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Sustainable Precision Farming Using Machine Learning Algorithms

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ABSTRACT: In the realm of sustainable agriculture, a pressing concern is the need for precision farming methodologies to optimize crop yield and resource utilization. This project introduces an integrated framework leveraging machine learning techniques to address this challenge. The Crop Recommendation module employs the XGBoost algorithm, analyzing soil characteristics, climate, and nutrient levels to provide personalized crop suggestions based on specific environmental conditions. Simultaneously, the Fertilizer Recommendation system enhances soil fertility by proposing optimal fertilizers and companion crops for a well-rounded nutrient profile. The Crop Yield Prediction model, utilizing a decision tree algorithm, forecasts potential yields by incorporating historical data and real-time inputs. The integration of these modules into a user-friendly website aims to furnish farmers with actionable insights, promoting sustainable farming practices and elevating overall agricultural productivity.

KEYWORDS: Machine Learning, XgBoost Algorithm, Decision Tree, Crop Recommendation, Fertilizer Management, Crop Yield Prediction, Sustainable Farming.

I. INTRODUCTION

In the expansive realm of agriculture, where cultivating crops is a pivotal endeavor, the need to modernize and optimize farming practices has never been more pronounced. Conventional methodologies grapple with inherent challenges, leading to issues such as crop failure, fertilizer wastage, and crop wastage. These challenges stem from difficulties in strategically selecting crops suited to specific conditions, enhancing soil fertility optimally, and accurately predicting crop yields.Past approaches, which often relied on algorithms like SVM and random forest, struggled to deliver the necessary accuracy for effective decision-making by farmers. This lack of precision contributed to instances of crop failure, where chosen crops were not well-suited to the environmental conditions, resulting in suboptimal yields and financial losses for farmers. Additionally, inefficient fertilizer management led to wastage, causing environmental concerns and economic inefficiencies.Moreover, inaccurate predictions of crop yields further compounded the challenges faced by farmers. Unreliable forecasts hindered their ability to plan and allocate resources effectively, leading to crop wastage and additional economic strain.In response to these challenges, this project introduces an integrated framework that harmonizes three crucial components: Crop Recommendation, Fertilizer Management, and Crop Yield Prediction, all seamlessly accessible through a unified website. Departing from the limitations of previous algorithms, we adopt cutting-edge methodologies, with XGBoost taking the lead for Crop Recommendation and decision trees steering Crop Yield Prediction. This strategic shift promises heightened accuracy and reliability in providing personalized recommendations and precise yield predictions, thereby empowering farmers with more informed choices.This amalgamation of three essential components into a user-friendly website signifies a comprehensive and sophisticated farming tool. It aspires to equip farmers with actionable insights, fostering sustainable practices, and augmenting overall agricultural productivity. In essence, this project stands as a beacon for the integration of advanced algorithms in precision agriculture, providing farmers with a holistic solution for efficient and informed decision-making.

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II. LITERATURE REVIEW

Previous research has highlighted the effectiveness of machine learning algorithms algorithms such as random forests, support vector machines, K-nearest neighbors, Naive Bayes, have demonstrated utility for crop and fertilizer recommendation, as well as crop yield prediction in diverse agricultural scenarios.

Bhuvaneswari Swaminathan, Saravanan Palani, Subramaniyaswamy Vairavasundaram, Ketan Kotecha, and Vinay Kumar[1] proposed An IoT driven artificial intelligence technique for fertilizer recommendation model. This paper proposes an innovative four-layered architectural framework. Leveraging various sensors in the sensor layer for real-time data collection on crop and environmental factors, the model ensures efficient data transmission through the network layer. The service layer utilizes deep learning algorithms to process this data, specifically focusing on fertilizer recommendation. The expert-level recommendations are then presented to farmers through a user-friendly mobile application interface in the application layer. This integration of IoT and artificial intelligence addresses previous research gaps, offering a promising solution for optimizing fertilizer usage and enhancing crop yields in smart farming practices.

Indira, Sobhana, Swaroop, and Kumar[2] proposed Machine learning based new recommendation system to the farmer. This paper proposes the project which addresses the challenge of low agricultural productivity in India using machine learning. Focusing on the nation's 54% arable land, the research aims to elevate agricultural practices through an advanced recommendation system. Leveraging diverse datasets, the system employs sophisticated models, including MobileNet for plant disease identification, XGBoost for crop prediction based on local soil conditions, and Random Forest for fertilizer recommendation and soil fertility improvement. The model showcases exceptional accuracy, outperforming alternative approaches with a 99% precision in suggesting crops tailored to input values and local soil conditions. Ultimately, the project contributes significantly to agricultural technology advancement, providing practical solutions to boost crop yield and benefit farmers.

Mahendra Choudhary, Rohit Sartandel, Anish Arun, and Leena Ladge[3] proposed Crop Recommendation System and Plant Disease Classification Using Machine Learning for Precision Agriculture. This paper proposes a transformative project to address challenges in India's agricultural sector, aiming to enhance crop yield and mitigate alarming suicide rates among farmers. Utilizing machine learning, the model predicts crop yield based on environmental factors, contributing to optimized crop selection and addressing growing food demand. The project extends its innovative approach to include an app for precision agriculture, empowering farmers to identify and address plant diseases promptly. This holistic initiative not only improves overall productivity but also fosters resilience in the agricultural sector, making significant strides towards sustainable and efficient farming practices. By integrating cutting-edge technology, the project aligns with global efforts to modernize agriculture, creating a pathway for India's farming community to thrive in a rapidly evolving agricultural landscape.

Deshmukh, Jaiswar, Joshi, and Shedge[4] proposed Farming assistance for soil fertility improvement and crop prediction. This paper proposes to address the challenge of enhancing agricultural productivity in regions like India. Leveraging the XGBoost algorithm, known for its superior performance, the authors develop a machine learning-based recommendation system. Analyzing soil properties, weather conditions, and historical crop yield, the system suggests the top three most suitable crops for a given location, providing flexibility to farmers. Personalized recommendations for soil improvement strategies, tailored to the desired crop, empower farmers to optimize practices. The inclusion of a five-day weather forecast enhances decision-making by allowing farmers to prepare for upcoming conditions. Overall, this research showcases the potential of XGBoost-based systems to offer data-driven insights for improved crop selection, soil fertility, and agricultural productivity.

Nguyen Ha Huy Cuong, Trung Hai Trinh, Duc-Hien Nguyen, Thanh Khiet Bui, Tran Anh Kiet, Phan Hieu Ho, and Nguyen Thanh Thuy[5] proposed An approach based on deep learning that recommends fertilizers and pesticides for agriculture recommendation. This innovative approach, detailed in the paper exploring a deep learning-based recommender system, demonstrates the fusion of tree data structures and the YOLO algorithm-based CNN for accurate recommendations tailored to farmers' needs. With promising results from a 400-sample dataset, the system showcases feasibility and effectiveness, offering the potential to empower farmers through data-driven decision-making. The model's emphasis on optimizing resource use and enhancing crop yields represents a pivotal stride toward sustainable and efficient farming solutions. Its integration into precision agriculture practices not only underscores its immediate impact but also positions itself as a catalyst for ongoing advancements in modernizing and improving agricultural practices, ensuring long-term resilience in the farming sector.

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Madhuri and Indiramma [6] proposed Artificial neural networks based integrated crop recommendation system. This paper proposes a location-specific crop recommendation system leveraging Artificial Neural Networks (ANNs). Addressing diverse factors like soil properties and climatic parameters, the study establishes suitability classes for maize, finger millet, rice, and sugarcane. Integrating real-time soil and climate data, the ANN model outperforms decision trees with a remarkable 96% overall accuracy. This research provides farmers with an efficient, data-driven tool for optimizing crop selection and agricultural planning.

III. METHODOLOGY OF PROPOSED SURVEY

The aim of the proposed system is to enhance agricultural practices through the integration of machine learning algorithms. The system empowers farmers with data-driven insights for sustainable crop cultivation, using user-friendly technologies to enhance informed decision-making in agriculture, leading to improved productivity and resource management.Fig 1. shows the System Architecture. There are 3 steps in proposed work.

1. Crop Recommendation:

The Crop Recommendation System offers farmers personalized insights for optimal crop selection. By employing the robust XGBoost algorithm, the system analyzes user-input parameters such as N, P, K, rainfall, pH, and state to accurately predict the most suitable crops.

2. Fertilizer Recommendation:

In the Fertilizer Recommendation System, historical nutrient averages are utilized to suggest fertilizers tailored to specific crops. This approach aids in maintaining optimal soil fertility and NPK balance, promoting sustainable farming practices.

3. Crop Yield Prediction:

The Crop Yield Prediction System, powered by the Decision Tree Regressor algorithm, provides valuable insights into anticipated crop yields. By considering inputs such as year, average annual rainfall etc. the system forecasts yields for selected crops.

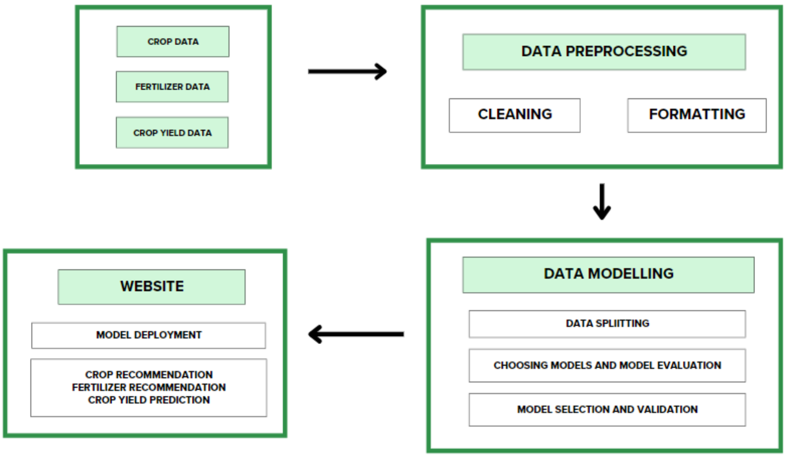

Figure 1. System Architecture

DATA COLLECTION

Data collection is the basic procedure of accumulating information from diverse sources. In this project, the datasets were meticulously sourced from Kaggle. The collected datasets encompass three primary categories: crop dataset, fertilizer dataset, and crop yield dataset. Fig 2. shows the overview of the Crop dataset, Fig 3. shows the overview of the Fertilizer dataset, and Fig 4. shows the overview of the Crop yield dataset.

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N	P	K	temperatu	humidity	ph	rainfall	label
90	42	43	20.87974	82.00274	6.502985	202.9355	rice
85	58	41	21.77046	80.31964	7.038096	226.6555	rice
60	55	44	23.00446	82.32076	7.840207	263.9642	rice
74	35	40	26.4911	80.15836	6.980401	242.864	rice
78	42	42	20.13017	81.60487	7.628473	262.7173	rice
69	37	42	23.05805	83.37012	7.073454	251.055	rice
69	55	38	22.70884	82.63941	5.700806	271.3249	rice
94	53	40	20.27774	82.89409	5.718627	241.9742	rice
89	54	38	24.51588	83.53522	6.685346	230.4462	rice
68	58	38	23.22397	83.03323	6.336254	221.2092	rice
91	53	40	26.52724	81.41754	5.386168	264.6149	rice
90	46	42	23.97898	81.45062	7.502834	250.0832	rice
78	58	44	26.8008	80.88685	5.108682	284.4365	rice
93	56	36	24.01498	82.05687	6.984354	185.2773	rice
94	50	37	25.66585	80.66385	6.94802	209.587	rice
60	48	39	24.28209	80.30026	7.042299	231.0863	rice
85	38	41	21.58712	82.78837	6.249051	276.6552	rice
91	35	39	23.79392	80.41818	6.97086	206.2612	rice
77	38	36	21.86525	80.1923	5.953933	224.555	rice
88	35	40	23.57944	83.5876	5.853932	291.2987	rice
89	45	36	21.32504	80.47476	6.442475	185.4975	rice
76	40	43	25.15746	83.11713	5.070176	231.3843	rice
67	59	41	21.94767	80.97384	6.012633	213.3561	rice
83	41	43	21.05254	82.6784	6.254028	233.1076	rice
98	47	37	23.48381	81.33265	7.375483	224.0581	rice

crop_recommendation

Figure 2. Overview of the Crop dataset

	Crop	N	P	K	pH	soil_moisture
0	rice	80	40	40	5.5	30
3	maize	80	40	20	5.5	50
5	chickpea	40	60	80	5.5	60
12	kidneybea	20	60	20	5.5	45
13	pigeonpea	20	60	20	5.5	45
14	mothbean	20	40	20	5.5	30
15	mungbean	20	40	20	5.5	80
18	blackgram	40	60	20	5	60
24	lentil	20	60	20	5.5	90
60	pomegran	20	10	40	5.5	30
61	banana	100	75	50	6.5	40
62	mango	20	20	30	5	15
63	grapes	20	125	200	4	60
66	watermelc	100	10	50	5.5	70
67	muskmelo	100	10	50	5.5	30
69	apple	20	125	200	6.5	50
74	orange	20	10	10	4	60
75	papaya	50	50	50	6	20
88	coconut	20	10	30	5	45
93	cotton	120	40	20	5.5	70
94	jute	80	40	40	5.5	20
95	coffee	100	20	30	5.5	20

Figure 3. Overview of the Fertilizer dataset

	Area	Item	Year	hg/ha_\	average	pesticid	avg_ter
0	Albania	Maize	1990	36613	1485	121	16.37
1	Albania	Potatoes	1990	66667	1485	121	16.37
2	Albania	Rice, padd	1990	23333	1485	121	16.37
3	Albania	Sorghum	1990	12500	1485	121	16.37
4	Albania	Soybeans	1990	7000	1485	121	16.37
5	Albania	Wheat	1990	30197	1485	121	16.37
6	Albania	Maize	1991	29068	1485	121	15.36
7	Albania	Potatoes	1991	77818	1485	121	15.36
8	Albania	Rice, padd	1991	28538	1485	121	15.36
9	Albania	Sorghum	1991	6667	1485	121	15.36
10	Albania	Soybeans	1991	6066	1485	121	15.36
11	Albania	Wheat	1991	20698	1485	121	15.36
12	Albania	Maize	1992	24876	1485	121	16.06
13	Albania	Potatoes	1992	82920	1485	121	16.06
14	Albania	Rice, padd	1992	40000	1485	121	16.06
15	Albania	Sorghum	1992	3747	1485	121	16.06
16	Albania	Soybeans	1992	4507	1485	121	16.06
17	Albania	Wheat	1992	24388	1485	121	16.06
18	Albania	Maize	1993	24185	1485	121	16.05
19	Albania	Potatoes	1993	98446	1485	121	16.05
20	Albania	Rice, padd	1993	41786	1485	121	16.05
21	Albania	Soybeans	1993	7998	1485	121	16.05
22	Albania	Wheat	1993	29976	1485	121	16.05
23	Albania	Maize	1994	25848	1485	201	16.96
24	Albania	Potatoes	1994	81404	1485	201	16.96

Figure 4. Overview of the Crop yield dataset

Using machine learning algorithms, predictive models are constructed from these patterns, seeking trends and anticipating future changes.

DATA PREPROCESSING

The initial data collection includes essential parameters like N, P, K, rainfall, and state. Due to the inherent characteristics of the dataset, a vital preprocessing phase is undertaken. This includes meticulous data cleansing to rectify errors and handle missing values for data integrity. The dataset is then categorized based on key features such as crop type, time of year, and geographical factors. These identified features are encoded to align with machine learning algorithms, ensuring compatibility with the Crop Recommendation, Fertilizer Recommendation, and Crop Yield Prediction systems. This preprocessing ensures a clean and well-prepared dataset, optimizing its utility for subsequent machine learning implementations.

CHOOSING MACHINE LEARNING MODELS

In the realm of Sustainable Precision Farming, our preference leans towards the utilization of supervised machine learning tools, primarily attributed to the presence of labeled data. This dataset encompasses numerous instances where we have prior knowledge of outcomes in diverse farming scenarios. The acumen of these machine learning tools steadily evolves as they immerse themselves in this rich repository of agricultural experiences, gaining a deeper understanding of the intricate dynamics of farming practices. Shifting the focus to the recommendation of suitable crops for cultivation, our chosen models specialize in sorting through variables such as soil nutrients, climate

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conditions, and geographical location. This meticulous approach tailors recommendations to address specific farming requirements, ensuring a personalized and context-aware advisory system. Conversely, when the task involves predicting crop yields, a distinct set of models takes center stage. These adept models demonstrate proficiency in forecasting continuous outcomes, providing comprehensive insights into the potential harvest volumes."Our methodical selection ensures seamless alignment with tasks, offering accurate crop categorization and reliable yield predictions. By incorporating tailored machine learning, our system navigates learning and delivers precise advice, revolutionizing agriculture for enhanced productivity, efficiency, and accessibility.

COMPARISON OF MACHINE LEARNING ALGORITHMS

The chosen machine learning algorithms are systematically applied to predict crop yield and names. Classification algorithms focus on crop names, while regression algorithms forecast crop yields. Evaluation using testing data ensures a thorough comparison, featuring XGBoost for Crop Recommendation and decision tree regressor for Crop Yield Prediction. Resampling methods like cross-validation estimate accuracy on unseen data, and performance metrics like precision and recall contribute to a comprehensive evaluation. This process aids in identifying the most effective algorithm for Sustainable Precision Farming, guiding informed decision-making in agriculture.Fig 5. shows the Classification Algorithm Accuracy Comparison and Fig 6. shows the Regression Algorithm Accuracy Comparison.

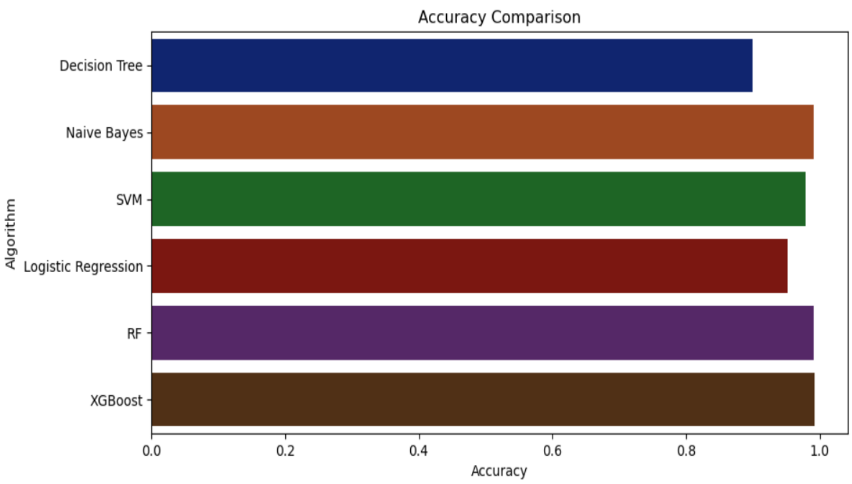

Figure 5. Classification Algorithm Accuracy Comparison

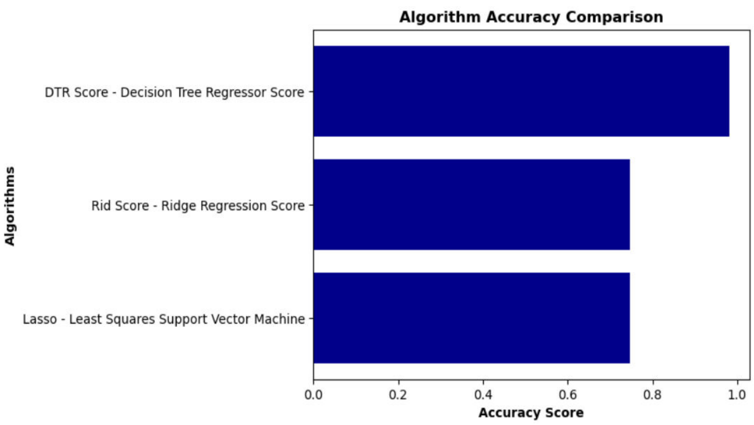

Figure 6. Regression Algorithm Accuracy Comparison

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SAVING THE TRAINED DATA

Upon identifying the most effective machine learning model with the highest accuracy for the given dataset, the training process is initiated. The selected model is applied to the dataset, facilitating the training phase. Once the training is complete, the resulting trained data is exported and securely stored in a file. This step ensures that the trained model can be readily accessed and deployed for future tasks without the need to retrain it from scratch, thus optimizing computational resources and time efficiency.

DEPLOYMENT WITH FLASK

To make crop prediction accessible to users, a user-friendly interface is constructed using Flask. This interface seamlessly showcases the results of crop predictions. During the prediction phase, the previously trained data is loaded into the model. Users are then prompted to input relevant agricultural parameters into the system. The model utilizes these inputs to generate accurate predictions. The forecasted results are efficiently presented to users through the purpose-built user interface, offering a streamlined and informative experience for individuals engaged in agriculture.This intuitive platform not only enhances accessibility but also empowers users to make informed decisions based on the predictions generated by the machine learning model. By leveraging technology to bridge the gap between data analytics and agriculture, this interface serves as a valuable tool for optimizing crop management and increasing agricultural productivity.

IV. RESULTS

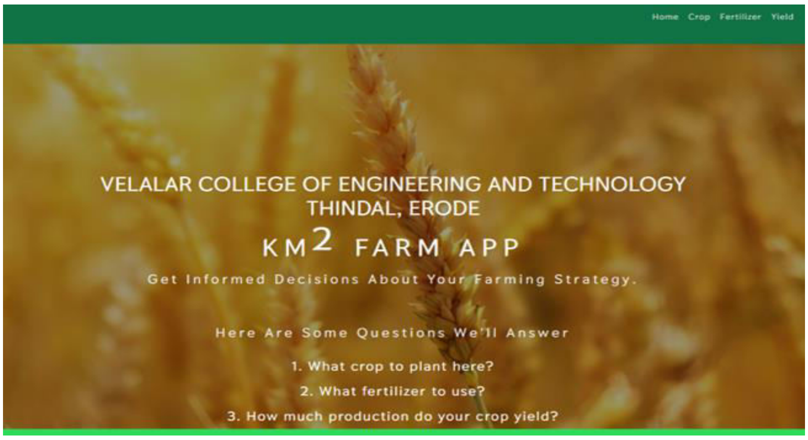

Figure 6. Home Page

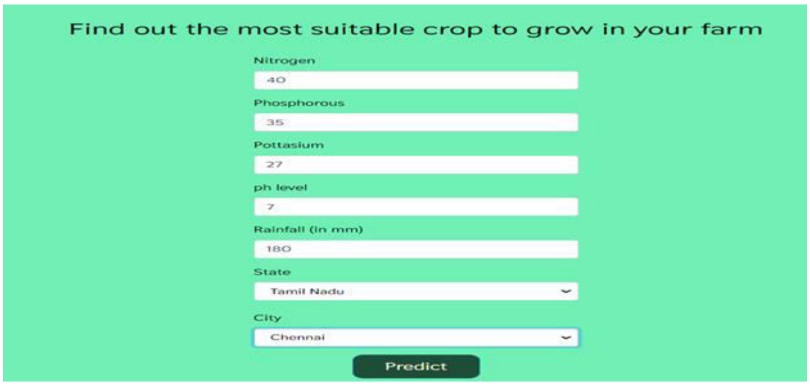

Figure 7. Crop Recommendation Form

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Figure 8. Crop Recommendation Result

Figure 9. Fertilizer Recommendation Form

Figure 10. Fertilizer Recommendation Result

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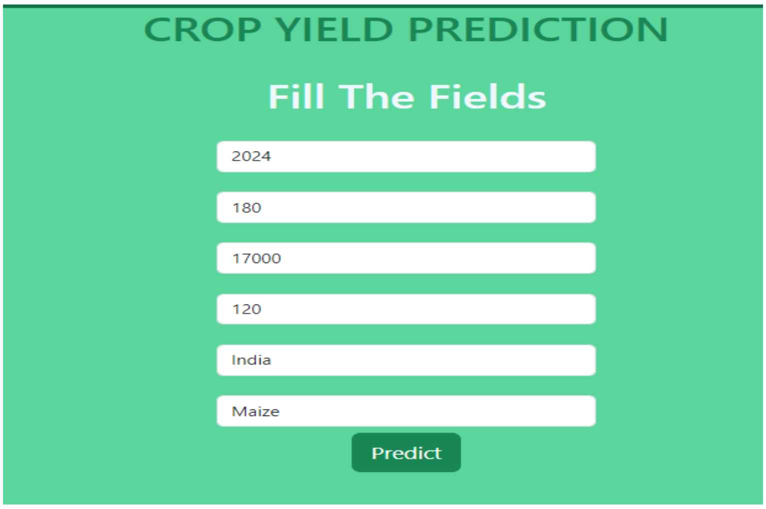

Figure 11. Crop Yield Prediction Form

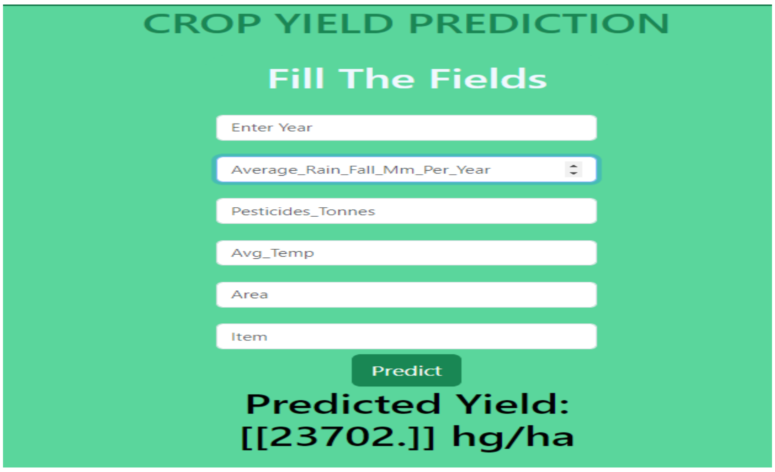

Figure 12. Crop Yield Prediction Result

V. CONCLUSION AND FUTURE WORKS

The development of the Sustainable Precision Farming System marks a significant stride towards revolutionizing agricultural practices. The integrated systems, encompassing Crop Recommendation, Fertilizer Recommendation, and Crop Yield Prediction, demonstrate the efficacy of advanced algorithms in providing actionable insights for farmers.The Crop Recommendation System, anchored by XGBoost, showcases the potential to guide farmers in optimal crop selection based on critical factors like soil nutrients, rainfall, and geographical nuances. Simultaneously, the Fertilizer Recommendation System, leveraging average NPK values, not only streamlines fertilization practices but also aids in preserving soil fertility.For future works, our focus is on continuous refinement and expansion of the platform. Introducing sophisticated machine learning algorithms, possibly delving into neural network models, holds promise for enhancing predictive accuracy. Incorporating a broader array of crops and factoring in additional regional considerations will further tailor the system to diverse agricultural landscapes.Beyond predictive analytics, envisioning a mobile application version of the platform aims to make these insights more accessible to farmers in the field. Concurrently, ongoing efforts will concentrate on augmenting the dataset, incorporating more features, and exploring emerging technologies to ensure the sustained relevance and effectiveness of the system.The broader vision includes the development of a comprehensive big data analytics platform, capable of processing diverse agricultural data for multifaceted applications. This evolution will facilitate a holistic understanding of farming dynamics, aiding in

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decision-making, resource optimization and sustainable agricultural practices. As we steer towards a future of data-driven precision farming, our commitment remains unwavering – to empower farmers, for promoting sustainability in agriculture

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