2023 International Conference on Integrative Precision Agriculture – Local Solutions Though Global Advances

Predicting Yield-Contributing Physiological Parameters of Cotton using UAV-Based Imagery

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Abstract

Lint yield in cotton is governed by light intercepted by the canopy (IPAR), radiation use efficiency (RUE), and harvest index (HI). However, the conventional methods of measuring these yield-governing physiological parameters are labor-intensive, time-consuming and requires destructive sampling. This study aimed to explore the use of low-cost and high-resolution UAV-based RGB and multispectral imagery 1) to estimate fraction of IPAR ($IPAR_f$), RUE, and biomass throughout the season, 2) to estimate cotton lint yield using the cotton fiber index (CFI), and 3) to determine the potential use of biomass and lint yield models for cotton HI prediction. An experiment was conducted during the 2021 and 2022 growing seasons in Tifton, Georgia, USA in randomized complete block design with five different nitrogen treatments. Different nitrogen treatments were applied to generate substantial variability in canopy development and yield. UAV imagery was collected bi-weekly along with light interception and biomass measurements throughout the season, and 20 different vegetation indices (VIs) were computed from the imagery. Generalized linear regression was performed to develop models using VIs and growing degree days (GDDs) to predict $IPAR_f$, biomass, and RUE in cotton. Lint yield was predicted using CFI, and HI was derived from CFI-based lint yield and the best performing biomass models. The $IPAR_f$ models had R2 values ranging from 0.66 to 0.90, and models based on RVI, RECI, NDRE, and SCCCI explained the highest variation (93%) in $IPAR_f$ during cross-validation. Similarly, cotton above-ground biomass was best predicted by models from MSAVI, OSAVI, RVI, and SAVI. Models from VIs based on green and red-edge reflectance such as RECI, NDRE, SCCI, and NIR/G were the best performing models for RUE prediction during cross-validation. Prediction of RUE using actual biomass measurement and RVI-based $IPAR_f$ model was able to explain 84% of variation in RUE. CFI from UAV-based RGB imagery had strong relationship (R2 = 0.69) with machine harvested lint yield. The predicted HI from CFI-based lint yield and MSAVI-based biomass models was able to explain 40 to 49% of variation in measured HI for the 2022 growing season. The models developed to estimate the yield-contributing physiological parameters in cotton showed low to strong performance, with $IPAR_f$ and above-ground biomass having greater prediction accuracy. Future studies on accurate estimation of lint yield is suggested for precise cotton HI prediction. This study is the first attempt of its kind and the results can be used to expand and improve research on predicting functional yield drivers of cotton.

Keywords: Fraction of Intercepted Photosynthetically Active Radiation, Radiation Use Efficiency, Harvest Index, RGB Imagery, and Multispectral Imagery