Enhancing rice biomass estimation with UAV-based models

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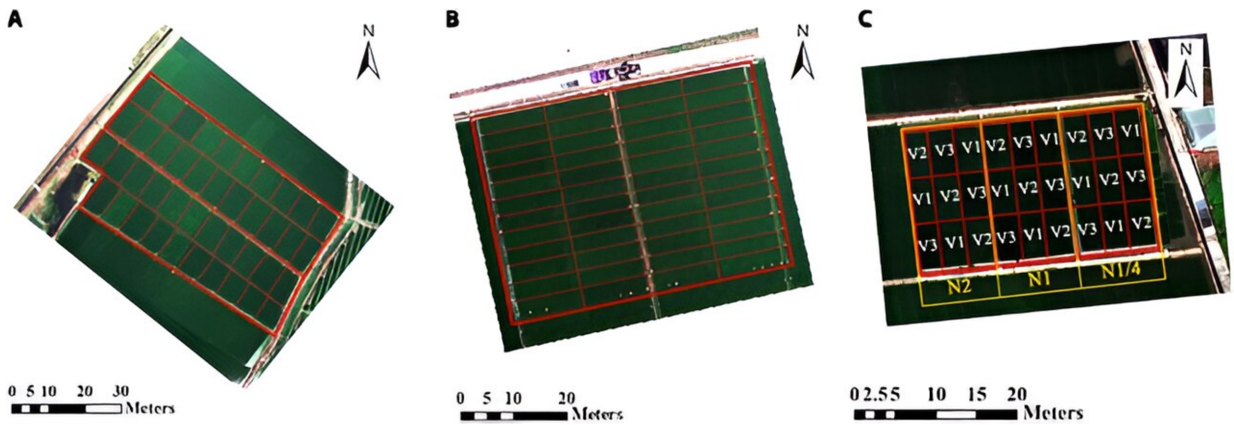

Study area. (A) Experiment 1 was conducted in Lingshui, Hainan. (B) Experiment 2 was conducted in Ezhou, Hubei. (C) Experiment 3 was conducted in Huashan, Hubei. In experiment 3, V1 stands for Fengliangyou 4, V2 for Luoyou 9348, and V3 for Changjingyou 582. Three levels of nitrogen fertilizer were set up at N1/4 (36 kg/ha), N1 (144 kg/ha), and N2 (288 kg/ha). Credit: *Plant Phenomics* (2023). DOI: 10.34133/plantphenomics.0056

Aboveground biomass (AGB) of rice, vital for carbon pool and yield estimation, is traditionally measured through labor-intensive manual sampling. Recent advancements employ remote sensing, particularly unmanned aerial vehicles (UAVs), to derive vegetation indices (VIs) from plant interactions with the electromagnetic spectrum.

However, these methods face challenges: the non-linear VI-biomass relationship leads to saturation at high biomass levels, and sensitivity loss during later growth stages. Additionally, varying effectiveness across rice cultivars and computational demands of advanced machine learning models add complexity.

In May 2023, *Plant Phenomics* published [a research article]() titled "Estimation of Rice Aboveground Biomass by UAV Imagery with Photosynthetic Accumulation Models," proposing a new model integrating VI and canopy height data from UAVs for more accurate and general biomass estimation throughout the rice growth season, addressing existing gaps in AGB monitoring.

In this study, initial findings revealed weak correlations between VI and AGB for the entire growing season, and limited accuracy in height models. However, the Photosynthetic Accumulation Model (PAM), combining NDVI and canopy height, significantly improved AGB estimation (R^2 = 0.95, RMSE = 136.81 g/m^2). Additionally, a Simplified Photosynthetic Accumulation Model (SPAM) was developed, requiring fewer observations while maintaining an R^2 above 0.8.

Verification of these methods showed consistent accuracy in canopy height estimation across three years using consistent equipment and flight parameters. Remote sensing proved effective in capturing canopy height, correlating well with actual plant heights (R^2 = 0.88, RMSE = 0.05 m). LAI estimation was examined using nine VIs, revealing variability in R^2 and RMSE across years and indices.

The H × VI model outperformed individual VI models, reducing saturation and hysteresis effects. In biomass estimation, PAM utilized two different VIs, showing that any two from a set of six (NDVI, EVI2, WDRVI, NDRE, OSAVI, and GNDVI) yielded stable results over two years. The correlation between PAM and AGB was significantly positive, with R^2 exceeding 0.8 in a two-year experiment.

SPAM's effectiveness was slightly lower than PAM but still outperformed traditional VI and height models. It demonstrated an improvement in estimation accuracy and a decrease in required observation frequency. Model transferability was tested with data collected at a different location in 2022, confirming PAM and SPAM's robustness and generalization ability. These models maintained better linear relationships with AGB across various rice cultivars throughout the growing season.

In conclusion, the study presents a reliable and efficient method for UAV-based estimation of rice AGB over the entire growing season. It offers a quantitative tool for evaluating rice growth and holds potential for large-scale field management and breeding. Future research aims to enhance model generality through multi-year experiments and broader rice cultivar sampling.

More information: Kaili Yang et al, Estimation of Rice Aboveground Biomass by UAV Imagery with Photosynthetic Accumulation Models, *Plant Phenomics* (2023). DOI: 10.34133/plantphenomics.0056

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