Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 8 Issue 10 October 2024

Research Article

Intelligent Modelling of Agricultural Cart for Precision Nutrient Application - A Fusion of Fuzzy Logic and Machine Learning

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DOI: 10.31080/ASAG.2024.08.1410

Received: August 09, 2024

Published: September 05, 2024

Abstract

The Indian agriculture industry is experiencing growth due to the COVID-19 pandemic, but the importance of organic food presents growth opportunities. Online marketing and precision farming techniques are crucial for optimal crop yields. Harvestify, an online application, provides crop and fertilizer recommendations based on soil information, enhancing agricultural productivity and decision-making for farmers. The problem statement aims to create an intelligent modeling system for exact nutrient administration on agricultural carts, combining fuzzy logic and machine learning methodologies to maximize nutrient spread. The system must dynamically modify fertilizer application rates in real time to reduce waste and environmental impact. This sophisticated decision-making framework will lead to increased productivity and sustainability in contemporary farming methods, adjusting to the intricacies and uncertainties present in agricultural operations.

Keywords: Agronomy; Nutrient; Management; Crop Selection; Soil Analysis; Yield Prediction; Seed Optimization; Agriculture; Technology; Sustainability; Profitability

Introduction

Agriculture serves as the primary livelihood for approximately 58% of India's population, leveraging its vast land area of over 1.6 million square kilometers. With the potential to emerge as a significant force in agriculture, India relies heavily on this sector, which not only caters to the nation's food needs but also stands as one of the leading exporters of agricultural goods globally [1]. Despite its pivotal role, the agricultural industry has encountered various challenges, including those exacerbated by the COVID-19 pandemic such as restrictions on travel and trade. This global crisis has disrupted food demand and supply chains, prompting farmers to make uninformed choices regarding crop selection and leading to inefficiencies in resource utilization. Various machine learning algorithms suitable for agriculture have distinct advantages and drawbacks [2]. Our platform offers recommendations for optimal crops and fertilizers based on soil data input. Through the Crop Recommendation feature, farmers can obtain predictions for suitable crops based on their soil data. Similarly, the Fertilizer Suggestions module analyzes soil information and crop type to provide insights into soil deficiencies or excesses, along with suggestions for improvement. Accessing accurate crop forecasts enables farmers to make informed decisions regarding crop selection.

There can be several detrimental effects on natural resources, including soil, water, and air when individuals are ignorant about scheduling and using appropriate planting practices. Farmers must employ efficient and sustainable planting strategies because variations in the seasonal environment have the potential to worsen these problems [3]. To help farmers maximize their agricultural yields while limiting their impact on the environment, machine learning algorithms can be quite helpful here.

Through the utilization of the Crop Recommendation tool, farmers can input their soil data to receive tailored suggestions on suitable crops for their specific soil and climate conditions. This assists in avoiding the wastage of time and resources on crops unsuitable for their land. Furthermore, the provision of fertilizer recommendations based on soil data aids farmers in optimizing fertilizer usage and enhancing soil health [4]. By inputting soil data and crop type into the Fertilizer Suggestions tool, farmers can obtain advice on nutrient deficiencies and suitable fertilizers to address them, thereby avoiding over- or under-fertilization. Utilizing soil data for crop and fertilizer recommendations also promotes environmental sustainability by enabling resource optimization and waste reduction [5]. This fosters more eco-friendly farming practices and mitigates pollution and nutrient runoff. Offering crop and fertilizer guidance using soil data enables farmers to make informed choices, enhancing crop yields, reducing environmental harm, and fostering sustainable farming methods.

Objective of the study

To establish links between the results of soil tests and the trimming response to fertilizers, as well as to set up a calibration for soil test-based fertilizer recommendations. To obtain various fertilizer tests as a basis for recommending fertilizers for yield-focused crops. to evaluate the viability of various soil test techniques in real-world settings. To evaluate the combination application of synthetic and organic fertilizers for enhanced supplement use efficiency. Using the initial soil test results as a basis, deduce a fertilizer recommendation for a complete pruning group.

The goal of the proposed system is to create an intelligent modeling system that will allow for exact nutrient administration on agricultural carts. The process involves the amalgamation of fuzzy logic and machine learning methodologies to maximize the spread of nutrients, considering multiple parameters like crop kind, soil composition, and environmental circumstances. To maximize crop health and productivity and reduce waste and environmental effects, the system must be designed with the ability to dynamically modify fertilizer application rates in real time. With the help of machine learning and fuzzy logic, a sophisticated framework for making decisions will be developed that can adjust to the intricacies and uncertainties present in agricultural operations [6], ultimately leading to increased productivity and sustainability in contemporary farming methods.

The CART method, which is a decision tree algorithm, has a cross-validation feature that identifies over-fitting and so prevents inaccurate forecasts for the future [7]. This characteristic has resulted in more precise forecasts compared to other statistical methodologies. Nevertheless, comprehending the efficacy of these methods continues to be a difficulty in determining their optimal use.

Land records can be used to classify land. Random Forest is the machine learning method used for soil classification. The outcome of the method will be the separation and presentation of the confusion matrix, precision and mean, and finally precision. Using crop, feeding, and source data, a crop yield forecast can be created [8]. Refer to this tactic as the random forest algorithm. Based on the available input, the algorithm will forecast the crop. Fertilizer data, crop data, and location data can all be used to provide fertilizer recommendations. For every crop, appropriate products and fertilizers are suggested in this section. To access temperature data, humidity, barometric pressure, and all descriptors, third-party apps are utilized.

The remainder of the paper is as follows, Sec 2 provides related works of the proposed methodology, whereas, Sec 3 discusses the methodology of the work. The experimental analysis is discussed in sec 4. Sec 5 provides the concluding remarks followed by the future work possibilities discussed.

Related works

The literature survey on the intelligent modeling of agricultural carts for precision nutrient application, combining fuzzy logic and machine learning, reveals a growing interest in leveraging advanced computational techniques to enhance agricultural practices. Studies have explored various aspects of this integration, focusing on improving nutrient management, crop yield, and resource efficiency. Researchers have investigated the application of fuzzy logic to capture the inherent uncertainties and imprecisions in agricultural data [9], allowing for more flexible decision-making processes. Concurrently, machine learning techniques such as neural networks and support vector machines have been utilized to analyze large datasets and extract meaningful patterns to optimize nutrient application strategies.

Additionally, the literature highlights the significance of real-time monitoring and control systems in agricultural carts, enabling adaptive nutrient application based on dynamic environmental conditions and crop requirements. Studies have proposed intelligent modeling frameworks that integrate fuzzy logic and machine learning algorithms to develop predictive models capable of adjusting nutrient application rates on the fly. These models consider diverse factors such as soil characteristics [10], weather patterns, crop growth stages, and historical data to make informed decisions, ultimately leading to improved crop health and yield. Overall, the literature underscores the potential of combining fuzzy logic and machine learning in agricultural cart modeling to revolutionize precision nutrient management and drive sustainable farming practices.

India is a farming nation, but it continues to supply its farmers using age-old techniques. These days, expert advice is derived from farmer-expert exchanges, and the opinions of many experts vary. It is possible to recommend plants and fertilizers using smartphones running the Android operating system, which is the most popular technology. Mobile devices like tablets and phones, as well as other domestic platforms, are the primary users of the Android operating system. A soil's quality is determined by its nitrogen, potassium, and phosphorus (NPK) content. Based on this, fertilizers can be added to the soil through soil testing to increase agricultural yields [11]. You can write an application for the Android operating system that uses the soil NPK test to suggest various fertilizers. The goal of this system is to close the divide between technology-particularly Android technology-and agriculture. The website itself makes it simple to buy the suggested fertilizers. Online retailers offer a variety of recommended fertilizers for purchase.

This research investigates the influence of climate-responsive factors on agricultural output in Bangladesh by using fuzzy logic. The prediction of agricultural productivity relies on several language factors, including temperature, meteorological disasters, water availability, monsoon level, illnesses, species extinction, and deforestation [12]. The findings indicate a negative correlation between rising temperatures weather-related calamities, and a decline in agricultural output. The impacts of temperature and water availability are uniform, with rising temperature counterbalanced by the presence of water. Monsoon levels lead to significant amounts of rainfall, but moderate temperatures and abundant access to clean water contribute to moderate levels of agricultural productivity. Nevertheless, the loss of species has enduring consequences, whereas deforestation has rapid effects.

The research used fuzzy membership functions to classify ripe tomatoes according to their color, size, and firmness. The samples were classified into five groups: “grade I”, “grade II”, “grade I-far market”, “processing”, and “storage”. A total of 81 fuzzy rules were reduced to 25 by using suitable rules. A total of six distinct algorithms, each using various fuzzifiers and defuzzifiers, were used. The outcomes obtained from these methods were then compared to the classifications provided by the panelists [13]. The findings demonstrated that fuzzy algorithms effectively categorized fruits into the right groups, yielding optimal outcomes when using zmf and sigmf as membership functions, gbellmf as the fuzzifier, and mom as the fuzzified. The research revealed that by using fuzzy membership functions, the combination of tomato attributes may effectively and precisely categorize tomatoes into appropriate groupings for various markets.

Fuzzy Logic may also be used to assess the quality of various crops, including [14] tomatoes [15], lettuce, cauliflower, and mangoes [16]. These methods include taking or entering images, extracting features, and then classifying and/or grading them [17]. The crop is graded based on factors such as size, form (Mustafa et al., 2009), color, fragrance, etc. The grading is done on a scale ranging from 1 to 10. Furthermore, farmers may effectively allocate their resources by grading date trees according to their condition and expected productivity [18].

Methodology

The system aims to assist farmers in cultivating high-yield crops by selecting varieties commonly grown in specific regions, considering local agricultural practices and climate conditions. Common crops may include Rice, Jowar, Wheat, Soybean, Sunflower, Cotton, Sugarcane, Tobacco, Onion, and Dry Chili, among others, depending on the area. To ensure accuracy, credible sources such as government agencies, research institutions, and historical records provide crop yield data for dataset creation. This dataset includes vital information like crop type, yield, nutrients, and location for soil classification, crop yield prediction, and fertilizer recommendation processes.

Land classification involves utilizing land records, and employing the random forest algorithm to generate a confusion matrix, precision, and mean output.

- **CAR**T: Predicting a destination variable based on other values is the function of the decision tree, a machine-learning analytical system [19]. This function divides an interpreter variable into individual nodes, where each node represents the estimated value of the destination variable at the end. This technique is used for categorizing the dataset of swine flu tests.

- **Fuzzy logic:** a mathematical idea pioneered by Lotfi Zadeh in the 1960s, is a variable processing technique that accurately represents the uncertainty inherent in spoken language. It is used in a fuzzy logic control system that adaptively modifies irrigation time in response to fluctuating environmental circumstances [20]. The system employs an algorithm to produce efficient (IF-THEN) fuzzy logic rules, hence enhancing irrigation effectiveness and decreasing total time. This technology automates the process of irrigation, removing the need for human involvement, and guarantees an ideal water supply for the development of crops. The system provides an ideal atmosphere for the cultivation of crops.
- **Crop yield forecast:** For crop yield forecasting, the random forest algorithm uses crop data along with feeding and source data to predict yields based on available input.
- **Fertilizer recommendation:** Fertilizer recommendations utilize fertilizer data along with crop and location specifics. Suitable products and fertilizers are suggested for each crop, with third-party apps used to access weather data, including temperature, humidity, barometric pressure, and other relevant factors.

Implementation analysis

- **Data Collection**: Gather relevant data on soil characteristics, crop types, nutrient levels, weather patterns, and historical crop yields. This data can be taken from Kaggle databases, which are publically available.
- **Data Preprocessing**: Clean and preprocess the collected data to remove noise, handle missing values, and standardize formats. This step ensures the data is suitable for analysis and modeling.
- **Agronomic Analysis**: Utilize agronomic principles to analyze soil properties, crop requirements, and environmental factors. This analysis helps determine optimal crop varieties, planting schedules, and cultivation practices for specific regions.
- **Nutrient Application Guidance**: Develop algorithms or models to recommend nutrient application strategies based on soil nutrient levels, crop nutrient requirements, and environmental conditions. These recommendations aim to optimize nutrient use efficiency, enhance crop yields, and maintain soil fertility.
- **Model Development**: Implement machine learning algorithms to predict crop yields, assess nutrient deficiencies, and recommend fertilizer application rates. Train these models using historical data and validate their performance using independent datasets.
- **Integration with Technology**: Develop user-friendly interfaces to deliver agronomic analysis and nutrient application guidance to farmers. Ensure these tools are accessible, intuitive, and compatible with various devices and operating systems.

Classification and regression trees (CART), also known as decision trees, are decision support tools used in agriculture for disease diagnosis, crop monitoring, and weed classification. They use a tree-like graph or decision model to represent test results and class labels, such as categorizing based on water stress, weed presence, and nitrogen application rates. The proposed work cart achieved 85.3% accuracy in predicting the results.

Fuzzy Logic is a computational method that uses algorithms to determine and forecast the best values of N-P-K fertilizers for promoting maximum crop development. This technology assists farmers in achieving higher crop yields while minimizing expenses on fertilizers. The system administers precise quantities of nutrients to the crop, resulting in reduced fertilizer use, prevention of over-fertilization, and mitigation of environmental risks. This technique optimizes fertilizer use, decreases agricultural yield, and mitigates soil deterioration, thereby diminishing environmental hazards. Fuzzy Analysis achieved 93.8% in predicting fertilizer recommendation.

Fuzzy logic plays a vital role in agricultural systems by dealing with uncertainties and imprecisions related to elements such as soil composition, crop needs, and environmental circumstances. It facilitates adaptable decision-making processes, enabling informed modifications to nutrient application rates. This integration improves the accuracy and efficiency of nutrient delivery tactics, enabling the agricultural cart to negotiate complicated situations with human intelligence.

Continuous Improvement: Iteratively refine and update the guidance system based on feedback, new research findings, and changing agricultural practices. This continuous improvement process ensures the system remains relevant and effective over time.

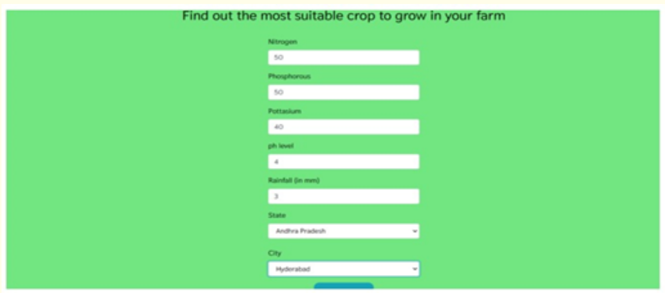


Figure 1: User Interface for entering Crop details. Recommendation of the name of the crop that is suitable to grow in the conditions given by the user.

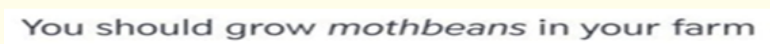
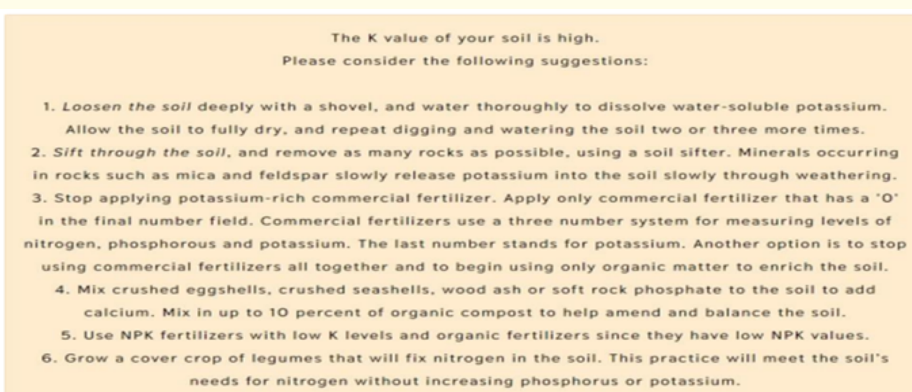


Figure 2: Prediction of Recommendation crop to farmers.

Figure 3: User Interface for Fertilizer details.



The K value of your soil is high.
Please consider the following suggestions:

1. *Loosen the soil* deeply with a shovel, and water thoroughly to dissolve water-soluble potassium. Allow the soil to fully dry, and repeat digging and watering the soil two or three more times.
2. *Sift through the soil*, and remove as many rocks as possible, using a soil sifter. Minerals occurring in rocks such as mica and feldspar slowly release potassium into the soil slowly through weathering.
3. Stop applying potassium-rich commercial fertilizer. Apply only commercial fertilizer that has a '0' in the final number field. Commercial fertilizers use a three number system for measuring levels of nitrogen, phosphorous and potassium. The last number stands for potassium. Another option is to stop using commercial fertilizers all together and to begin using only organic matter to enrich the soil.
4. Mix crushed eggshells, crushed seashells, wood ash or soft rock phosphate to the soil to add calcium. Mix in up to 10 percent of organic compost to help amend and balance the soil.
5. Use NPK fertilizers with low K levels and organic fertilizers since they have low NPK values.
6. Grow a cover crop of legumes that will fix nitrogen in the soil. This practice will meet the soil's needs for nitrogen without increasing phosphorus or potassium.

Figure 4: Result Page for Fertilizer Recommendation.

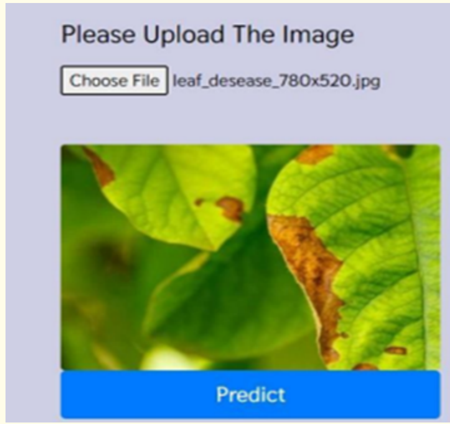
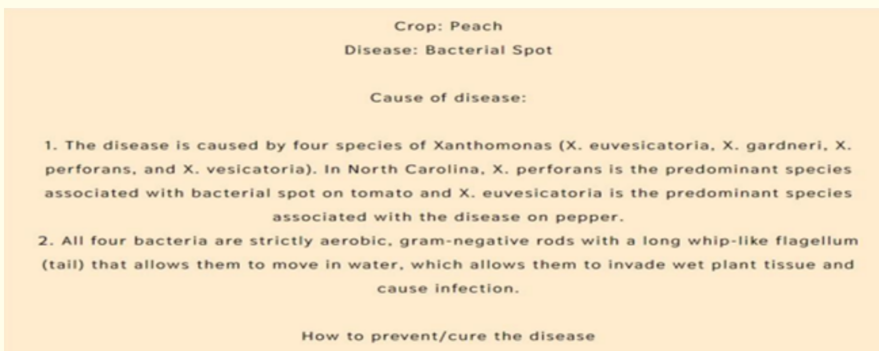


Figure 5: User Interface to upload picture for Disease prediction.



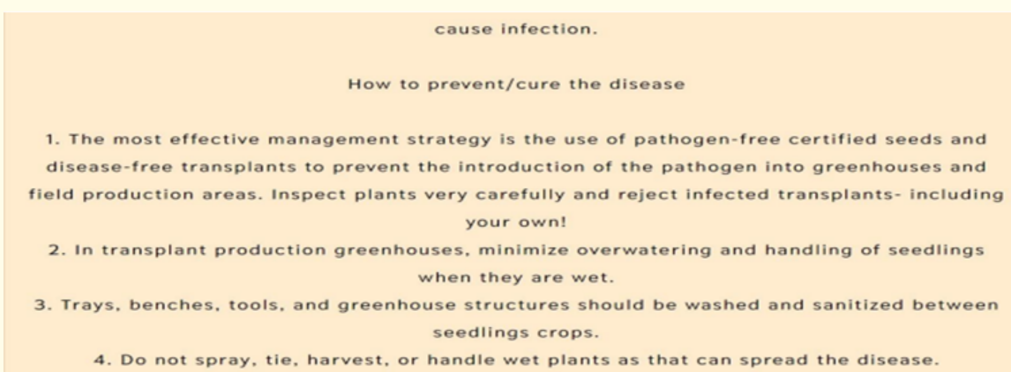
Crop: Peach
Disease: Bacterial Spot

Cause of disease:

1. The disease is caused by four species of Xanthomonas (X. euvesicatoria, X. gardneri, X. perforans, and X. vesicatoria). In North Carolina, X. perforans is the predominant species associated with bacterial spot on tomato and X. euvesicatoria is the predominant species associated with the disease on pepper.
2. All four bacteria are strictly aerobic, gram-negative rods with a long whip-like flagellum (tail) that allows them to move in water, which allows them to invade wet plant tissue and cause infection.

How to prevent/cure the disease

Figure 6: The result of Crop disease prediction.



cause infection.

How to prevent/cure the disease

1. The most effective management strategy is the use of pathogen-free certified seeds and disease-free transplants to prevent the introduction of the pathogen into greenhouses and field production areas. Inspect plants very carefully and reject infected transplants- including your own!
2. In transplant production greenhouses, minimize overwatering and handling of seedlings when they are wet.
3. Trays, benches, tools, and greenhouse structures should be washed and sanitized between seedlings crops.
4. Do not spray, tie, harvest, or handle wet plants as that can spread the disease.

Figure 7: Result Page for recommendation for Disease.

Conclusion

This user-friendly system aims to bridge the gap between agriculture and technology, offering farmers accessible tools for crop selection and management. Through a graphical user interface (GUI), farmers can easily input land details like soil type, weather conditions, and water availability, receiving precise predictions on suitable crops to grow. A key feature is nutrient recommendations, where our system analyzes soil and crop data to suggest the ideal type and number of fertilizers, enhancing nutrient management and crop health for higher yields. Additionally, our system advises on seed quantity for planting, considering factors like planting density and germination rates, thus optimizing seed usage, and cutting costs. It also forecasts yields based on historical and current data, aiding farmers in planning sales strategies for improved financial management. Real-time market price updates for various crops enable informed decisions, potentially leading to better profits by aligning crop selection with market demand. Our system empowers farmers to make informed choices in crop selection, nutrient management, seed usage, and market strategies, contributing to agricultural development and enhancing farmers' livelihoods globally.

Future Enhancement

In the future, boost crop forecast accuracy by comparing the effects of suitable machine learning techniques and refining a machine learning model using Metaheuristic algorithms, which leads to better performance and fewer mistakes.

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