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"Reconcile land system changes
with planetary health"

Integrated use of radiation-based methods and deep learning techniques for estimating sorghum crop yield

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Abstract

Accurate and spatially explicit crop yield estimation is vital for enhancing food security and guiding sustainable agricultural practices. This study introduces an integrated methodology that combines a radiation-based semi-physical model with deep learning techniques to estimate crop yields at the pixel level.

The radiation-based semi-physical model simulates biomass accumulation by quantifying the interception and utilisation of solar radiation within the crop canopy. It incorporates environmental variables such as solar radiation, temperature, plant water content, alongside crop-specific parameters like leaf area index, harvest index and light use efficiency. This model provides a mechanistic understanding of how radiation influences photosynthesis and, subsequently, yield formation throughout the crop growth cycle. Semi-physical crop yield models offer useful insights but face several limitations, such as requiring intensive calibration, being susceptible to errors from spatial and temporal variability, and struggling to scale local predictions to larger regions.

Complementing this, stage-wise vegetation indices derived from remote sensing data capture the spectral and biophysical properties of the crop at various growth stages. EVI, SAVI, LAI and NDWI are calculated from satellite imagery, enabling the monitoring of crop health, biomass accumulation, and canopy structure over time.

These vegetation indices serve as inputs to a deep learning model, which are trained to learn the complex relationships between spectral data and crop yield. The deep learning approach enhances predictive performance and generalisation by combining multiple neural networks, each capturing different aspects of the data. During training, the models adjust their parameters to minimise the difference between predicted and actual yields, as estimated by the semi-physical model. Once trained, the model can predict pixel-level yields facilitating high-resolution yield mapping with a coefficient of correlation 0.98 and mean absolute percentage error of 12 %.

Keywords: Crop yield estimation, deep learning, precision agriculture, radiation-based model, remote sensing, vegetation indices

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