Deep Convolutional Neural Networks Exploit High-Spatial- and -Temporal-Resolution Aerial Imagery to Phenotype Key Traits in Miscanthus

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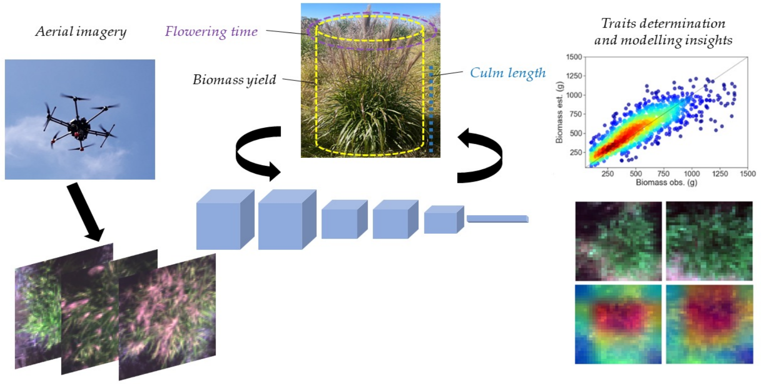
Background/Objective

Miscanthus, with its high yield potential, is one of the most promising perennial crops for bioenergy production. The increasing interest in this crop requires accelerated selection and the development of new screening techniques. The aim of the study was to evaluate how spectral and geometric features in aerial imagery collected throughout the growing season could be exploited in analyses by convolutional neural networks (CNNs) for phenotyping time-series-based plant-level predictions of three relevant Miscanthus productivity traits: flowering time, culm length, and biomass yield.

Approach

We used persistent multispectral and photogrammetric UAV time-series imagery collected 10 times over the season, together with ground truth data for thousands of Miscanthus genotypes. We then compared the performance of CNN architectures that used image data from single dates (2D-spatial) versus the integration of multiple dates by 3D-spatiotemporal architectures.



Aerial data collection and pre-processing (left), CNNs modeling's implementation (center) and outputs (right), including plant-level predictions (above) and activation maps (bottom).

Results

3D-CNNs, which analyzed the time-courses of remote sensing imagery outperformed 2D-CNNs, which analyzed imagery from single dates. Combining more spectral features along with geometric features in the imagery led to better trait predictions.

Significance/Impacts

Our analysis demonstrates that Miscanthus can be effectively characterized using high-spatial- and -temporal-resolution aerial imagery integrated with CNNs. To our knowledge, this is the first effort to characterize individual plant traits in large, genetically diverse populations of Miscanthus in large-scale field trials using remote sensing. This lays the foundation for accelerating the breeding of highly productive, sustainable and resilient perennial grasses.

Varela, S., Zheng, X., Njuguna, J.N., Sacks, E.J., Allen, D.P., Ruhter, J., Leakey, A.D.B. Oct. 25, 2022. "Deep Convolutional Neural Networks Exploit High-Spatial- and -Temporal-Resolution Aerial Imagery to Phenotype Key Traits in Miscanthus." *Remote Sensing* 2022, 14(21), 5333. DOI: 10.3390/rs14215333.