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

Sebastian Varela[1,2], Xuying Zheng[3], Joyce Njuguna[3], Erik Sacks[3], Dylan Allen[3], Jeremy Ruhter[3], and Andrew D B Leakey[1,2]

[1]Center for Advanced Bioenergy and Bioproducts Innovation, Department of Plant Biology, Department of Crop Sciences, University of Illinois at Urbana Champaign
[2]University of Illinois at Urbana Champaign
[3]Affiliation not available

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***Sebastian Varela*[1]**, *Xuying Zheng*[5], *Joyce Njuguna*[5], *Erik Sacks*[2,5], *Dylan Allen*[3], *Jeremy Ruhter*[2], *Andrew D.B. Leakey* [1,2,3,4,5]

1. *Center for Advanced Bioenergy and Bioproducts Innovation, Urbana, USA*
2. *Institute for Genomic Biology, University of Illinois at Urbana Champaign, Urbana, USA*
3. *Department of Plant Biology, University of Illinois at Urbana Champaign, Urbana, USA*
4. *Center for Digital Agriculture, University of Illinois at Urbana Champaign, Urbana, USA*
5. *Department of Crop Sciences, University of Illinois at Urbana Champaign, Urbana, USA*

ORCiD: [0000-0001-8064-3636]

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Miscanthus is one of the most promising perennial crops for bioenergy production, with high yield potential and low environmental footprint. The increasing interest in this crop requires accelerated selection and the development of new screening techniques. The development of analytical methods for improved estimation and reduced manual inspection are needed to better characterize the effects of genetics and the environment in key traits under field conditions. We used persistent multispectral and photogrammetric UAV time-series imagery collected 10 times in the season, together with ground-truth data over thousands miscanthus accessions to determine flowering time, culm height, and biomass yield traits. We compared the performance of Convolutional Neural Network (CNN) architectures that used image data from single dates (2D-spatial) versus the integration of multiple dates (3D-spatio-temporal) architectures to evaluate the value of persistent monitoring and the type of features to predict the traits. The ability of UAV-based remote sensing to rapidly and non-destructively assess large-scale genetic variation in flowering time, height and biomass production was improved through use of 3D-spatio-temporal CNN architectures versus 2D-spatial CNN architectures. The performance gains of the best 3D-spatio-temporal analyses compared to the best 2D-spatial architectures manifested in up to: 23 % improvements in R^2 and 20 % reduction in mean absolute error (MAE). The integration of

photogrammetric and spectral features with 3D- architecture was key to the improved assessment of all traits, which are relevant and challenging for plant-level analysis in bioenergy feedstocks such as miscanthus under field conditions.