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"Towards multi-functional agro-ecosystems
promoting climate resilient futures"

AI-based quantification of availability and sustainability of renewable energy and groundwater for irrigation across India (AQUASURGE)

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Abstract

Ensuring drought resilience and sustainable agricultural production is one of the most pressing challenges in India. Groundwater underpins irrigation across the country, yet its long-term availability under climate change remains uncertain, while the growing expansion of renewable energy and green hydrogen production is creating new demands on water and energy systems. In response, our Indo-German consortium is developing an interactive online map service that provides high-resolution information on groundwater sustainable yield for agriculture and the renewable energy required for pumping. The platform will offer seamless, spatially explicit insights into current conditions and future projections, supporting farmers, planners, policymakers, and investors in making informed decisions. At the scientific core of the project is a novel physically-informed AI framework that combines process-based land surface water and energy balance equations with advanced machine learning techniques. By integrating *in situ* groundwater measurements, hydrogeological data, remote sensing products, and climate projections, the system generates spatially continuous maps while maintaining physical consistency, such as mass balance and ecological flow requirements. The AI foundation model incorporates both spatial and temporal neural network architectures and explicitly accounts for human water use and future demand trends. Using transfer learning, it will simulate groundwater sustainable yield under different climate scenarios, enabling on-demand assessments for selected years between 2030 and 2100 and ensuring robust long-term planning for sustainable irrigation. Beyond agriculture, the project lays the groundwork for evaluating groundwater and renewable energy resources for green hydrogen production, an area where no comparable integrated planning tool currently exists for India. Renewable energy assessments, including wind and solar resource analysis and cost estimates, are coupled with groundwater availability and carbon accounting to explore long-term climate-resilient investment pathways. Field-based hotspot investigations using advanced geophysical and geochemical surveys will validate the AI results and strengthen scientific credibility. Within three years, the consortium will deliver a fully operational, open-access web platform that advances transparent science, fosters Indo- German collaboration, and provides, for the first time,

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an integrated perspective on the water– energy–climate nexus for sustainable agriculture and future green energy development.