AI-Driven Climate Downscaling and Crop Resilience Mapping Using Parallel Data Processing

CDAC ACTS, Pune – ACC-HPC Project Group 07

Project Team

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Project Overview: Revolutionizing Agricultural Preparedness

This project introduces a groundbreaking framework leveraging artificial intelligence and High-Performance Computing (HPC) to generate precise local climate data and assess crop resilience. Our goal is to empower climate-smart agriculture in the face of escalating climate variability.

Understanding the Challenge

Climate Variability

Climate change profoundly impacts agriculture through unpredictable rainfall patterns and extreme temperature fluctuations.

Coarse Resolution Data

Existing global climate datasets often lack the fine-grained detail needed for effective local agricultural planning.

AI for Precision

AI-based downscaling techniques are critical for transforming coarse-resolution data into actionable, fine-resolution local climate information.

Resilience Mapping

Developing crop resilience maps provides vital insights for fostering climate-smart agricultural practices and ensuring food security.

Key Project Objectives

AI-Based Climate Downscaling

Develop and implement AI models for high-resolution climate data generation.

Crop Yield Prediction

Forecast crop yields accurately using downscaled climate variables.

Resilience Index Computation

Quantify crop resilience to climate stressors.

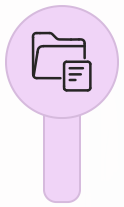
Visualization and Mapping

Create intuitive maps for actionable agricultural insights.

Methodology & Workflow

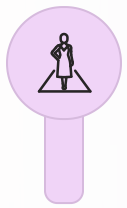
Data Collection

Gathering comprehensive climate and crop datasets.



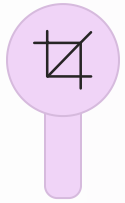
Data Preprocessing

Cleaning, transforming, and preparing data for model input.



Climate Downscaling using ML

Applying Machine Learning algorithms to generate fine-resolution climate data.

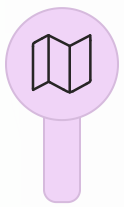


Crop Yield Prediction

Utilizing climate variables to forecast potential crop yields.

Resilience Index Calculation

Determining the resilience of various crops to environmental changes.



Visualization

Presenting insights through interactive maps and dashboards.

Our Data Sources

Climate Dataset

Source: NASA POWER (Prediction Of Worldwide Energy Resources)

- Variables: Rainfall, Average/Maximum/Minimum Temperature
- Provides global, long-term climate data for research and application.

Crop Dataset

Source: Government agricultural agencies / FAOSTAT (Food and Agriculture Organization Statistical Database)

- Variables: Crop Yield, Cultivated Area, District-level information
- Essential for understanding agricultural productivity and spatial distribution.

AI Models for Precision Downscaling

Our project employs advanced Machine Learning models to overcome the limitations of traditional methods, which often rely on linear assumptions. These models are adept at capturing the complex, non-linear relationships inherent in climate data.

Random Forest

An ensemble learning method operating by constructing a multitude of decision trees. Highly effective for regression tasks like climate downscaling.

XGBoost

An optimized distributed gradient boosting library designed for speed and performance. It has proven superior in various predictive modeling challenges.

Input: Coarse-resolution climate variables

Output: Fine-resolution local climate data

Metrics: Root Mean Square Error (RMSE), R^2 Score for model evaluation.

Quantifying Crop Resilience

To evaluate how well crops withstand climate variability, we calculate a Crop Resilience Index. This metric provides a crucial indicator for identifying areas and crops most susceptible or adaptable to changing environmental conditions.

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Resilience Index Formula

Resilience Index = Actual Yield / Predicted Yield

Highly Resilient

Index ≥ 0.75

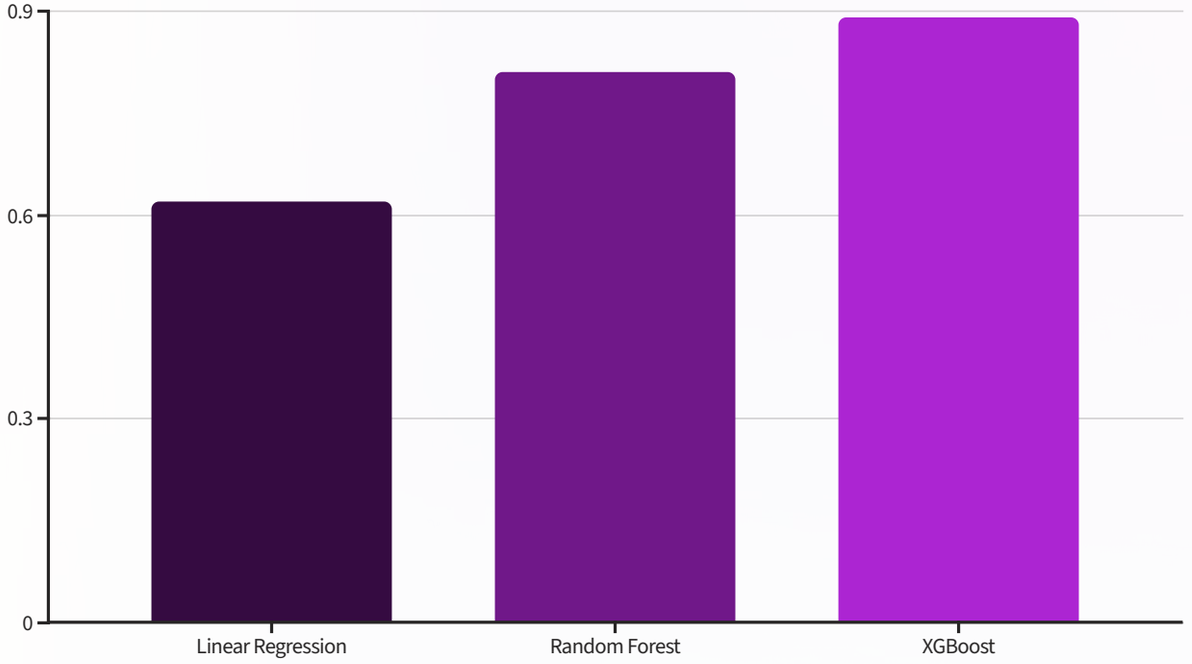
Crops in this category demonstrate strong adaptability and stable yields.

Moderately Resilient Index 0.50 – 0.75 These crops show some vulnerability but can recover with targeted interventions.

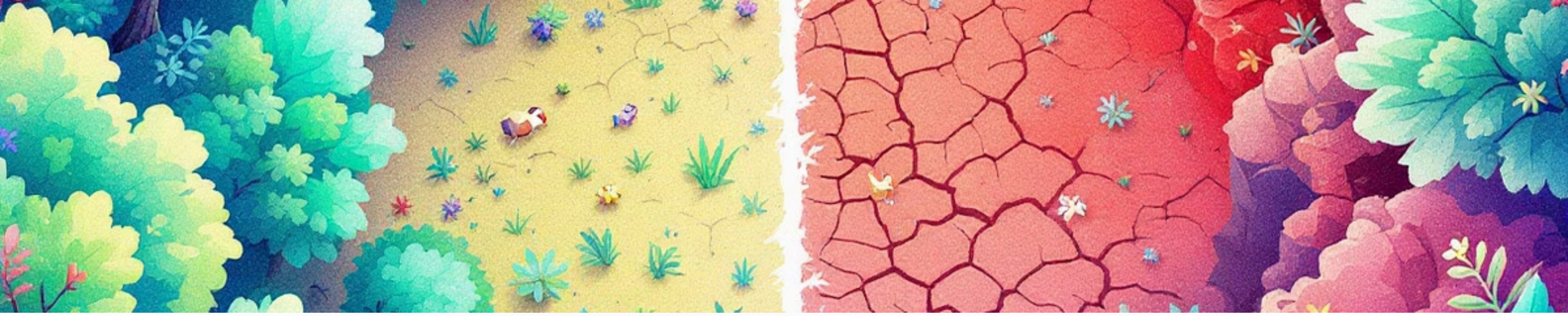
Vulnerable Index < 0.50 These crops are highly susceptible to climate shocks, requiring urgent attention and adaptation strategies.

Model Performance: Outperforming Traditional Methods

Our evaluation metrics clearly demonstrate the superior predictive power of AI-driven models compared to conventional approaches, particularly in capturing complex climate-yield relationships.



The R^2 score, representing the proportion of variance in the dependent variable predictable from the independent variables, shows a significant improvement with ensemble methods. XGBoost achieved the highest R^2 score of 0.89, indicating its strong capability in predicting crop yields based on climate data.



Project Analysis: Advantages and Disadvantages

Advantages

- **Enhanced Climate Precision:** Provides highly localized and accurate climate data, crucial for micro-level agricultural planning.
- **Proactive Risk Management:** Enables farmers to anticipate and prepare for climate-related risks like droughts or excessive rainfall.
- **Optimized Resource Allocation:** Facilitates more efficient use of water, fertilizers, and other resources based on precise forecasts.
- **Improved Crop Yield & Food Security:** Leads to better yield predictions and contributes to overall food security and resilience.
- **Data-Driven Decision Making:** Empowers stakeholders with actionable insights for climate-smart agricultural practices.

Disadvantages

- **High Computational Demand:** Requires significant High-Performance Computing (HPC) resources for data processing and model training.
- **Data Dependency:** Relies heavily on the availability of large volumes of high-quality climate and crop data.
- **Model Complexity:** Development and maintenance of advanced AI models can be complex and require specialized expertise.
- **Initial Investment Costs:** Significant upfront investment in technology infrastructure and skilled personnel is necessary.
- **Potential for Bias:** AI models can inherit biases from training data, potentially leading to inaccuracies if not carefully managed.

Real-Life Applications & Impact

Farmer Advisory Systems

Provide localized, precise climate forecasts and resilience insights directly to farmers.

Climate-Resilient Crop Planning

Guide selection of crop varieties and planting schedules optimized for future climate conditions.

Drought & Flood Risk Assessment

Identify high-risk areas, enabling proactive measures and early warning systems.

Policy Decision Support

Inform agricultural policies and resource allocation for sustainable development.

This project is not just theoretical; its outputs have tangible benefits for stakeholders across the agricultural ecosystem, from individual farmers to national policymakers.

Key Takeaways & Future Vision

AI-Driven Precision

Our advanced AI models deliver unprecedented accuracy in climate downscaling and crop resilience mapping, surpassing traditional methods.

Enhanced Resilience

This project directly contributes to global food security by enabling proactive risk management and climate-smart agricultural practices.

Actionable Insights

Providing farmers and policymakers with vital, localized data for informed decision-making and optimized resource allocation.

We are not just predicting the future; we are enabling a more resilient and sustainable agricultural landscape for generations to come. This project lays the foundation for continuous innovation in climate adaptation.

Questions & Discussion

Thank you for your attention. We are now open for any questions you may have regarding our AI-driven climate downscaling and crop resilience mapping project.

Thank You!

We appreciate your time and interest in our AI-driven climate downscaling and crop resilience mapping project. Together, we can build a more resilient and sustainable future for agriculture.