The crucial role of realistic 3D canopy models in light interception analysis for crop resilience and sustainability

December 29 2023

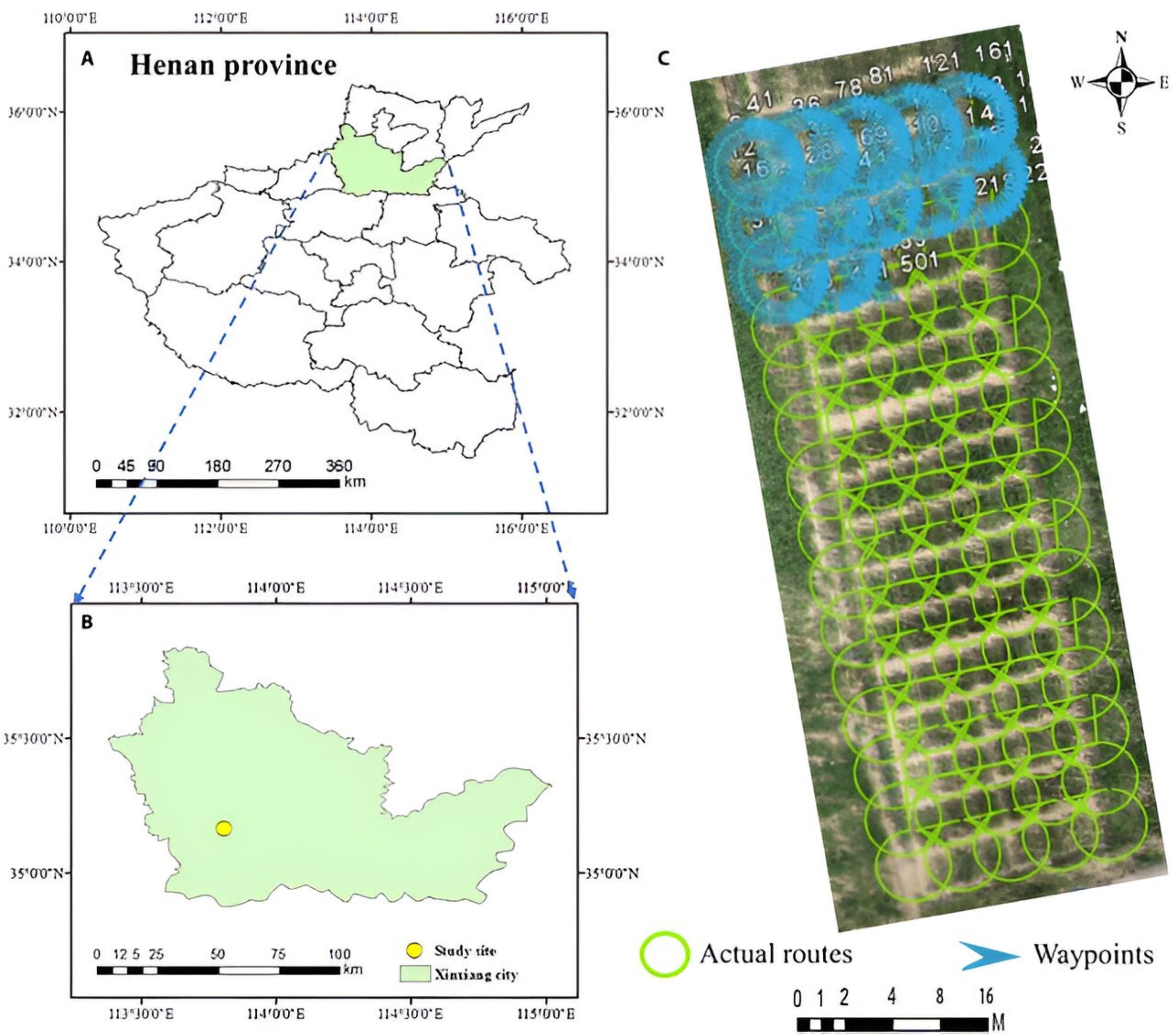

Fig. 1. (A) Location of the city where the study area is located within the

province; (B) location of the study site in the city; (C) the orthomosaic image acquired on 2022 August 12 and actual CCO flight paths for 90 plots. Credit: TranSpread

Grasping the complex interplay between light and plant canopies is crucial for unlocking the secrets to enhanced crop yields and resilience.

Researchers have traditionally used photosynthetically active radiation sensors and leaf area index calculations to measure light interception, but these methods struggle with the complex spatial arrangement of canopies. Recent advancements employ 3D models and optical simulations to conduct detailed analyses, yet obtaining realistic 3D canopy models (RCMs) in the field remains challenging due to technological limitations.

The current focus is on improving these 3D reconstructions to precisely quantify light distribution and enhance our understanding of plant growth, with methods like Structure from Motion (SfM) offering promising avenues for more accurate field data acquisition.

In August 2023, *Plant Phenomics* published a research article titled "The Importance of Using Realistic 3D Canopy Models to Calculate Light Interception in the Field ."

This study focuses on a comparative analysis of light interception between realistic 3D maize canopy models (RCM) and virtual canopy models (VCMs), aiming to enhance the precision of light interception calculations substantially. Detailed reconstruction of a large-area RCM was realized by employing an advanced unmanned aerial vehicle (UAV) with a cross-circling oblique (CCO) route alongside a structure-from-motion multi-view stereo method.

Three types of VCMs (VCM-1, VCM-4, and VCM-8) were then created by replicating 1, 4, and 8 individual realistic plants in the center of the RCM. The results indicated significant deviations in daily light interception per unit area (DLI) between the VCMs and RCM, with relative root mean square error (rRMSE) values of 20.22%, 17.38%, and 15.48% for VCM-1, VCM-4, and VCM-8 respectively.

The deviation decreased as the number of plants used to replicate the virtual canopy increased, but even with eight plants, a significant discrepancy remained. The reconstructed 3D models provided detailed visualizations of the plant structure, showing high accuracy in estimating leaf dimensions, corroborated by R^2 and RMSE values.

Comparing light interception at 48 and 70 days after sowing (DAS) revealed that the differences between RCMs and VCMs were smaller in the early stage than in the late stage, indicating a more pronounced variation in canopy structure and light interception as the plants matured. Hourly light capture comparisons also demonstrated a consistent trend, with the RCM capturing the intricate dynamics of light distribution more accurately than the VCMs, especially at later stages.

Furthermore, the study explored the structural differences between RCM and VCMs, finding that as canopy density increased, the 1D phenotypic differences (like plant height and canopy cover) between the models diminished, while the 2D and 3D phenotypic differences (like plant area index and COV) increased.

This signifies that the structural complexity of the canopy is better captured by RCM, particularly for denser canopies. The research confirmed that RCMs provide a more accurate representation of light interception in the field, particularly at later growth stages, and emphasized the importance of capturing realistic 3D canopy structures for precise light distribution analysis.

Despite these advancements, the challenge of extracting precise leaf angle information persists, underscoring an urgent need for continued research and innovative methodologies to segment individual plants accurately and leaves from 3D point clouds.

In conclusion, the study not only validates the superiority of RCMs over VCMs in analyzing light interception but also paves the way for groundbreaking advancements in agricultural research through accurate 3D reconstructions.

More information: Shunfu Xiao et al, The Importance of Using Realistic 3D Canopy Models to Calculate Light Interception in the Field, *Plant Phenomics* (2023). DOI: 10.34133/plantphenomics.0082

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Citation: The crucial role of realistic 3D canopy models in light interception analysis for crop resilience and sustainability (2023, December 29) retrieved 28 April 2024 from https://phys.org/news/2023-12-crucial-role-realistic-3d-canopy.html