

Smart Fertilizer Management: An AI Approach to Sustainable Optimization

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Abstract: Excessive fertilizer use has resulted in wide soil degradation, decreased yield, and lower farmer incomes. The Sustainable Fertilizer Usage Optimizer (SFUO) is a data-driven tool which will help improve agricultural sustainability. Crop types, soil health metrics, and weather data are integrated, and the system offers customized fertilizer recommendations. To minimize misuse and guarantee the balance of nutrients needed for particular crops. The application optimizes fertilizer type and quantity using data analytics and machine learning algorithms. This method not only increases crop productivity but also prevents the environment from damaging agriculture and restoring soil health. The study also looks at the solution's socioeconomic advantages, highlighting how it could save input costs and boost farmer revenue. The results show how sophisticated digital tools can enable farmers to make appropriate choices, thereby improving sustainable farming methods around the world. This study describes the application's creation, deployment, and testing, demonstrating its efficiency in a range of agricultural contexts.

Keywords: fertilizer optimization, data-driven solutions, machine learning, sustainable fertilizer usage optimizer (SFUO)

I. INTRODUCTION

Farming is very important because it helps feed the world and supports the economy, especially in poorer countries [1]. But using too much artificial fertilizer in the wrong way can hurt the soil, pollute water and air, and make it harder for farmers to earn a living[2]. These problems are making people think more about sustainable farming. Using fertilizers the right way can help protect nature, improve soil health, and grow more crops[3]. The Sustainable Fertilizer Usage Optimizer (SFUO) is a smart tool that combines science and technology to help farmers[4]. It has been used to account for demands of crops, soil type and weather conditions and to generate the best fertilizer prescription. This guarantees that the crop is not deficient in the correct amount of nutrients while on the other hand the fertilizers are wasted[5]. The device is very simple and easy to install by the farmer and is effective result i. e. increased food and income production. This paper discusses the design of the SFUO and its possible application to farms[6]. It also describes how it may contribute towards agricultural intensification with minimal environmental pollution[7]. SFUO is a demonstration of the feasibility of this kind of technology to the intelligent development of the farmers' and the environment's fertilizer problems resolution [8].

Literature Survey

Research [9] described the major challenges. A fertilizer user in sub-Saharan Africa as such[10]. It is not uncommon that farmers have no idea how much fertilizer of certain types has to be applied to a certain crop[11]. This is because inefficient agriculture results in a loss of money[12]. Although, in contrast, that the best use of chemical fertilizers to achieve the highest yield is not always the case, the present situation of the heterogeneous farmers is an unattainable situation to be able to choose chemical fertilizers effectively[13]. For all of these problems, the paper proposes the Fertilizer Optimization Utility (FOT). This is the kind of tool which allows us to obtain a rational decision for fertilizer introduction as it gives the farmer information, e.g., crop area to be irrigated, type of outcome to be achieved (to



maximize the farmer's earnings), and up to which input the farmer is willing to have it [14]. Then it provides farmers with recommendations regarding the application of fertilizers to maximize their profits[15]. However, there are some issues. Firstly, a majority of farmers do not have access to computers or skills to utilize this tool, thus there is a need for a hardcopy version[16]. Because the hardcopy version relies on average data, it is not as precise and such an approach may reduce farmers' possible earnings by 20%. In addition, such a version has to be updated from time to time[17]. Last but not least, in order for the tool to be effective, farmers need extension services and education, something that may not be easy to offer in all regions. This [18] paper outlines the challenges of phosphorus (P) fertilizer control in the field. It describes issues, such as phosphorous deficiency, phosphorous poor and negative use, and that the availability of phosphorous to producers is difficult to track[19]. For tackling these problems, the accompanying paper, H-WOA-VNS algorithm, is suggested[20]. This is a clever computer program that may lead to a more reasonable approach to utilization that could be made of the newly discovered phosphorus. The algorithm is designed upon several goals including, crop yield, phosphorus uses efficiency and cost decrease[21]. Restructuring nearly optimal plans with two specific strategies of anthropoid optimization and variable neighborhood search is used. Results showed an increase respectively in rice yield of 33% and PUE in 27.8% more. But there are some challenges[22]. Computing resources needed for that algorithm are also very high and expensive. Of course, this is also due to the absence of ground truth (and potentially that, e.g. There is a possibility that there are people who are not familiar with how to apply such a new technique [23]. Moreover, such a routine must be adapted to new environmental conditions, starting from fertilizer application. In this paper [24], the challenges associated with cultivating wheat in rainfed agriculture (low crop yield and soil nutrient depletion) are described[25]. In accordance with studies impaired soil and of farmers soils have been degraded, in turn, farmers do not use the appropriate quantity, or none at all. This has caused wheat production to stop improving [26]. To deal with these problems, authors have been investigating how to process the nutrients more optimally[27]. They used chemical fertilizers (NPK) and organic amendments (e.g., manure). This approach aimed to make the soil healthier, provide more nutrients, and help wheat grow better. [28] indicated such a fertilizer/organic amendment package to be highly favorable to soil and crop growth production. However, there are challenges[29]. Not all farmers are keeping an eye on the management of organic waste, i.e., Farmyard Manure (FYM) or even the ability of daily intake of FYM [30]. The method may not be accurate throughout the area, as it is necessary to be calibrated to local factors[31]. These methods could also be. On the other hand, it is not quite usable by farmers, because it adds more labor and effort. This article [32] comments on the degree to which agricultural farmers occasionally apply excessive amounts or not enough fertilizer because of insufficient knowledge about the amount of fertilizer that is required by their crops[33]. This makes growing crops harder and costs more money[34]. On the other hand, most of the tools do not consider the fertilizer costs, i.e., farmers cannot afford fertilizer[35]. To help, the authors made an app called Ecofert. It is a mobile application that, through an intelligent system, directs the farmer to fertilize[36]. Growers can select a crop from the menu, define the scale at which the crop is growing culture of their choice, and the app gives them indications relative to fertilizing[37]. In addition to being a cost, Ecofert log fertilize also determines an optimal blend of fertilizers in order to save costs and maximize yield[38]. But there are some challenges to the app as it needs a large amount of data which may not be always available, and farmers may not have the technology to access it. The study [39] discusses fertilizer application and soil management in Bangladesh. It draws attention to the issue of decreased food yields due to unsustainable farming practices[40]. Furthermore, farmers commonly apply fertilizers inconsistently, using imbalanced dosages. The establishment of a thorough Soil and Land Resource Information System (SOLARIS) is one of the institutional strategies that are mentioned in the article[41]. The goal of this system is to gather and evaluate soil data so that farmers and other agricultural stakeholders can easily access it. Farmers can improve nitrogen management and soil health by using SOLARIS to receive customized fertilizer recommendations[42]. However, some restrictions can make it less successful. The precision and quality of soil data are critical to SOLARIS's efficiency[43]. Furthermore, a lack of knowledge may make farmers hesitant to adapt. Significant obstacles arise during implementation since it calls for a large expenditure[44]. Furthermore, Bangladesh's various agroecological zones can call for solution modifications that are distinct to each area. The study [45] discusses



important agricultural issues in Junagadh, Gujarat, where low levels of phosphorus (P) and nitrogen (N) in the soil severely restrict crop yield[46]. The main problem is that applied phosphorus has a high fixation rate (75–95%), which makes it mostly unavailable to crops because of interactions with calcium ions[47]. Through a factorial randomized block design, this study investigates the best ways to manage nutrients over a four-year period[48]. It assesses the effects of varying fertilizer application rates (0, 50, 100, and 150% of recommended NP levels) on a variety of crops, including mustard, ground nut, wheat, sunflower, and chickpea[49]. The goal of the study is to increase yields while evaluating sustainability and productivity utilizing indices like the Sustainability Yield Index (SYI), Total System Productivity (TSP), Partial Factor Productivity (PFP), and Agronomic Efficiency (AE) [50]. The study did have several drawbacks, though. The long-term sustainability of these approaches is not thoroughly evaluated, and its conclusions might not be readily extrapolated to other areas with distinct soil types or nutrient profiles[51]. Furthermore, many smallholder farmers may not be able to afford the resources and labor-intensive nature of implementation [52]. Additionally, there is a chance of overfertilization, which could harm the ecosystem if nutrient runoff happens[53]. The present study [54] is concerned with the environment impacts of excessive fertilizer application in tea production in Shaoxing City, China[55]. It tested three ways to fix this problem. At the start, CRFS slowly released special fertilizers etc[56]. The second CAOF is a composite organic fertilizer (e.g., rapeseed cake) and chemical fertilizer feeding[57]. Specifically, the 3rd one, SRCF, continuously reduced rates of chemical fertilizer application[58]. These methods were tested in soil as well as tea plants over up to 2 years[59]. Even though CAOF generated some financial gain from tea, some of its methods did not stand well on soil or plant matters[60]. The duration of the study was, unfortunately, not sufficiently long to enable it to determine the long-term effects[61]. There is little research in this field to identify the best practice for soil or tea farming practices[62]. The inefficiency of fertilizer usage among smallholder farmers in sub-Saharan Africa is discussed in the study [63]. To solve this problem, the authors created Fertilizer Optimization Tools (FOTs), which use linear programming to assist farmers in identifying the most cost-effective crop, nutrient, and application rate combinations [64]. The Excel and paper-based tools provide customized fertilizer recommendations[65]. These are based on regional ecological conditions and offer advice for the best times and techniques to apply fertilizer[66]. Additionally, even though the FOTs maximize the use of fertilizer, they don't deal with the financial constraints[67]. Reliance on technology may provide accessibility issues in areas with low resources. All things considered, the solutions show progress, but more specific solutions are needed for successful application[68]. This study [69] examines the methods of determining the correct amount of nitrogen fertilizer for growing potatoes in different regions of China[70]. The problem occurs because the concentration of nitrogen in soil may vary from region to region resulting in either poor crop growth or wastage of nitrogen fertilizers[71]. Scientists incorporated math models that were linear and quadratic among others to come up with better uses of nitrogen[72]. They further stated that there is a good understanding of Indigenous Nitrogen Supply (INS) which is crucial[73]. There are however hurdles[74]. The methods do not work the same way in some areas and rely on very old data which may not be true [75]. The recommendation may not agree with the present circumstances concerning soil or weather, and it may be too costly for small farmers[76]. Although the study provides useful guidelines, additional efforts will have to be made to make it more practical. This [77] study talks about fertilizers with nitrogen (N), phosphorus (P), and potassium (K) and their effects on the environment and food safety[78]. It explains how using too much nitrogen can harm ecosystems and people, like causing problems in water bodies (eutrophication). As a solution to the experiments conducted, the authors propose practicing the 4R as well as developing precision farming gradually[79]. These concepts address the problem of sustainable fertilizer use[80]. The authors also suggest reducing N from regions of surplus to regions of scarcity, as well as establishing international governance to regulate fertilizers[81]. But, of course, there are limitations like poor nations may lack enough resources or sound legislation to implement it [82]. Some farmers may lack the necessary technology to implement these techniques, and climate change may affect the situation. These problems need a collaborative approach for resolution. This [83] study talks about how important nitrogen (N), phosphorus (P), and potassium (K) are for healthy soil and better yield. But farmers sometimes waste these nutrients, which can pollute water and harm people[84]. To solve this, the authors use an Improved Genetic Algorithm (IGA).



This tool helps give better fertilizer advice by studying lots of information about crops and soil[85]. It uses smart techniques to work better in local areas. However, there are challenges, the algorithm needs a lot of good data to work well, and farmers, especially in poorer countries, might find it hard to use this technology[86]. It can also be expensive at first. Sudden changes in the environment might affect its accuracy[87]. More effort is needed to make it work in real life. This article talks about how to save energy and make farming more profitable for rice farming in India[88]. Authors say that farmers sometimes use energy inefficiently and wastes resources[89]. The authors use a method called Data Envelopment Analysis (DEA) to study energy use in farming[90]. This tool looks at how much energy is used, finds the best practices, and gives ideas to save energy based on real farm data[91]. But there are challenges. Significant issues facing Indian agriculture, especially those brought on by the Green Revolution, like soil degradation and a greater reliance on chemical inputs, are covered in the paper [92]. Smallholders, who make up 78% of farmers and oversee fragmented land, have been sidelined and agroecosystem management has been eroded despite the increase in productivity[93]. Furthermore, socioeconomic gaps have deepened, and agricultural stability is at risk due to climate change. Overall, the study recognizes the difficulties and constraints of putting sustainable agriculture into practice even as it promotes it as a means of enhancing resilience. This study [94] talks about how food, energy, and water are all connected, especially in places where resources are limited. It explains that using too much nitrogen fertilizer can harm soil, pollute water, and add to greenhouse gases[95]. The authors suggest using a special method that combines climate, ecosystem, and economy models to study these problems. The idea is to manage nitrogen better and use resources more wisely. But there are challenges. Farmers might not want to change old methods, and the plan needs a lot of accurate local data. It can also be expensive, which is hard for small farmers. Changing weather makes it even trickier. This study [96] talks about the big challenges in growing enough wheat for everyone in the future. Wheat production isn't increasing fast enough, but the world's population is growing and will reach 9 billion by 2050. Right now, wheat yield grows less than 1% a year, but it needs to grow at least 1.6% to meet demand. Bad weather conditions, shifts in the marketplace, or lack of nutrients, predominantly nitrogen, seem to increase the difficulty of increasing wheat production[97]. The authors recommend improving the effectiveness of fertilizers and cultivating resilient crops able to withstand stress. However, there are obstacles[98]. The solutions may be too expensive for poor farmers, have detrimental effects on the agriculture environment or may not be compatible with local agricultural practices[99]. It gets worse. Climate changes magnify those issues even further. This paper discusses misuse in the application of fertilizers[100]. Due to the neglect of proper fertilizer application, there are times when the farmers lose their investment, damage the ecological balance and cause water pollution[101]. At times farmers practice over-fertilization and other times fertilizers are underutilized, both of which harm crop production and the soil. The authors recommend a better alternative called Site-Specific Nutrient Management (SSNM). It employs soil and crop tests to determine the effective fertilizer rate to apply. They also discuss soil requirements within context to precision agricultural strategies like GPS and GIS[102]. But there are challenges. Farmers may consider it a costly or complex application. In addition to that, appropriate availability of data is a must, which is not very often the case. Regardless, the findings of the paper suggest this would be positive factors in enhancing agricultural practices while caring for the environment. This paper [103] discusses a major problem in Indian farming which is Soil Organic Carbon (SOC). They also talk about planting crops like legumes and changing crop systems to help soil health. But they say more research is needed to find the best ways to keep SOC levels stable[104]. However, there are challenges. Different soil types and climates can make it harder to use these methods. Small farmers might find it too costly, and not all farmers know how to do it. The study [105] shows it's hard but important to improve soil health. This study talks about some big problems in farming, like not enough workers, wasting resources, and the harm caused by old farming ways. Using too much water, fertilizers, and pesticides hurts both the environment and farmers' profits. The authors say artificial intelligence (AI) can help. AI can make farming smarter by saving water, boosting crops, and helping farmers make good choices based on soil and weather data[106]. AI machines can also handle hard jobs like planting and harvesting. It even predicts pest or disease problems before they happen. But there are challenges. AI costs a lot, and farmers need training to use it. Some places don't have the right tools or internet. The study shows AI can help if these problems are solved.



This paper discusses the problems raised due to poor irrigation practices, delayed disease detection and changing market prices. The Plantix app uses deep learning to detect diseases from crop photos. Drones and robots can do jobs like spraying and harvesting, making work easier. Improved weather predictions help farmers plan better. The e-National Agriculture Market (eNAM) helps farmers sell their crops more easily, and blockchain technology in projects like Jivabhumi makes supply chains better. But there are challenges, like the digital divide, high costs, and the need for training. Data quality and privacy concerns are also important. Even with these challenges, AI can help improve farming if these problems are fixed. This article [20] presents an example of how machine learning (ML) can be used to provide farmers with crops and farm practice decision support. In it, problems of low yield and damage product resulting from fertilizer misuse are also alluded to. The research also shows the use of ML for predicting crop yields based on soil pH, NPK and weather parameters. Authors designed models which can assist farmers in choosing the right crops for a given location. However, there are drawbacks of these techniques, such as, a good performance requires high quality data. Also, while models are parameterized to take various states into account, some models may fail because of state variation. Technicians may not be sufficiently proficient with ML tools in an efficient way and prevent the natural evolutionary process of adopting these concepts. This dataset [107] was built by augmenting datasets of rainfall, climate and fertilizer data available for India. Precision agriculture is in a trend nowadays. It helps the farmers to get informed decisions about the farming strategy. Here is a dataset which would allow the users to build a predictive model to recommend the most suitable crops to grow on a particular farm based on various parameters. I used this [22] online tool for paraphrasing this paper to maintain formal writing and grammar of the paper.

II. METHODOLOGY

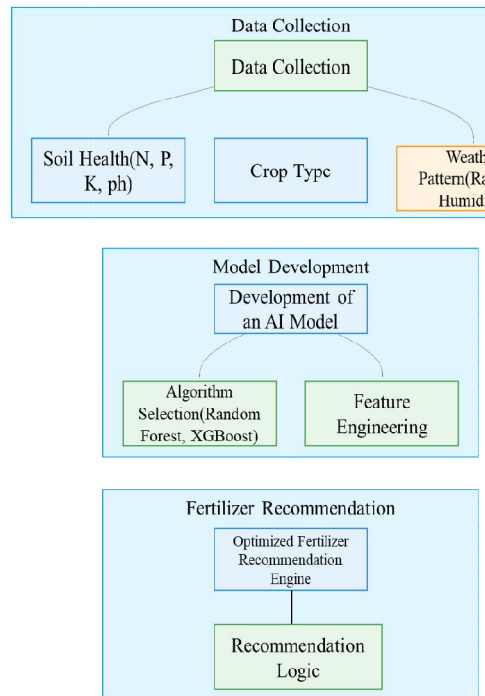


Fig1: Flowchart



A. Data Collection and Integration

- Soil Health Data: Utilize sensors in the field to gather real-time data on soil health parameters (e.g., pH, moisture, organic matter content, nutrient levels).
- Crop Type Data: Collaborate with agricultural databases to obtain information on crop types, growth cycles, and their specific nutrient requirements.
- Weather Pattern Data: Integrate data from meteorological APIs that provide forecasts and historical weather trends affecting crop growth (precipitation, temperature, humidity).

B. Development of an Adaptive Machine Learning Model

- Algorithm Selection: Develop a machine learning model (e.g., Random Forest, Gradient Boosting) that can adapt over time by learning from new data inputs.
- Feature Engineering: Create features from the collected data using statistical analysis and machine learning techniques, identifying interactions among soil health, crop types, and weather patterns.

C. Optimized Fertilizer Recommendation Engine

- Recommendation Logic: Implement an application logic that uses the machine learning model to provide optimal fertilizer types and quantities tailored to specific soil conditions, crop choices, and expected weather scenarios.
- Scenario Analysis: Allow the model to run various scenarios (e.g., predicted rainfall levels) to recommend adjustments in fertilizer use dynamically. *Fig1* clearly depicts the methodology.

III. PROPOSED SYSTEM

Reading the Data: Open the dataset [22] with information about crop types, weather, and soil health.

Data preprocessing includes handling missing values, cleaning the dataset, and converting any category variables into numerical representation.

Establish the features (inputs) and the target variable (output) in the feature and target setup.

Train-Test Split: To assess the model, divide the dataset into training and test sets.

Model Training: Use the training data to build a Random Forest regression model.

Model Evaluation: Use R-squared and Mean Squared Error (MSE) metrics to assess the model's performance.

Suggestion Logic: Establish guidelines for fertilizer recommendations according to the anticipated amounts of rainfall.

Output: Show the forecasted rainfall together with the appropriate fertilizer dosage.

IV. RESULTS AND DISCUSSION

The results show rainfall-related predictive modeling and how it affects fertilizer recommendations in farming operations. The mean squared error (MSE), R-squared value (R²), anticipated rainfall levels, and related fertilizer recommendations are all reflected in two distinct predictions. The model's mean squared error in predicting rainfall remains constant regardless of the amount of rainfall, as evidenced by the Mean Squared Error (MSE), which is 595.47 for both predictions. Nonetheless, the R-squared value of 0.8075 is significant; it indicates that the model can account for almost 80.75% of the variation in the rainfall forecasts. In environmental modelling, this degree of explanatory power is typically regarded as good, suggesting a respectable degree of confidence in the forecasts. The first output indicated a higher projected amount of rainfall (67.47 mm) than the second (44.34 mm), indicating a considerable difference in the predicted rainfall. This disparity can indicate that different soil types, environmental factors, or seasonal fluctuations are influencing the amount of water available, requiring customized fertilizer recommendations to maximize agricultural yields. In conditions when more rain is anticipated, there may be a greater need for nitrogen to maximize crop productivity, as indicated by the prescription for high amounts of nitrogen fertilizers in line with the higher anticipated rainfall. Nitrogen is essential for vegetative growth and general plant health, particularly in wetter environments when nutrient loss may occur, according to the reasoning. In contrast, a



more cautious approach is shown in the suggestion for medium amounts of phosphate fertilizers given the lower anticipated rainfall (44.34 mm). Prevent excessive runoff and negative effects on the environment, phosphate application should be carefully managed with water availability. Phosphate is essential for plant root development and energy transfer.

```
Mean Squared Error: 595.4732553904219
R-squared: 0.8075184975092654
Predicted Rainfall: 67.47 mm
Recommendation: Use high levels of Nitrogen fertilizers (150-250 kg N/ha).
```

Fig2: Output Rainfall >50mm

```
Mean Squared Error: 595.4732553904219
R-squared: 0.8075184975092654
Predicted Rainfall: 44.34 mm
Recommendation: Use medium levels of Phosphate fertilizers (30-75 kg P205/ha).
```

Fig3: Output 20mm> Rainfall> 50mm

```
Mean Squared Error: 676.9000235787909
R-squared: 0.7811980094907298
Predicted Rainfall: 69.34 mm
Recommendation: Use high levels of Nitrogen fertilizers (150-250 kg N/ha).
```

Fig4: Output Rainfall >50mm

```
Mean Squared Error: 676.9000235787909
R-squared: 0.7811980094907298
Predicted Rainfall: 48.90 mm
Recommendation: Use medium levels of Phosphate fertilizers (30-75 kg P205/ha).
```

Fig5: Output 20mm> Rainfall> 50mm

Fig2 and Fig3 both show the output of the recommendation system for Random Forest Model where it recommends high levels of Nitrogen fertilizer for predicted rainfall more than 50mm and recommended medium levels of Phosphate fertilizer. Fig4 and Fig5 both show the output of the recommendation system for XGBoost Model where it recommends high levels of Nitrogen fertilizer for predicted rainfall more than 50mm and recommended medium levels of Phosphate fertilizer. The amount of fertilizer used is mentioned based on the guidelines given by the International Fertilizer Development Center (IFDC) and Food and Agriculture Organization (FAO). If the rainfall levels drop 20mm then use of Organic fertilizers is recommended as to prevent leaching due to synthetic fertilizers.

Metric	Random Forest Model	XGBoost Model
Mean Squared Error	595.47	676.90
R-Squared (R ²)	0.8075	0.7812

Table 1: Analysis of Models

Table 1 shows that the Random Forest Regression Model exceeded the XGBoost Regression Model in both metrics: The reduced MSE indicates that Random Forest yields more precise predictions. A greater R² suggests that Random Forest accounts for a more substantial portion of the variance in the target variable. This evidence robustly endorses the choice of the Random Forest model for this research because of its exceptional predictive abilities and overall effectiveness. The reason for this is that the dataset is not very large and moderately complex.

Aspects	Proposed System	Existing System
Data	Existing Dataset	Real-time Soil Data
Algorithm	Random Forest Regression	Naïve Bayes Classifier
Accuracy	High	Moderate



Hardware	No Hardware	Sensors and Cloud Infrastructure
Connectivity	Offline Possible	Requires connectivity
Scalability	Easily scalable	Limited Scalability
Cost	Low	High
Accessibility	Moderate	User Friendly

Table 2: Comparative Analysis

Table 2 shows the comparative analysis of an existing system proposed in [23] where they used probability to recommend fertilizers with IoT integration. We can clearly see that the proposed system in this paper has more advantages than the existing system in accuracy, connectivity as well as operational cost. The proposed system even has the scope of integration with IoT which will enhance accessibility as well as scalability. The accuracy of the proposed system is higher because it uses ensemble learning which works best with complex data whereas Naïve Bayes has limitations with complex data. The proposed system not just uses soil nutrient content into consideration but also the weather conditions and crop type which enhances its accuracy whereas existing system just takes soil nutrient content into consideration.

V. CONCLUSION

The "Sustainable Fertilizer Usage Optimizer (SFUO)" solves the urgent problem of excessive and improper use of fertilizer. It degrades soil and lowers agricultural output, which affects farmers' profits. This technology recommends fertilizers to farmers based on data related to crops, soil, and weather by employing smart machine learning algorithm. The coupling of vast amounts of data and advanced IT technologies creates a simple farmer's tool. Farmers' comments may as well be collected, which helps the system improve and other information to be more personalized. This feedback enhances productivity and is environmentally friendly by facilitating farming and minimizing destruction to nature. It could work with big global farming databases to handle different types of soil and weather. Adding IoT technology can help watch crops and soil in real time. Using tools like big data and deep learning can make predictions smarter and more helpful. The system can also look into using eco-friendly fertilizers like organic ones. To help farmers, training and community programs can teach them how to use the system. Working with leaders and policymakers can help make sustainable farming more important everywhere. In short, the "Sustainable Fertilizer Usage Optimizer (SFUO)" is a smart idea that can change how farmers use fertilizers. It helps protect the planet, improves farmers' incomes, and makes farming ready for a changing world.

FUTURE SCOPE

To make the system able to behave more suitably in other environments, we experiment with other soil constituencies and also in different weather conditions. Upon supplying information to the system from the extensive global crop database, for example, USDA or FAO (incorporating information from the extensive global crop database into the system), the system should be able to extract more information from soils, and from the crops it will work with. Using cool IoT technology, we, for instance, are able to monitor soil and crops, and react to their needs, in real time, and deliver advice to farmers immediately. Through these big data tools, we can see some effective patterns within the long records of farms and farming. This is to say that better data can assist AI, for example in the case of deep learning models, to be more precise than it is now. AI can also recommend safer sources of fertilizers, for instance organic fertilizers. This type of system can increase food supply for farmers while keeping farming secure for the earth and adaptable to any large-scale transformations in the future.

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