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Interpretable Machine Learning For Predicting Climate Change Effect On Agricultural Land Suitability In Eurasia

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ABSTRACT

Climate change is rapidly transforming temperature and precipitation patterns, posing serious challenges to agricultural sustainability across Eurasia. Accurately predicting changes in agricultural land suitability is essential for effective long-term planning. Conventional statistical models often fail to provide both high accuracy and interpretability. This project presents an interpretable machine learning approach to assess climate change impacts on agricultural land suitability. Multiple climate indicators, soil properties, and land-use parameters are used as input features. Machine learning models such as Random Forest and Gradient Boosting are developed for prediction. Model performance is evaluated using standard accuracy and error metrics. To enhance transparency, interpretability techniques such as SHAP are applied. These methods reveal the relative importance of climatic and environmental factors. Spatial analysis is conducted to identify regional variations in suitability changes. The model highlights vulnerable and resilient agricultural zones across Eurasia. The findings support explainable, data-driven agricu

Keywords: Climate Change, Agricultural Land Suitability, Interpretable Machine Learning, Explainable AI, SHAP, Random Forest, Gradient Boosting, Eurasia, Spatial Analysisltural policy and climate adaptation strategies.

I. INTRODUCTION

Agriculture plays a vital role in ensuring food security and economic stability across the Eurasian region. Climate change has introduced significant variations in temperature, rainfall, and extreme weather events affecting agricultural productivity. These climatic shifts directly influence soil moisture, crop growth cycles, and land suitability. Accurate assessment of land suitability is essential for sustainable agricultural planning. Traditional assessment methods rely on static thresholds and expert judgment, which limits scalability and adaptability. Recent advancements in machine learning offer powerful tools for analyzing complex environmental data. However, many machine learning models operate as black boxes, reducing trust in their predictions. Interpretable machine learning addresses this limitation by providing transparent and explainable results. This project applies interpretable models to predict agricultural land suitability under changing climate conditions. The study integrates climate, soil, and land-use datasets across Eurasia. Feature importance and explanation methods are used to understand driving factors. The proposed approach supports informed decision-making for climate-resilient agriculture.

II. LITERATURE SURVEY

Climate Change Impact on Agricultural Land Suitability
Author: Ramankutty et al.
Abstract:
This study analyzes the effects of climate change on global agricultural land suitability. The authors highlight how temperature and precipitation variations alter crop-growing regions. The work emphasizes the need for predictive models to support future agricultural planning.

2. Machine Learning Approaches for Crop and Land Suitability Prediction
Author: Jeong et al.
Abstract:
This paper explores the use of machine learning techniques such as Random Forest and Support Vector Machines for agricultural suitability analysis. The results show improved prediction accuracy compared to traditional statistical methods. The study demonstrates the potential of ML in handling complex environmental data.

3. Climate Data–Driven Agricultural Assessment Using Remote Sensing
Author: Lobell and Burke
Abstract:
The authors investigate the integration of satellite-based climate data with agricultural models. The study shows that remote sensing improves spatial accuracy in land suitability assessment. It highlights the importance of large-scale climate datasets for regional analysis.

4. Interpretable Machine Learning Models in Environmental Studies
Author: Lundberg et al.
Abstract:
This work introduces SHAP as an interpretability technique for machine learning models. The authors demonstrate how feature contribution analysis improves transparency in environmental predictions. The approach enhances trust and explainability in climate-related decision systems.

5. Predicting Climate Change Effects on Agriculture Using Explainable AI
Author: Zhao et al.
Abstract:
This study applies explainable artificial intelligence methods to analyze climate impacts on agriculture. The results identify key climatic drivers affecting land productivity. The authors emphasize the role of interpretable models in policy-making and sustainable land management.

III. EXISTING SYSTEM

The existing systems for assessing agricultural land suitability primarily rely on traditional statistical methods and rule-based models. These approaches use fixed thresholds for climatic parameters such as temperature, rainfall, and soil characteristics. Most conventional models depend heavily on historical climate data and expert-defined rules. While these methods are simple to implement, they lack adaptability to rapidly changing climate conditions. Many existing systems are region-specific and do not scale well across large and diverse areas like Eurasia. Additionally, they struggle to capture complex, non-linear relationships among climate variables. Some recent approaches apply machine learning models but focus mainly on prediction accuracy. However, these models often function as black boxes, offering little insight into decision-making processes. The lack of interpretability reduces trust among policymakers and agricultural planners. Overall, existing systems provide limited transparency, scalability, and effectiveness in long-term climate impact assessment.

IV. PROPOSED SYSTEM

The proposed system introduces an interpretable machine learning framework to predict the effects of climate change on agricultural land suitability across Eurasia. It integrates multi-source data including climate variables, soil characteristics, and land-use information. Advanced machine learning models such as Random Forest and Gradient Boosting are used to capture complex, non-linear relationships among environmental factors. Unlike traditional black-box approaches, the system incorporates interpretability techniques such as SHAP to explain model predictions. This enables clear identification of key climatic and environmental drivers affecting land suitability. Spatial analysis is applied to visualize regional variations and vulnerability patterns. The system supports both classification and regression-based suitability assessment. Model performance is evaluated using accuracy and error metrics to ensure reliability. The explainable outputs improve transparency and user trust. Overall, the proposed system provides a scalable, accurate, and interpretable solution for climate-resilient agricultural planning.

V. SYSTEM ARCHITECTURE

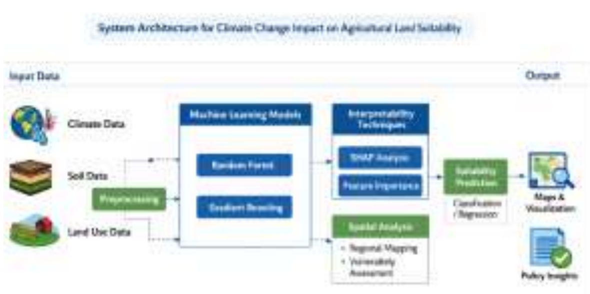

Fig 5.1: System Architecture

The diagram illustrates a dual-layer secure data communication process that combines cryptography and steganography. Initially, the original message is passed through an encryption process using a symmetric key (specifically AES-128), converting the readable message into an encrypted form that ensures confidentiality. This encrypted message is then embedded into a cover media (such as an image) using the LSB (Least Significant Bit) steganography technique, producing a stego media that conceals the very existence of the secret data. During reception, the reverse process is applied: the encrypted message is first extracted from the stego media, and then a decryption process using the same symmetric key is performed to recover the original message. This workflow ensures both data secrecy and invisibility, providing strong protection against unauthorized access and interception.

VI. IMPLEMENTATION

Fig 6.1: Home page

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Fig 6.2: Register page

Fig 6.3 login page

VII. CONCLUSION

This project successfully demonstrates the use of interpretable machine learning techniques to predict the impact of climate change on agricultural land suitability across Eurasia. By integrating climate, soil, and land-use data, the proposed system effectively captures complex relationships influencing agricultural productivity. The use of machine learning models such as Random Forest and Gradient Boosting improves prediction accuracy compared to traditional methods. Interpretability techniques like SHAP provide transparent explanations for model predictions, increasing trust and usability. Spatial analysis helps identify vulnerable and resilient regions under changing climate conditions. The system supports informed decision-making for sustainable agricultural planning and policy formulation. Overall, the proposed approach offers a scalable, accurate, and explainable solution for climate-resilient agriculture.

VIII. FUTURE SCOPE

The proposed system offers several features to effectively predict and analyze the impact of climate change on agricultural land suitability. It supports integration of multi-source datasets including climate, soil, and land-use data. The system performs data preprocessing such as cleaning, normalization, and feature selection to improve model accuracy. Machine learning-based prediction enables both classification and regression of land suitability levels. Interpretable AI techniques provide clear explanations of model outputs through feature importance analysis. Spatial mapping allows visualization of suitability changes across different regions of Eurasia. The system identifies key climatic factors influencing agricultural productivity. Performance evaluation ensures reliability using standard metrics. The framework is scalable and adaptable to different regions and future climate scenarios. Overall, the feature scope supports transparent, accurate, and data-driven agricultural decision-making.

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