Solution:

Crop-water-climate modelling for resource quantification and its optimization

Submitter: (ICRISAT)

Solution Overview

Crop-water-climate modeling forms a central component of ICRISAT's approach to resource quantification and optimization. Using tools such as SWAT, HYDRUS, WIC, APSIM, DSSAT, etc, the institute evaluates scenarios for water use, climate adaptation, and crop productivity across different management options. These models enable the development of customized recommendations for maximizing yields while ensuring sustainable resource use, especially under climate variability and water stress conditions. By leveraging real-time weather data, soil moisture conditions, crop types, and phenological stages, modelling framework enables precision agriculture and evidence-based policymaking. It also incorporates future climate scenarios using projections from the Coupled Model Intercomparison Projects (CMIP5 and CMIP6) to estimate shifts in agricultural water demands. This integrated modelling framework equips stakeholders farmers, irrigation planners, and policymakers with actionable insights to optimize yields, conserve water, and enhance climate resilience.

Key Features & Benefits:

- Integrated Modelling Approach: Combines hydrological, crop-growth, and climate models for holistic analysis.
- Implementation of AI/ML: To reduce the uncertainties associated with the climate projections
- Integration of Remote Sensing: Enhance the spatial-scale analysis
- Data-Driven Decision Support: Provides insights using AI/ML techniques for resource optimization.

Where It Works and Where It Can Work

- Water-stressed Regions: Ideal for semi-arid and arid zones needing efficient irrigation strategies
- Agro-climatic Research Institutes: Used in academic and policy-making institutions for scenario analysis and climate adaptation planning
- Rainfed Agriculture Areas: Can be adapted to support decision-making based on seasonal climate forecasts.

Evidence & Impact

The research demonstrates the robustness and applicability of crop-water-climate modelling frameworks in enhancing water resource management and agricultural planning under climate uncertainty;

- Dey et al. (2022, International Journal of Climatology) introduced a multimodel ensemble machine learning approach leveraging CMIP6 projections in the Damodar River Basin, India. The study showed improved reliability in downscaling climate variables, which are crucial inputs for long-term water resource and crop planning. This method significantly reduced the uncertainty of climate model outputs, offering a more confident basis for water demand forecasting.
- Complementing this, Dey and Remesan (2022, Journal of Hydrology) presented a detailed quantification of green and blue water components using multiple model structures. Their findings highlight how parameter uncertainty and input data choice affect the accuracy of hydrological assessments critical for crop-water optimization.
- Sahoo et al. (2024, Remote Sensing Applications: Society and Environment) developed a multi-mission virtual monitoring station framework for streamflow estimation, providing high-resolution hydrodynamic data. This innovation supports the calibration and validation of crop-water-climate models in data-sparse regions, enhancing the reliability of simulation outcomes.
- Additionally, Panda et al. (2022, Journal of Hydrology) proposed the RGL-MARS

downscaling algorithm for improved seasonal rainfall prediction. By accurately capturing both dry and wet season dynamics, the method enhances the temporal precision of water availability assessments, directly impacting irrigation scheduling and water-use planning.

Collectively, these studies validate the effectiveness of advanced modelling techniques in quantifying water resources, reducing uncertainty, and strengthening agricultural resilience. They also provide a foundation for scaling up these approaches to other river basins and agro-ecological zones, with demonstrated utility in both research and operational contexts.

Scalability & Adoption Support

The crop-water-climate modelling system is highly scalable due to its modular architecture and cloud-based platforms. It can be deployed from local farm-level applications to regional and national-scale planning. Scalability is further supported by advances in remote sensing, AI, and cloud computing, allowing the model to handle diverse datasets and large geographical areas.

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