A COMPARATIVE STUDY OF RGB AND MULTISPECTRAL SENSOR BASED COTTON CANOPY COVER MODELLING USING MULTI-TEMPORAL UAS DATA

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Abstract

Recent years have witnessed enormous growth in Unmanned Aerial System (UAS) and sensor technology, which made it possible to collect high temporal and spatial resolution data over the crops throughout the growing season. We present a comparative study of multispectral and RGB sensor based cotton canopy cover modelling using multi-temporal UAS Data. Moreover, we propose a canopy cover model using RGB sensor that combines RGB based vegetation index with morphological closing. For this experiment, the whole study area is divided into approximately one square meter size grids. Later, grid-wise percentage canopy cover is computed using both RGB and multispectral sensors over ten epochs during the growing season of the cotton crop. Initially, 'Canopeo' canopy cover classification algorithm is used to extract canopy using RGB images and an empirically determined NDVI value is used as a threshold to extract canopy from multispectral images. Both canopy cover models were validated using ground truth canopy cover. Multispectral sensor based canopy cover model turned out to be more stable and estimated canopy cover accurately. Whereas, RGB based canopy cover model was very unstable and failed to identify canopy when it started changing color. We proposed a morphological closing based approach to improve RGB based canopy cover modeling to account for change in color in the canopy later in the growing season. As multispectral sensors are more sensitive and expensive, proposed canopy cover model provides an affordable alternate to agriculture scientists and breeders.

Introduction

With the increasing population, it is important to pay attention to the agricultural research to not only provide food, but also to provide clothing and linen that comes from cotton. Comprising around 6 million acres, cotton is Texas' leading cash crop and Texas produces more than 50% of the total cotton produced by the entire country (Peabody et al., 2016). Numerous efforts are being witnessed for cotton crop growth monitoring which is very important in precision agriculture. Recent years have witnessed enormous growth in the application of Unmanned Aerial Systems (UAS) for precision agriculture (Zhang & Kovacs, 2012). UAS have the potential to provide information on agricultural crops quantitatively, instantaneously and, above all, nondestructively over large areas. The objective of this project is to compare multi-source canopy cover estimates and to improve RGB-based canopy cover estimation to provide an affordable alternate.

Materials and Methods

Field Location and Experimental Setup

A field experiment was established at the Texas A&M AgriLife Research and Extension Center in Corpus Christi, TX. The trial consisted of 5 cotton genotypes from the Texas A&M AgriLife Cotton Breeding Program. Genotypes were planted March 22nd, 2017, in skip and solid row patterns (i.e. one- or two-row plots, respectively), each replicated four times. For canopy cover estimation, another field experiment was established at the same location in 2018. The trial consisted of 10 cotton genotypes from the Texas A&M AgriLife Cotton Breeding Program. Genotypes were planted in the first week of April, in skip and solid row patterns.

Canopy Cover estimation

A classification algorithm to delineate crop canopy from other non-canopy objects (background) was used to calculate canopy cover from the ortho-mosaic images. The same grid structure designed for the crop growth pattern analysis was used to calculate canopy cover from the binary classification maps. And percentage canopy cover per grid is calculates as per Equation 1, where canopy condition was extracted from the binary classification maps generated using vegetation Indices.

$$CC = \frac{[(\sum pixel\ size^2), if\ canopy]}{\sum(pixel\ size^2)} * 100 \quad (1)$$

Binary classification maps using MS data were generated using NDVI, where NDVI values higher than 0.6 were considered as canopy. Binary classification maps using RGB data were generated using four different vegetation indices namely, Canopeo Algorithm, Excessive Greenness Index, Modified Red Green Vegetation Index and Red Green Blue Vegetation Index computed as follows.
Canopeo Algorithm computes canopy as per Equation 2.

$$canopy = (i_1 < \theta_1) * (i_2 < \theta_2) * (i_3 > \theta_3) \quad (2)$$

where, $\theta_1 = 0.95, \theta_2 = 0.95, \theta_3 = 20,\ \ i_1 = \frac{red}{green}, i_2 = \frac{blue}{green},\ \ i_3 = 2 * green - blue - red$

Excessive Greenness Index (ExG) was computed as per Equation 3.

$$2G_n - R_n - B_n \quad (3)$$

where, $R_n = \frac{R}{R+G+B}, G_n = \frac{G}{R+G+B}, B_n = \frac{B}{R+G+B}$

Modified Green Red Vegetation Index was computed as per Equation 4.

$$\frac{G^2-R^2}{G^2+R^2} \quad (4)$$

Red Green Blue Vegetation Index was computed as per Equation 5.

$$\frac{G^2-R\times B}{G^2+R\times B} \quad (5)$$

Over Red Green Blue Vegetation Index based binary maps, morphological closing operation was applied to improve the canopy identification which combines erosion and dilation image processing operations. Moreover, for validation of canopy cover estimations, ground truth canopy cover was also generated. Ground truth was generated using a semi-automated procedure. Firstly, k-means clustering algorithm was applied over RGB orthp-mosaic images with five number of clusters. With visual interpretation, clusters were merged to obtain a binary image (canopy/non-canopy). A through manual inspection was performed to correct any misclassification which improved the reliability of the ground truth.

Results and Discussion

Plant canopy cover relates to crop growth, development, water use, and sunlight energy capture which makes it an important trait to be observed throughout the growing season. Preliminary analysis has confirmed that canopy cover estimates using MS sensor are very stable over time and seem to remain relatively unaffected by changes in environmental conditions (e.g. sunlight angle, cloud cover, etc.) throughout the crop growing season. However, MS sensors are more sensitive and expensive as compared to RGB sensors. If an RGB based canopy cover estimation is comparable to MS sensor based canopy cover estimation, it could potentially be a more affordable option to breeders and agriculture scientists. Looking at 2017 canopy cover analysis (Fig. 1), it was observed that canopy cover kept on increasing and reached a peak and decreased later in the season. NDVI-based canopy cover estimation seemed to match the ground truth better as compared to RGB-based canopy cover estimations which reached to the peak early in the season. When comparing ground truth average canopy cover with average canopy cover collected using RGB and MS sensors during the growing season, no differences were found between estimates generated from the different sensors up to June 7th, 2017 (78 days after planting). The difference in average canopy cover estimates derived from RGB and ground truth average canopy cover became statistically significant on June 19, 2017 (90 days after planting), where the beginning of crop canopy senescence is easily discernable by the naked eyes. However, Red Green Blue Vegetation Index with morphological closing operation applied found to be well commensurate with ground truth. Looking into correlation analysis, NDVI-based canopy cover estimation found to have a very high degree of correlation with ground truth with an R^2 of 0.98 (Fig. 2.b.). On the other hand, RGB-based canopy cover estimations using canopeo algorithm, ExG and Modified Red Green Vegetation Index do not seem to have a high degree of correlation with ground truth (Fig. 2.c., 2.d. and 2.e.). However, it became evident that correlation was in fact good initially (up to June 7th, 2017), after which point measurements shifted away from the 1 to 1 line because plants' canopies were starting to senesce. Since RGB-based estimates, as calculated here, are directly dependent upon the 'green' color, as soon as senescence starts and leaves transition to a more 'yellow/brown' coloration, RGB-based estimates of canopy cover tend to drop. This does not necessarily mean plants are losing leaves but may simply indicate a change in leaf coloration. Red Green Blue Vegetation Index with the morphological closing operation applied (Fig. 2.f.), exceeded other RGB-based canopy cover estimations and highly correlated with the ground truth. Main reason being this vegetation index is more tolerant to changes in color of the plant. Similar results are witnessed in the year 2018 also, however the results are not shown here.

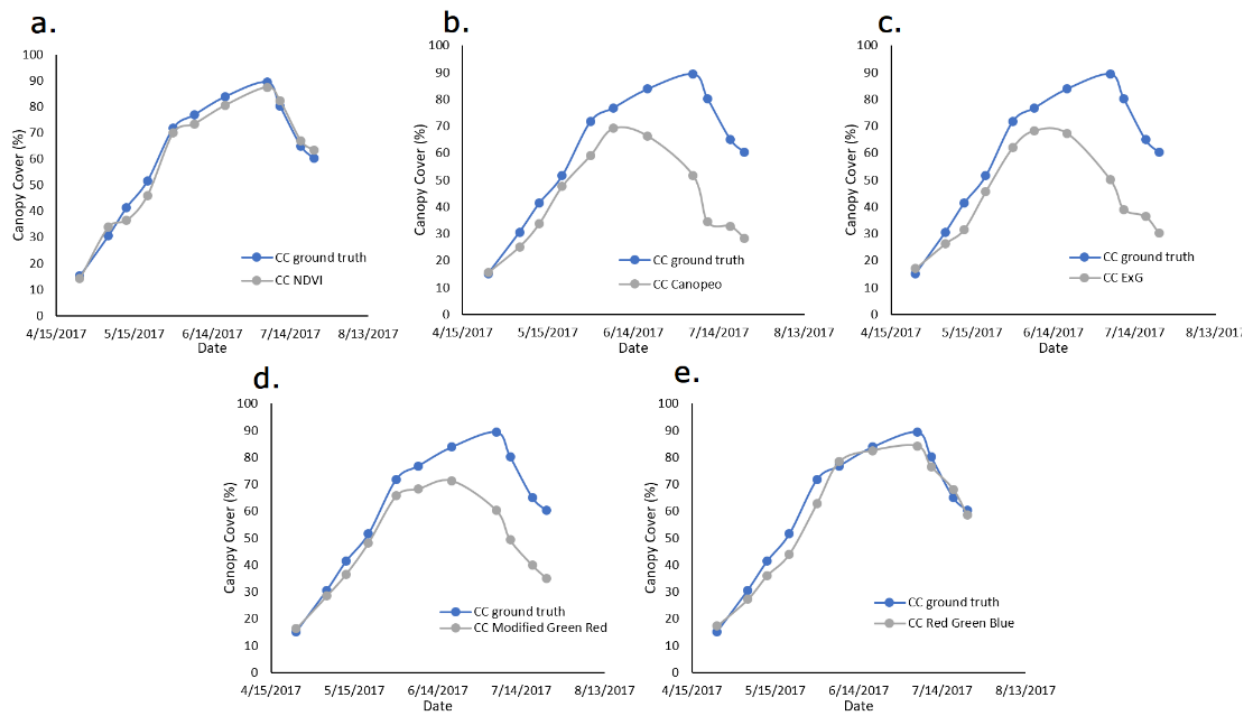

Figure 1. Average canopy cover estimation using (a.) NDVI, (b.) Canopeo, (c.) Excessive Greenness Index, (d.) Modified Green Red Vegetation Index, (e.) Red Green Blue Vegetation Index, along with the canopy cover ground truth throughout the growing season at eleven dates between April 24 to July 23, 2017.

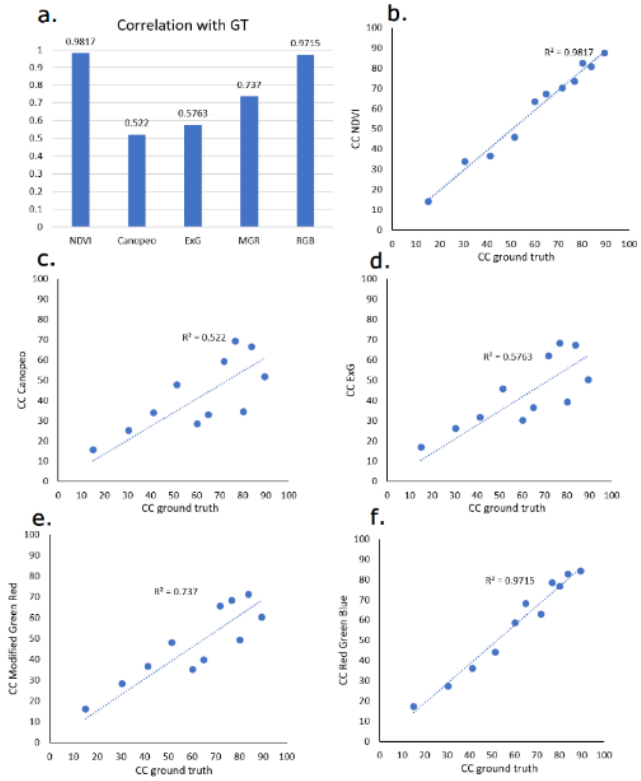

Figure 2. Correlation between ground truth plant canopy cover and plant canopy cover as estimated using (b.) NDVI, (c.) Canopeo, (d.) Excessive Greenness Index, (e.) Modified Green Red Vegetation Index, (f.) Red Green Blue Vegetation Index for 11 dates throughout the growing season at eleven dates between April 24 to July 23, 2017. Dashed line represents the trend line.

Summary

With multi-year canopy cover analysis NDVI-based canopy cover estimation turned out to be more stable and accurate estimation with respect to ground truth. Correlation of RGB-based canopy cover estimates with ground truth showed high correlation initially until the beginning of crop senescence. However, Red Green Blue Vegetation Index based canopy cover estimation found to be more tolerant to the change in color of the canopy when canopy started to senescence. Moreover, when applied morphological closing operation, Red Green Blue Vegetation Index based canopy cover estimation found to be as accurate as NDVI-based canopy cover estimation. As multispectral sensors are more sensitive and expensive, proposed RGB-based canopy cover estimation could provide an affordable alternate to agriculture scientists and breeders.

References

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