UNMANNED AERIAL SYSTEM (UAS) BASED COTTON LEAF TEMPERATURE MEASUREMENT SYSTEM

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Abstract

Unmanned Aircraft System (UAS) and sensor technology are offering great opportunity for precision agriculture and high-throughput phenotyping (HTP) systems. In this study, a novel UAS system is proposed to measure cotton leaf temperature using a thermal sensor. Thermal images were acquired with significant overlap from the UAS platform, and the images were calibrated by the sensor's algorithm with parameters such as emissivity and air temperature. Ortho-mosaic image was generated by applying Structure from Motion (SfM) algorithm. Cotton canopy temperature acquired from UAS data was compared with ground measurement to validate the accuracy. The results showed that the integrated system of UAS and thermal sensor could be successfully used to measure cotton leaf temperature.

Introduction

Unmanned Aircraft System (UAS) and sensor technology have developed rapidly and are offering great opportunities for precision agriculture and high-throughput phenotyping (HTP) systems. The UAS system can provide finer spatial and higher temporal resolution data so that crop characteristics such as plant height, growth curve, and vegetation index can be estimated (Anthony et al., 2014). Plant temperature is one of the most important factors since it has been recognized an indicator of water stress (Jackson et al., 1981). Plant temperature has been measured with contact sensors on leaves for specific locations. In this study, a novel UAS system is proposed to measure canopy temperature for cotton using a thermal camera. The actual thermal map was generated from thermal images acquired by our integrated UAS system. The result was compared with measurements from ground thermocouple sensors.

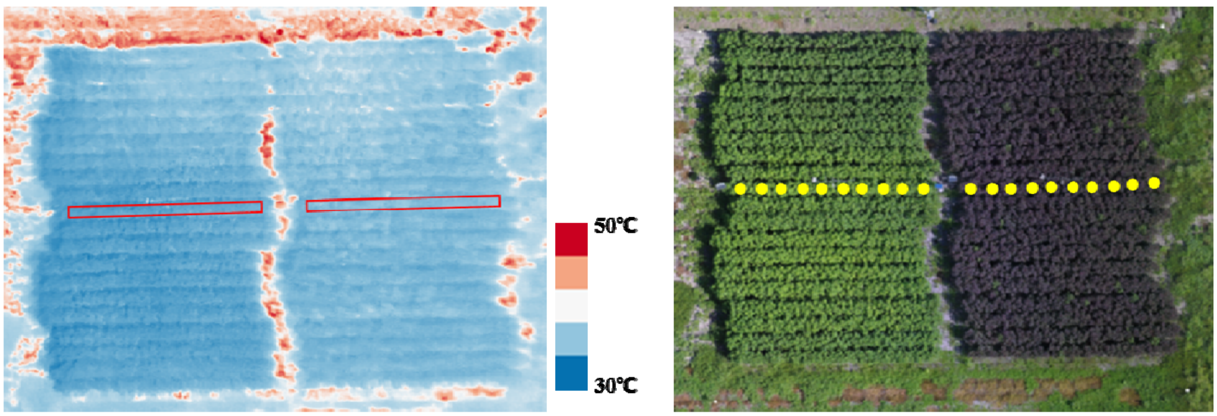
Study Area and Methods

A 3DR X8+ platform and Flir Vue Pro R640 thermal camera were integrated to collect thermal images. All thermal images were geo-tagged to generate ortho-mosaic images after flight. The image locations were extracted from the flight log. The cotton plot was located at the Texas A&M AgriLife Research and Extension Center in Corpus Christi, Texas, USA. The study area was 30×20 meter and included two types of cotton (Red and Green) planted in 20 rows each. Ten ground sensors (thermocouple) for each cotton types were installed in the middle of the tenth row. 89 thermal images were acquired on September 8th, 2016 at a 50m altitude with 75×85 % overlap. In addition, 254 RGB images were also collected by DJI Phantom 4 at 20m altitude with 85% overlap.

Raw images acquired from thermal camera need to be converted to actual temperature images. The actual temperature of all pixels was calculated by the algorithm provided by the sensor company (FLIR). Five initial parameters (Emissivity, Atmosphere Temperature, Relative Humidity, Reflective Temperature, and Distance) were imported from an in-field weather station and flight conditions. After temperature conversion, an ortho-mosaic image was generated using SfM (Structure from Motion) algorithm, which performs a bundle adjustment among images based on initial image locations and matching features between the overlapped images. Thermal and RGB UAS data sets were processed using the Photoscan Pro software (AgiSoft LLC, St. Petersburg, Russia).

Results and Discussion

Figure 1 shows the ortho-mosaic images of study area. The spatial resolution of actual thermal and RGB mosaic images was 7cm and 0.6 cm, respectively. In the temperature map, blue color indicates lower temperature. It shows that the green cotton had lower canopy temperature. In order to compare the canopy temperature with leaf temperature measured by ground sensors, 1200 pixels for each cotton type located at tenth row were selected (red box in Fig. 1 (a)). 10 ground sensors were located at tenth row (yellow circles in Fig. 1 (b)).



(a) (b)

Figure 1. Ortho-mosaic images from the study area of (a) actual thermal and (b) RGB.

The average of the pixels and ground sensors for each cotton type was compared (Fig. 2). The average difference between the UAS system and the ground sensor was 0.71 ºC for red cotton and 0.19 ºC for green cotton. The result showed small (< 1 °C) temperature difference between the UAS system and ground sensors, regardless of cotton type. It implies that the UAS system could provide accurate temperature data over the whole crop area.

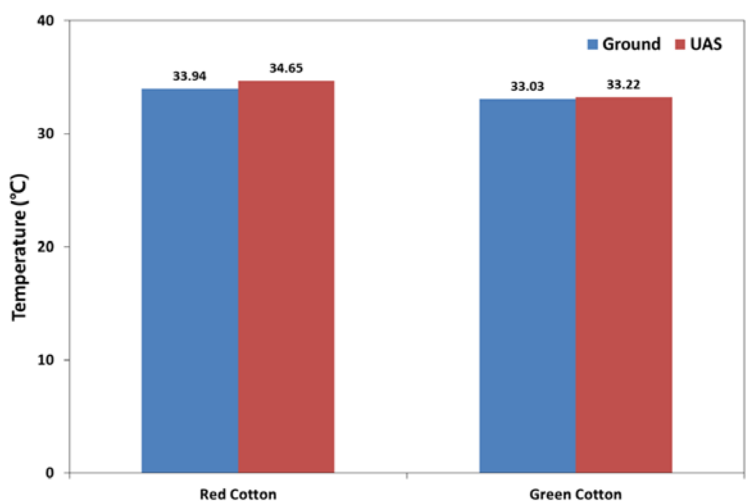


Figure 2. Temperature difference between averages of ground sensor & UAS system.

The difference between green and red cotton temperature for each measurement method was compared. The average difference between red and green cotton was 0.91 ºC and 1.43 ºC, as measured by the ground sensors, and UAS, respectively (Fig. 3). Standard deviation for these measurements were 1.78 (red) and 1.28 (green), and 0.39 (red) and 0.49 (green) for ground and UAS measurements, respectively. UAS measurements showed larger differences in average temperature between cotton types. In addition, it had a smaller standard deviation (Fig. 3). The result showed red and green cotton temperature could be statistically distinguished by UAS thermal data.

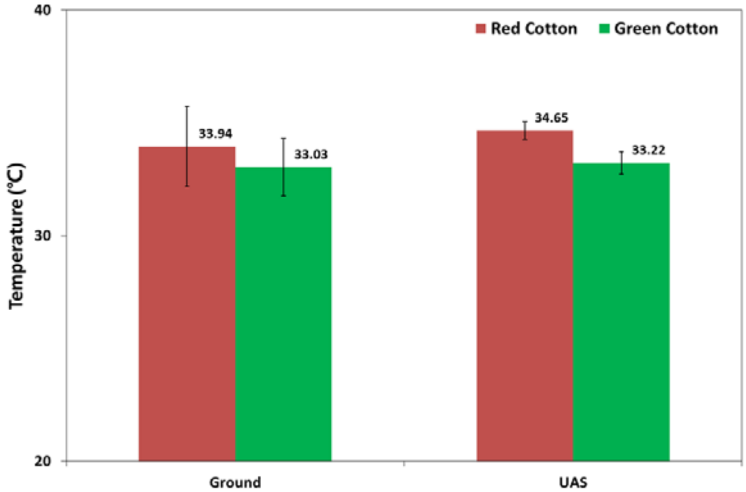


Figure 3. Average temperature difference between red & green cotton. Bars represent standard deviation.

Acknowledgements

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