and a support vector machine. The trained algorithms will then be able to predict the optimal amount

of nutrients for different crop types and soil types. The training phase will involve splitting the collected data into validation sets and training modules. The models will then be tuned using various optimization techniques.

iv. Performance evaluation and comparison

The algorithms that have been selected will be evaluated through various metrics, including precision, accuracy, recall, F1-score, and more. The objective of these measures is to determine if the models can accurately predict the optimal amount of fertilizer for different crop types and soil types and provide reliable weather information. The performance of the different algorithms will be evaluated to identify the best one for optimizing fertilizer recommendations. The findings of this study will help small-scale farmers make informed decisions when it comes to choosing the best fertilizer recommendation system.

Results and Output

The four different machine learning algorithms that were used in this study performed well when it came to identifying the optimal amount of fertilizer for different crop types and soil types. The Random Forest was the most accurate in terms of its classification accuracy and performance metrics. The Neural Network algorithm performed well by having an AUC of 93.72%, a recall rate of 74.99%, a classification accuracy of 74.85%, an F1 score of 71.48 percent, a precision of 75.15 percent, and a recall of 75.15%. On the other hand, the SVM algorithm performed well by having an AUC of 91.36%, a recall rate of 68.69% and a classification accuracy of 68.79%. In terms of its performance, the Naive Bayes algorithm was the most accurate. Its AUC was 90.42%, its classification accuracy was 55.56%, its recall rate was 55.56%, and its F1 score was 60.15%.

The results as shown in table-1 and figure-1,2 of the study indicate that the proposed IFRS can help small-scale farmers make informed decisions when it comes to choosing the appropriate fertilizer. The recommended algorithm, which is known as the Random Forest, provides consistent and accurate recommendations. The proposed IFRS can help farmers improve their income and productivity, while also supporting sustainable practices. The study's findings can be used by policymakers and experts to inform the development of machine learning in the agricultural sector.

i. Evaluation analysis

Table 1 Evaluation of various ML model

Model	AUC	CA	F1	Precision	Recall
Naive Bayes	90.42	55.56	60.15	69.78	55.56
SVM	91.96	68.69	67.09	66.89	68.69
Neural Network	94.72	74.75	74.78	75.15	74.75

Random Forest	95.96	80.81	80.45	80.33	80.81

ii. Graphical representation

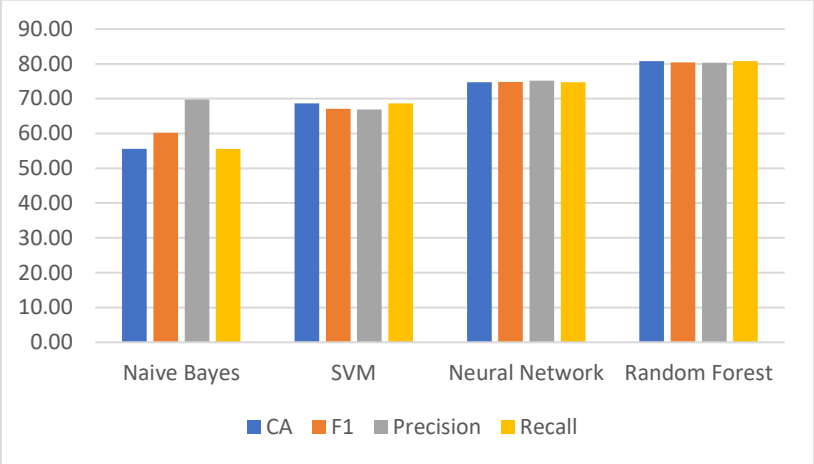

Figure 1 Graphical representation of ML parameters

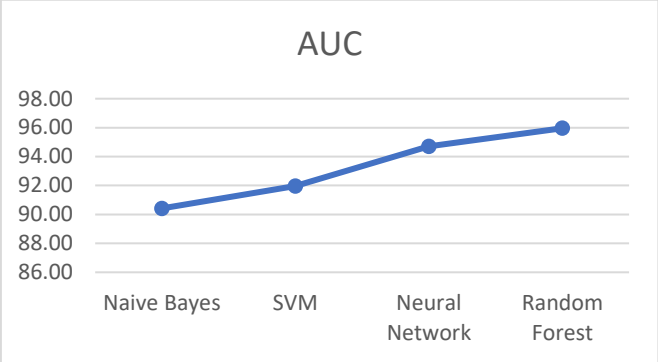

Figure 2 AUC

iii. Dashboard

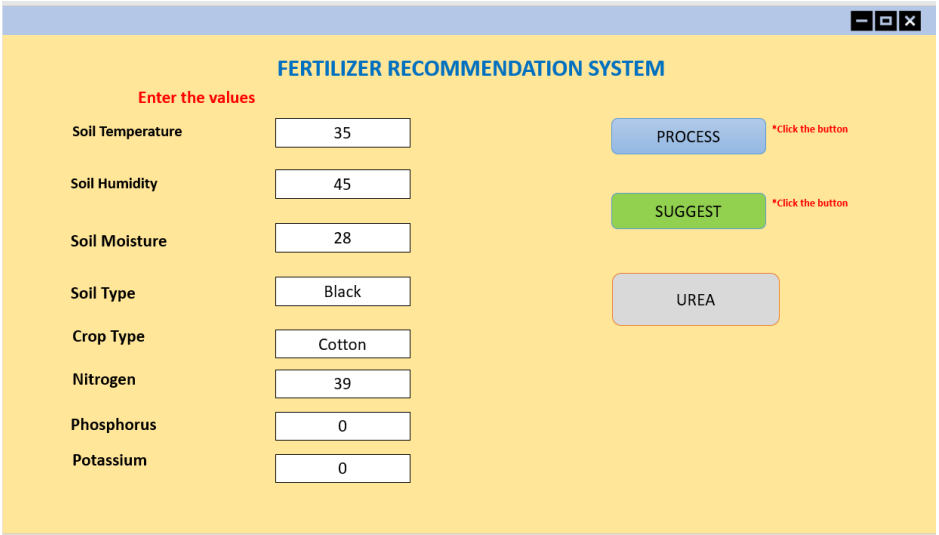

Figure 3 Dashboard - IFRS

Conclusion and future scope

The goal of this study is to develop an intelligent fertilizer recommendation system that will help small-scale farmers improve their productivity and income. The system utilizes machine learning technologies to provide customized recommendations based on the soil type, crop type, and weather conditions applicable to them. The algorithm known as Random Forest was selected as the most suitable for recommending fertilizer due to its superior performance. The implementation of the IFRS system can help address various agricultural issues and contribute to sustainable practices. It can provide farmers with valuable information on the optimal fertilizer type and quantity, as well as help them reduce their environmental impact. This study's findings can be utilized by policymakers and agricultural experts to implement data-driven practices in order to improve the sector's efficiency.

The IFRS can be expanded to include additional features and data sources, such as pest infestations and crop disease. Through feedback from farmers, the system can improve its accuracy and customize recommendations to suit the needs of individual farmers. The IFRS can be utilized as a web-based or mobile app, which makes it accessible to a wider range of farmers. Its recommendations can also be validated through field trials, which ensure that they are effective and practical. The system can eventually be extended to other geographical regions to contribute to the sustainable practices of agriculture.

References

[1] X. Xu *et al.*, "Fertilizer recommendation for maize in China based on yield response and agronomic efficiency," *F. Crop. Res.*, vol. 157, pp. 27–34, 2014, doi: 10.1016/j.fcr.2013.12.013.

[2] X. Yan *et al.*, "Fertilizer nitrogen recovery efficiencies in crop production systems of China with and without consideration of the residual effect of nitrogen," *Environ. Res. Lett.*, vol. 9, no. 9, 2014, doi: 10.1088/1748-9326/9/9/095002.

[3] M. S. Suchithra and M. L. Pai, *Improving the Performance of Sigmoid Kernels in Multiclass SVM Using Optimization Techniques for Agricultural Fertilizer Recommendation System*, vol. 837. Springer Singapore, 2018.

[4] G. Prabakaran, D. Vaithiyanathan, and M. Ganesan, "Fuzzy decision support system for improving the crop productivity and efficient use of fertilizers," *Comput. Electron. Agric.*, vol. 150, no. August 2017, pp. 88–97, 2018, doi: 10.1016/j.compag.2018.03.030.

[5] V. B. Bado, K. Djaman, and V. C. Mel, "Developing fertilizer recommendations for rice in Sub-Saharan Africa, achievements and opportunities," *Paddy Water Environ.*, vol. 16, no. 3, pp. 571–586, 2018, doi: 10.1007/s10333-018-0649-8.

[6] G. Zelleke, G. Agegnehu, D. Abera, and S. Rashid, "Fertilizer and Soil Fertility Potential in Ethiopia Table of Contents," *Fertil. Soil Fertil. Potential Ethiop.*, no. July, pp. 1–66, 2010.

[7] Y. Duan *et al.*, "Nitrogen use efficiency in a wheat-corn cropping system from 15 years of manure and fertilizer applications," *F. Crop. Res.*, vol. 157, pp. 47–56, 2014, doi: 10.1016/j.fcr.2013.12.012.

[8] A. Bationo, D. Ngaradoum, S. Youl, F. Lompo, and J. O. Fening, "Improving the

Profitability, Sustainability and Efficiency of Nutrients Through Site Specific Fertilizer Recommendations in West Africa Agro-Ecosystems," *Improv. Profitab. Sustain. Effic. Nutr. Through Site Specif. Fertil. Recomm. West Africa Agro-Ecosystems*, vol. 1, pp. 1–339, 2018, doi: 10.1007/978-3-319-58789-9.

[9] K. S. Ezui, P. A. Leffelaar, A. C. Franke, A. Mando, and K. E. Giller, "Decision support system for site-specific fertilizer recommendations in cassava production in Southern Togo," *Improv. Profitab. Sustain. Effic. Nutr. Through Site Specif. Fertil. Recomm. West Africa Agro-Ecosystems*, vol. 2, pp. 125–138, 2018, doi: 10.1007/978-3-319-58792-9_8.

[10] F. M. Tetteh, S. A. Ennim, R. N. Issaka, M. Buri, B. A. K. Ahiabor, and J. O. Fening, "Fertilizer recommendation for maize and cassava within the breadbasket zone of Ghana," *Improv. Profitab. Sustain. Effic. Nutr. Through Site Specif. Fertil. Recomm. West Africa Agro-Ecosystems*, vol. 2, pp. 161–184, 2018, doi: 10.1007/978-3-319-58792-9_10.

[11] B. R. McFadden, B. W. Brorsen, and W. R. Raun, "Nitrogen fertilizer recommendations based on plant sensing and Bayesian updating," *Precis. Agric.*, vol. 19, no. 1, pp. 79–92, 2018, doi: 10.1007/s11119-017-9499-4.

[12] K. U. K. Nampoothiri, V. Krishnakumar, P. K. Thampan, and M. Achuthan Nair, *The coconut palm (Cocos nucifera L.) - Research and development perspectives*. 2019.

[13] S. M. Ichami, K. D. Shepherd, A. M. Sila, J. J. Stoorvogel, and E. Hoffland, "Fertilizer response and nitrogen use efficiency in African smallholder maize farms," *Nutr. Cycl. Agroecosystems*, vol. 113, no. 1, pp. 1–19, 2019, doi: 10.1007/s10705-018-9958-y.

[14] S. Sharma *et al.*, "Web-based tool for calculating field-specific nutrient management for rice in India," *Nutr. Cycl. Agroecosystems*, vol. 113, no. 1, pp. 21–33, 2019, doi: 10.1007/s10705-018-9959-x.

[15] Bijay-Singh, Varinderpal-Singh, and A. M. Ali, *Site-Specific Fertilizer Nitrogen Management in Cereals in South Asia*. 2020.

[16] B. G. Hopkins, J. C. Stark, and K. A. Kelling, *Potato Production Systems*. 2020.