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AI-Driven Crop Rotation Planning System

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Abstract—Agriculture plays a vital role in maintaining food security,economicgrowth,andenvironmentalsustainability.Traditional farming practices often result in soil nutrient depletion, reducedcropproductivity,andincreaseddependenceonchemical fertilizers. Crop rotation is one of the most effective agricultural techniques used to improve soil fertility and maintain long-term agricultural productivity.

This research presents an AI-driven crop rotation planning systemusingMachineLearningtechniques.Theproposedsystem analyzes soil nutrients, weather conditions, rainfall, humidity, and previous crop history to recommend suitable crop sequences for future farming seasons.

The agricultural dataset undergoes preprocessing operations such as missing value handling, duplicate record removal, normalization, and categorical encoding before model training. A Random Forest Classifier algorithm is used for prediction due to its high accuracy, robustness, and ability to handle agricultural datasets effectively.

AStreamlit-baseddashboardwasdevelopedtoprovideauser-friendly interface for farmers and researchers. The dashboard enables users to input agricultural parameters, generate crop rotation plans, and visualize soil nutrient changes graphically.

Experimental results demonstrate that the proposed system provides intelligent and adaptive crop recommendations for precision agriculture and sustainable farming practices.

Index Terms—Artificial Intelligence, Machine Learning, Crop Rotation, Random Forest, Precision Agriculture, Streamlit, Smart Farming, Agricultural Data Analysis.

A Random Forest Classifier algorithm is used as the primary Machine Learning model because of its robustness, high prediction accuracy, reduced overfitting capability, and efficient handling of agricultural datasets with multiple features. The trained model predicts adaptive crop recommendations based on changing environmental and soil conditions. To improve usability and accessibility, a Streamlit-based graphical dashboard was developed that allows users to enter agricultural parameters, generate crop rotation plans, and visualize soil nutrient changes using graphical representations.

The experimental results demonstrate that the proposed system successfully generates intelligent and sustainable crop rotation recommendations under varying agricultural conditions. The graphical visualization of nutrient changes helps users understand soil fertility trends across farming seasons. The proposed framework supports precision agriculture, sustainable farming practices, intelligent nutrient management, and AI-assisted agricultural planning. The system can further assist farmers, researchers, and agricultural organizations in improving crop productivity while reducing environmental degradation and resource wastage.

I. INTRODUCTION

Agriculture is one of the most essential sectors contributing to global food production and economic development. The increasing population and changing climatic conditions have created significant challenges in maintaining agricultural pro-ductivity and soil sustainability.

Traditional farming methods often involve cultivating the same crop repeatedly on agricultural land. This practice grad-ually reduces soil nutrients and increases the risk of crop diseases, pest infestations, and poor yield quality.

Crop rotation is a sustainable agricultural technique where different crops are cultivated sequentially to improve soil fer-tility and reduce environmental damage. Proper crop rotation improves nutrient availability, minimizes pest attacks, and supports long-term soil health.

Artificial Intelligence (AI) and Machine Learning (ML) have recently become important technologies in smart agri-culture.Thesetechnologiesenableintelligentdecision-making.

he proposed research focuses on developing an AI-driven crop rotation planning system using Machine Learning techniques. The system analyzes agricultural parameters such as soil nutrients, rainfall, humidity, temperature, and previous crop history to recommend suitable crop rotation sequences for future farming seasons.

A Random Forest Classifier algorithm is used to train the prediction model because of its robustness, high prediction accuracy, and ability to handle agricultural datasets effectively.

To improve usability and accessibility, a Streamlit-based graphical dashboard is developed that allows users to input agricultural parameters and generate crop rotation recommendations dynamically. The dashboard also provides graphical visualization of soil nutrient changes across multiple farming seasons, helping users understand nutrient depletion patterns and farming sustainability.

The proposed framework aims to support precision agriculture, intelligent farming practices, and sustainable crop management. By integrating Machine Learning with agricultural analysis, the system can assist farmers, researchers, and agricultural organizations in improving productivity, reducing environmental impact, and promoting data-driven farming techniques. byanalyzinglargeagriculturaldatasetsandidentifyinghidden patterns in farming conditions.

The proposed AI-driven crop rotation planning system in-tegrates Machine Learning algorithms with agricultural data analysis to provide intelligent crop recommendations. The framework assists farmers in selecting suitable crops basedon soil and environmental conditions.

The system also provides graphical visualization of soil nutrient changes across multiple farming seasons using a dashboard interface developed in Streamlit.

II. OBJECTIVES

The primary objective of the proposed AI-Driven Crop Rotation Planning System is to develop an intelligent agricultural recommendation framework using Machine Learning techniques. The system aims to assist farmers and agricultural researchers in selecting suitable crop rotation sequences based on soil nutrient conditions, weather parameters, and previous crop history. The proposed framework focuses on improving agricultural productivity while supporting sustainable farming practices and intelligent nutrient management.

Another important objective of the system is to reduce soil degradation caused by repetitive cultivation of the same crop. By analyzing agricultural data and generating adaptive crop recommendations, the system helps maintain soil fertility and improves long-term crop sustainability. The framework also aims to support precision agriculture through data-driven decision-making and graphical nutrient visualization.

The major objectives of the proposed system are as follows:

begin{itemize}

1) item Toanalyze important agricultural parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, and rainfall.
2) item To preprocess and clean agricultural datasets for improved prediction accuracy.
3) item To develop a Machine Learning-based crop recommendation system using the Random Forest Classifier algorithm.
4) item To recommend suitable crop rotation sequences for multiple farming seasons.
5) item To provide graphical visualization of soil nutrient changes across crop seasons.
6) item To improve agricultural productivity and nutrient management using AI-driven recommendations.
7) item To design a user-friendly Streamlit dashboard for farmers and agricultural researchers.
8) item To reduce excessive dependency on chemical fertilizers and improve environmental sustainability.
9) item To support sustainable farming practices and precision agriculture techniques.

end{itemize}

III. LITERATURE REVIEW

Several researchers have explored the use of Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), and data analytics in modern agriculture to improve farming efficiency and productivity. The rapid growth of smart farming technologies has enabled intelligent agricultural systems capable of supporting decision-making processes related to crop recommendation, soil management, irrigation, and environmental monitoring. Researchers have focused on developing data-driven agricultural frameworks that can improve sustainability, reduce resource wastage, and increase crop yield.

Kumar et al. developed a Machine Learning-based crop recommendation system using soil and environmental param-eters. Their work demonstrated improved prediction accuracy using supervised learning algorithms.

M. Lee and K. Wong proposed deep learning approaches for agricultural analysis and smart farming applications. Their research utilized neural networks and predictive analytics for crop monitoring, disease detection, and agricultural forecasting. The study highlighted the growing importance of deep learning algorithms in improving prediction accuracy and automation in agriculture.

R. Singh and P. Sharma explored the application of Artificial Intelligence in smart agriculture and precision farming systems. Their work focused on AI-driven agricultural decision-making techniques capable of analyzing large agricultural datasets and generating intelligent recommendations for crop management. The study demonstrated that AI-based systems can improve farming efficiency, reduce operational costs, and support sustainable agriculturalpractices.

J. Brown studied sustainable crop rotation techniques and their impact on soil fertility management and long-term agricultural productivity. The research explained how crop rotation practices help maintain nutrient balance, reduce soil degradation, minimize pest infestation, and improve crop yield quality. The study also discussed the environmental benefits of sustainable farming methods and highlighted the importance of proper crop sequencing in agricultural planning.

Existingagriculturalrecommendationsystemsmainlyfocus on crop prediction but often lack adaptive crop rotation plan-ning and graphical nutrient visualization features.

The proposed system addresses these limitations by pro-viding intelligent crop rotation recommendations along with graphical analysis of nutrient changes.

IV. PROPOSED METHODOLOGY

The proposed framework follows a systematic approach for collecting, processing, and analyzing agricultural data.

Themethodologyconsistsofthefollowingstages:

1) DataCollection
2) DataCleaningandPreprocessing
3) FeatureSelection
4) MachineLearningModelDevelopment
5) CropRotationRecommendation
6) DashboardVisualization

The system workflow begins with collecting agricultural parameters such as Nitrogen, Phosphorus, Potassium, temper-ature, humidity, rainfall, and crop history.

The collected data is preprocessed and provided to the MachineLearningmodelforpredictionandrecommendation.

The proposed system uses the Random Forest Classifier algorithm for crop prediction and recommendation. Random Forest is an ensemble Machine Learning algorithm that combines multiple decision trees to improve prediction accuracy and reduce overfitting. The algorithm analyzes soil nutrients, weather conditions, and crop history to recommend suitable crop sequences for future farming seasons.

Once the model generates predictions, the system provides intelligent crop rotation recommendations based on current agricultural conditions. The recommendation process helps farmers select crops that can maintain soil nutrient balance, reduce pest infestation, and improve agriculturalproductivity.

A. *DataCleaningandPreprocessing*

DatapreprocessingisanimportantstageinMachineLearn-ing because prediction accuracy depends heavily on dataset quality.

The dataset underwent several preprocessing operations before model training.

1) *Handling Missing Values:* Missing numerical values were handled using mean-value imputation methods. Missing categoricalvalueswereeithercorrectedorremoveddepending on dataset completeness.

This process improved data consistency and prevented pre-diction errors during model training.

2) *Removal of Duplicate Records:* Duplicate rows were identified and removed from the dataset to avoid redundancy and improve training efficiency.

Removing duplicate records also reduced bias in the Ma-chine Learning model.

3) *Data Normalization:*Numerical parameters such as Ni-trogen, Phosphorus, Potassium, rainfall, humidity, and tem-perature were normalized to maintain uniformity across all features.

Normalization improved model performance and reduced feature imbalance.

4) *Encoding Categorical Data:* Categorical crop names were converted into numerical labels using Label Encoding techniques.

This allowed the Machine Learning model to process crop information effectively.

5) *Feature Selection:*The following important agricultural features were selected for prediction:

- Nitrogen(N)

- Phosphorus(P)
- Potassium(K)
- Temperature
- Humidity
- Rainfall
- PreviousCropHistory

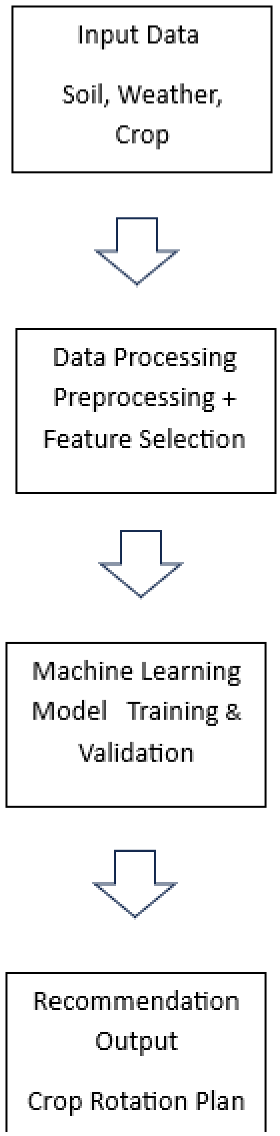

Fig.1.WorkflowDiagramofProposedSystem

Fig. 1 illustrates the workflow architecture of the proposed AI-drivencroprotationplanningsystem.Theworkflowbegins withagriculturaldatacollectionfollowedbypreprocessingand feature selection.
The processed data is used to train the Machine Learning model, which generates intelligent crop rotation recommen-dations. The final recommendations are displayed through the dashboard interface.

V. MACHINE LEARNING MODEL

The proposed system uses the Random Forest Classifier algorithm for crop prediction and recommendation.
Random Forest is an ensemble learning algorithm that constructs multiple decision trees and combines their outputs to improve prediction accuracy.

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Themodelwastrainedusingagriculturaldatasetscontaining soilnutrients,weatherparameters,rainfall,humidity,andcrop history.
The Random Forest algorithm was selected because of its advantages such as:

- Highpredictionaccuracy
- Betterhandlingofagriculturaldatasets
- Reducedoverfitting
- Fasterpredictionperformance
- Abilitytoprocessmultipleinputfeatures
- Improvedrobustnessandreliability

Thetrainedmodelpredictssuitablecropsforfuturefarming seasons based on current agricultural conditions.

The agricultural dataset used for training the model contains important farming parameters such as soil nutrients, temperature, humidity, rainfall, and previous crop history. These parameters directly influence crop growth, soil fertility, and agricultural productivity. The dataset was preprocessed and cleaned before model training to improve prediction quality and reduce inconsistencies.

The Random Forest algorithm was selected for this research because of its ability to handle agricultural datasets effectively and generate reliable predictions under varying environmental conditions. The algorithm can process both numerical and categorical features efficiently and provides better generalization compared to many traditional Machine Learning algorithms.

The major advantages of using the Random Forest Classifier in the proposed system are as follows:

- High prediction accuracy
- Better handling of agricultural datasets
- Reduced overfitting problems
- Faster prediction performance
- Ability to process multiple input features simultaneously
- Improved robustness and reliability
- Better decision-making capability
- Efficient handling of complex agricultural conditions
- Capability to generate stable predictions under varying data patterns

VI. SYSTEM IMPLEMENTATION

The implementation phase of the proposed AI-Driven Crop Rotation Planning System involved developing the Machine Learning prediction model and integrating it with a graphical dashboard for user interaction and visualization. The implementation process focused on creating an intelligent and user-friendly agricultural recommendation system capable of analyzing soil and environmental conditions to generate crop rotation plans dynamically.

The complete system was implemented using Python and several Machine Learning, data processing, and visualization libraries. The implementation process included agricultural dataset preprocessing, Machine Learning model training, crop recommendation generation, dashboard development, and graphical nutrient visualization.

The developed framework provides an interactive environment where users can enter agricultural parameters such as soil nutrients and weather conditions to obtain intelligent crop rotation recommendations.

A. Development Environment

The proposed system was implemented using the following tools and technologies:

• Python Programming Language
• Scikit-learn
• Pandas
• NumPy
• Matplotlib
• Streamlit
• Visual Studio Code

Python was selected as the primary programming language because of its simplicity, flexibility, and extensive support for Machine Learning and data analysis libraries.

Scikit-learn was used for implementing the Random Forest Classifier algorithm and training the Machine Learning model.
Pandas and NumPy libraries were used for dataset handling, preprocessing, feature extraction, and numerical computations. These libraries provided efficient tools for cleaning agricultural datasets and managing large amounts of farming-related data.
Matplotlib was used for generating graphical visualization of soil nutrient changes across different crop seasons. The generated graphs help users analyze nutrient depletion trends and understand soil fertility conditions effectively.
Streamlit was used to develop the graphical dashboard interface because it provides a simple and efficient framework for building interactive web-based applications using Python.
Visual Studio Code was used as the primary development environment for coding, debugging, and system integration.
The implementation process also included integrating Machine Learning prediction logic with the dashboard interface to provide real-time crop rotation recommendations dynamically.

B. Dashboard Development

A user-friendly dashboard was developed using Streamlit to improve interaction between users and the recommendation system. The dashboard provides a simple graphical interface where users can enter agricultural parameters and generate intelligent crop rotation recommendations.
The dashboard allows users to:
- Enter soil nutrient values
- Provide weather conditions
- Select current crop details
- Generate crop rotation recommendations
- Visualize nutrient changes graphically

The dashboard interface accepts agricultural parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, rainfall, and current crop information from the user. After receiving the input values, the system processes the data and sends it to the trained Machine Learning model for prediction. The Random Forest Classifier model analyzes the provided agricultural conditions and generates suitable crop rotation recommendations for future farming seasons. The generated recommendations are displayed dynamically on the dashboard.
In addition to crop recommendations, the dashboard also provides graphical visualization of nutrient changes across multiple crop seasons. The graphical representation helps users understand variations in Nitrogen, Phosphorus, and Potassium levels over time. This feature supports better nutrient management and sustainable agricultural planning.
The Streamlit dashboard significantly improves system usability by providing an interactive and visually understandable environment for farmers, researchers, and agricultural organizations. The integration of Machine Learning prediction with graphical visualization makes the proposed framework efficient, practical, and suitable for precision agriculture applications.

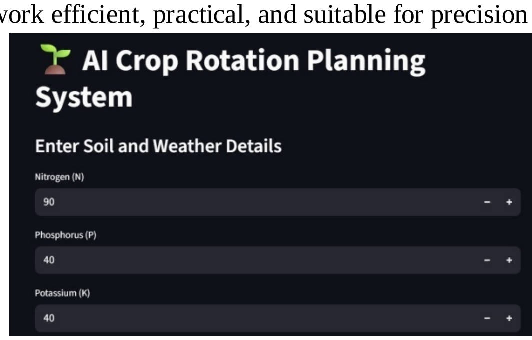

Fig.2.AICropRotationDashboard

Fig. 2 shows the developed Streamlit dashboard interface. Users can enter agricultural parameters and generate crop rotation plans dynamically.
The dashboard also displays graphical visualization of soil nutrient changes across farming seasons.

VII. VISUALIZATION

The system provides graphical representation of nutrient changes using Matplotlib visualization libraries.
The graphical dashboard helps users understand nutrient depletion trends across different farming seasons.

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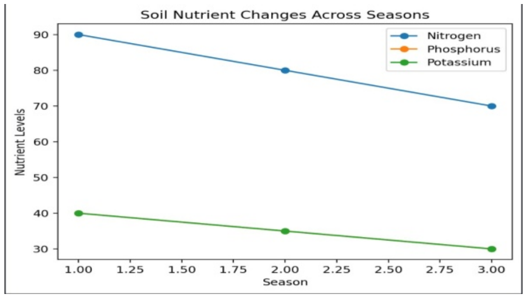

Fig.3.SoilNutrientChangesAcrossSeasons

Fig. 3 illustrates changes in Nitrogen, Phosphorus, and Potassium values across multiple crop seasons.
The visualization assists farmers in understanding nutrient management and selecting suitable crops accordingly.

VIII. EXPERIMENTAL RESULTS

The proposed system successfully generated crop rotation recommendations based on varying soil nutrient values and weather conditions.
Experimental testing demonstrated that the system adapts crop recommendations dynamically according to agricultural parameters.
SampleOutput:

- Season1:Wheat
- Season2:Rice
- Season3:Beans

The Random Forest Classifier achieved reliable prediction performance and generated stable recommendations for mul-tiple farming conditions.
The developed dashboard successfully visualized nutrient reduction trends across farming seasons.

IX. APPLICATIONS AND USE CASES

Theproposedsystemhasapplicationsin:

- PrecisionAgriculture
- SmartFarming
- AgriculturalAdvisorySystems
- SustainableFarmingPractices
- IoT-integratedAgriculturalMonitoring
- EducationalAgriculturalResearch
- GovernmentAgriculturalPrograms
- IntelligentNutrientManagement

The framework can assist farmers, researchers, and gov-ernment agencies in improving agricultural productivity and sustainability.

Precision Agriculture

The proposed system supports precision agriculture by analyzing soil nutrients and environmental conditions to generate accurate crop rotation recommendations. Precision agriculture focuses on optimizing farming resources and improving productivity using data-driven techniques. The system helps farmers make informed agricultural decisions based on real-time soil and environmental conditions.

Smart Farming

The framework can be integrated into smart farming environments where agricultural decisions are supported using Artificial Intelligence and Machine Learning technologies. Smart farming systems improve efficiency, reduce manual effort, and support automated agricultural management.
Theproposed system assists in selecting suitable crops for differentfarming seasons and improving long-term soil health.

The Streamlit dashboard improved user interaction by pro-viding graphical visualization of nutrient changes and real-time recommendation generation.

The developed framework supports precision agriculture, sustainable farming practices, and intelligent agricultural decision-making.

The proposed system demonstrates the growing importance ofArtificialIntelligenceinmodernagricultureanditspotential to improve productivity and environmental sustainability.

X. ADVANTAGES

Theproposedsystemoffersseveraladvantages:

1) Intelligentcroprecommendation
2) Reducedsoildegradation
3) Improvedagriculturalproductivity
4) Betternutrientmanagement
5) Automatedrecommendationsystem
6) User-friendlydashboardinterface
7) Graphicalvisualizationsupport
8) Sustainablefarmingassistance
9) Reduceddependencyonfertilizers
10) Improvedfarmingefficiency

XI. FUTURE ENHANCEMENTS

Futureimprovementscaninclude:

1) IntegrationwithIoTsensors
2) Real-timeweatherAPIsupport
3) Deeplearning-basedpredictionsystems
4) Mobileapplicationdeployment
5) Cloud-basedagriculturalmonitoring
6) Multi-languagedashboardsupport
7) GPS-enabledsmartfarmingsystems
8) AIchatbotassistanceforfarmers

Theseenhancementscanfurtherimprovesystemscalability, prediction accuracy, and user interaction.

XII. CONCLUSION

ThisresearchpresentedanAI-drivencroprotationplanning system using Machine Learning techniques.

The proposed system successfully predicted suitable crop rotationsequencesbasedonsoilnutrients,weatherconditions, and crop history.

The Random Forest Classifier provided reliable prediction performance and adaptive crop recommendations.

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