THERMAL INFRARED IMAGERY FOR BETTER WATER CONSERVATION IN AGRICULTURAL FIELDS

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Abstract. Water conservation is an issue that involves all citizens in Georgia. Within the agricultural row crop community, water is a very important part of producing a harvestable and profitable product. Although irrigation is used only as a supplement to natural rainfall, it can greatly affect crop yield and quality. Because of increasing public and industrial concerns over water quality and quantity, the agricultural community must also develop sustainable management systems that conserve water. One method that can be used is conservation tillage. The benefit of water savings through reduced tillage and residue management is a function of: 1) the amount of crop residue that remains after planting, and 2) the amount of water available for the growing plant. The main objective of this study was to evaluate field scale variability in crop response to tillage regime using an unmanned aerial system (UAS). The UAS is equipped with a thermal infrared imager (8-12um) and has an approximate spatial resolution of 0.5 –1.0 m. Treatments consisted of three different cover crops (clover, rye and a rye/clover mix) managed as a strip tillage system and one conventional tillage system with no winter cover. Soil water content (10 –20 cm) and stomatal conductance measurements were collected coincident with each UAS data acquisition. Thermal infrared imagery was validated using hot and cold calibration targets (2 m x 2m each) equipped with thermal couples that were monitored every second and averaged over a one minute span throughout the data acquisition. The soil moisture was significant between the clover and other plots in June, but the rye was significant as compared to the other plots in august. The digital values as recorded by the thermal near infrared camera were significant between the three treatments of rye and clover and conventional tillage in June, but no difference was seen in august. Overall, the use of the soil moisture probes and thermal near infrared camera can be useful tools in helping determine if ample water is being applied to crops.

INTRODUCTION

Conservation tillage is a tillage method that uses a systems approach to protecting water, soil and air resources. The system incorporates cover crops during the non-growing times of the year (typically winter months) and planting crop into residue produced from winter cover. By definition conservation tillage is any operation that covers the soil surface with at least 30% crop residue after planting (CTIC, 2006). Since conservation tillage is defined the way it is there are multiple ways to actually accomplish this goal. The typical tillage method used in Georgia is either no-till or strip-till systems. These are tillage methods that leave at least 2/3 of the field undistributed from harvest to planting. This is accomplished by using implements that only disturb the soil in a thin strip (strip ranges from 0 to 12 inches). Other conservation tillage methods includes ridge-till and mulch-till which leaves greater than 30% residue cover after planting, reduced-tillage (15-30% residue cover after planting) and conventional or intensive-tillage (full width tillage). These last two tillage types are not considered conservation tillage systems by definition.

Some advantages of using the conservation tillage system is that it can be useful in protecting water resources by reducing runoff, increasing infiltration and providing better water holding capacity. The systems also protect soil through reduced erosion, better retention of nutrients and building soil quality. Air quality is improved through carbon sequestration processes. However, there are disadvantages in that it takes years (3-4 in sandy soils and longer in heavier soils) to see the benefits of converting an intensively tilled field into a conservation tillage field. The farmer also has to buy or rent different equipment and the management is different with conservation tillage.

In the conservation tillage system measuring the affects of conservation tillage on plant responce on a large scale is difficult. However, remotely sensed thermal infrared data show great potential as an indicator of plant response to environmental stressors. Stresses such as water, nutrient availability, pests, disease, and temperature impact the ability of a plant to efficiently cool itself via evapotranspiration (Hatfield and Pinter, 1993). Plants regulate temperature in one of two ways: 1) heat up and emit increased amounts of radiation or 2) dissipate energy via evapotranspiration and minimize radiated heat. Thus, healthy plants with plenty of available water remain cool, radiating away less energy.

Because sustainable water resources are increasingly important, it is critical to evaluate the risks and benefits of conservation tillage systems for Georgia's producers. Therefore, the objectives of this study were: 1) use UAS to evaluate field scale variability in crop response to tillage practices, and 2) relate volumetric water content within tillage treatments to plant stress.

METHODS AND PROCEDURES

Treatments

Residue and the breakdown products of cover crops are expected to be the key to increasing water holding capacity in a soil. To test this theory, 5 cover crop treatments were established and replicated in a randomized complete block design. The 5 treatments were a rye cover (both new planting and a 3 year planting of rye), a clover cover, a mixed cover with rye and clover and a fallow conventional tilled treatment. The different treatments can be seen in Table 1. The five treatments were stripped-tilled with a KMC strip-till rig with tilled strips being 30.5 cm (12 inches) wide. In all treatments the peanuts were planted with a Monosem twin-row peanut planter.

Table 1. Treatments used for determining soil moisture content differences across tillage treatments

Tillage Treatment	Symbol
Rye Cover (3 yr Conservation tillage)	R3
Rye Cover (Previously intensively tilled land)	RN
Rye/Clover Cover (3 year Conservation tillage)	RC
Clover Cover (3 year Conservation tillage)	C
Conventional tillage plots	CT

Soil Moisture Probes

Soil Moisture probes were installed in all 15 plots of the three blocks. The soil moisture probes used in this study were ECH2O probes manufactured by Decagon Devices. They were oriented vertically with the top of the probe being 10 cm (4 inches) below the soil surface and the tip being 30 cm (12 inches) below soil surface (Figure 1).

The probes measure the dielectric constant of the soil and output a millivolt signal. To determine volumetric soil moisture content the probes were read every three to five days with a hand held reader "ECH2O check". The values read from the reader were in units of millivolts. This millivolt reading was then converted into a volumetric soil moisture based on a calibration equation. The volumetric soil moisture content was used to indicate and trigger an irrigation event. When the average soil moisture dropped below 16% on the strip tilled plots then a 2.54 cm (1 inch) application of water was applied to all plots.

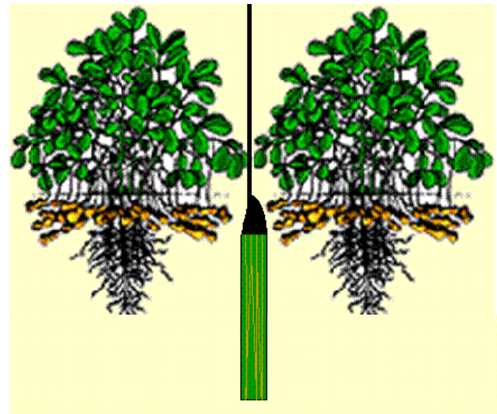

Figure 1. Installation of Soil Moisture probe

Calibration Targets

Two calibration targets were used for converting thermal near infrared digital values of treatment plots to temperatures. The two targets were 2 meters by 2 meters each. One target was constructed of a wood frame with wood paneling and painted brown (hot target). The second target was a wood frame with a tarp draped over the frame. The cavity formed by the frame and tarp, was filled with ice water (cold target). Both targets had a type-T thermocouple positioned so that the surface temperature was measured. The data from each was stored on a datalogger for processing.

Unmanned Aerial System (UAS)

Thermal infrared data were collected using an unmanned aerial system (UAS) equipped with a ThermalEye 2500AS sensor (7 –1 um) (L-3 Communications Infrared Products, TX). The sensor was not radiometrically corrected and is sensitive to < 100 mK. The UAS was flown at approximately 90 m, with a target ground resolution of 0.5 m.

All UAS data were acquired on clear days, proximate to noon. Data were captured via video stream and Sonic MyDVD software was used to extract still images. Frames were extracted based on the following criterion: 1) 75% of plots were within the field of view, 2) minimal image distortion, and 3) nadir-view. Time in flight was recorded for each image. Using ERDAS Imagine 8.7 (Leica Geosystems GIS and Mapping, LLC) digital values from within each plot were extracted, avoiding plot boundaries, and exported to ascii format.

Data extracted from the hot and cold targets were used to develop a calibration function and transform digital values to canopy temperature measurements.

RESULTS AND DISCUSSION

Volumetric Soil Moisture

Soil moisture readings collected every 3 to 5 days were used to trigger irrigation events for maintaining volumetric soil moisture (VSM) as well as to evaluate variability in soil water content between treatments. Collected data from the months of July and August 2006 is plotted in Figure 2. From this graph you can see that the VSM across all treatments tracked each other pretty well. Generally, the New Rye plots (RN) had higher VSM over the two plotted months. Likewise, the Clover cover (C) generally had the lowest VSM over the two months plotted. If the average VSM for each treatment is calculated for the year the same conclusion can be made (Figure 3). Also you can see in figure 3 that the VSM in the RN and CT treatments were not significantly different from each other. However, there were significant differences between other treatments such as between clover treatment and all other except the rye-clover (RC) treatment. From Figure 3, it can also be seen that the two treatments that had clover had the lowest average yearly VSM.

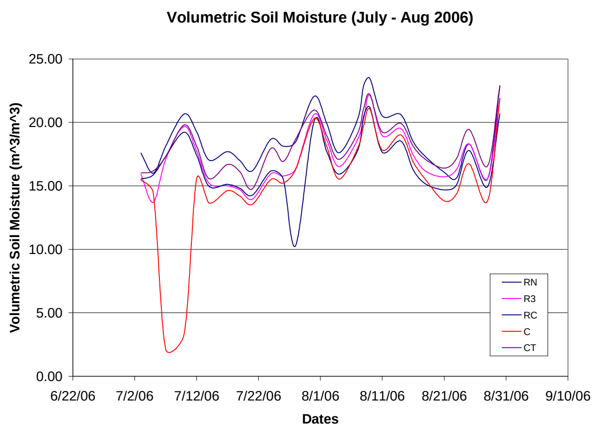

Figure 2. Average treatment volumetric soil moisture content in the months of July and August 2006.

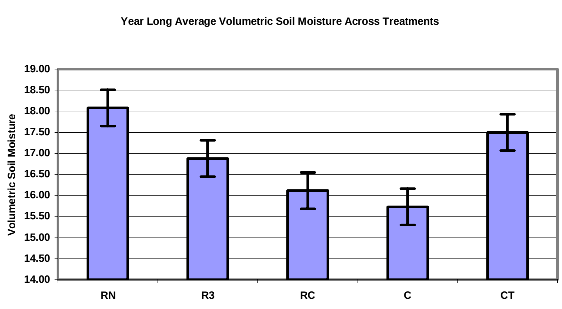

Figure 3. Average volumetric soil moisture across the year for each tillage treatment.

The UAS was flown two times during the growing season (June 30, 2006 and August8, 2006). The average digital values recorded from the thermal-eye 2500AS camera for both flight dates of the UAS are plotted in figure 4. The digital values presented in figure 4 represent the amount of reflected heat from the measured surface. High digital values indicate high energy reflectance and a corresponding lower surface temperature. Likewise a low reflectance indicates a high surface temperature.

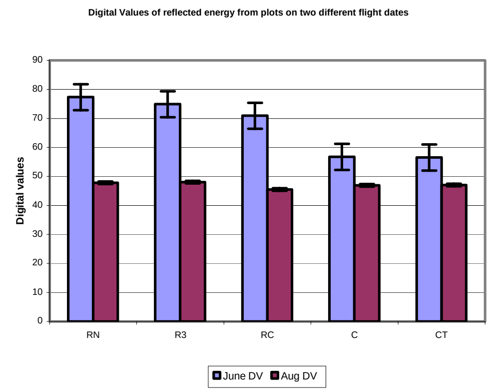

Figure 4. Plot of average digital values recorded from plots on two flight dates flown with the UAS.

The digital values presented in figure 4 can be compared within dates, but should not be compared across dates. From figure 4 it can be seen that the values for the C and CT treatment plots were lower than that of the RN, R3 and RC treatments. These lower digital values indicate that the surface was warmer than that of the other three treatments. The warmer temperatures of the C and CT plots is most likely associated with the lack of cover as compared to the other three plots. Ground cover was not measured, but it is expected that the cover on the C and CT plots had decayed thereby leaving the soil surface. The soil surface would then be warmer than the residue on the other plots and hence a lower digital value. From figure 4, it can be seen that the digital values for all of the treatments in August are virtually the same. These equal digital values indicate that the surface being measured is completely covered with vegetation and no or very little soil is exposed.

The VSM in the treatment plots is plotted in figure 5. From this graph, it can be seen that in both June and August the VSM content was above the 16% used to trigger an irrigation event. This indicates that more water was applied to these plots than was needed. However, the June sampling of the C treatment had a higher VSM, but it was not significantly different from the other treatments. In August however, the RN treatment had a significantly higher VSM than the other treatments. This higher VSM could be attributed to a thicker residue layer retarding the evaporation of soil moisture thereby allowing deeper vertical movement as compared to the other plots. Since no surface coverage was measured this can not be fully proven since there appears to be no correlation between the higher VSM in the RN plot and DV readings.

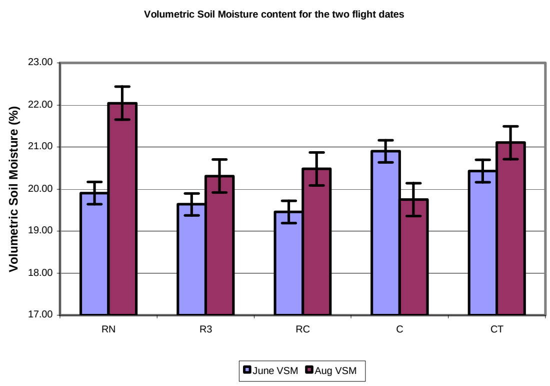

Figure 5. Average Volumetric Soil Moisture of the treatments for both flight dates of the UAS.

CONCLUSIONS

The research described here was designed as a randomized complete block design to determine if there is a difference in the volumetric soil moisture with different cover crops being used in a conservation tillage system. Overall there was a difference seen in the yearly average of the treatments. The new rye (RN) and conventional tillage (CT) had the highest VSM soil moisture with the two treatments with clover (RC and C) having the lowest VSM. This maybe contributed to the clover decaying quicker than the rye, thereby have more exposed soil for evaporation.

Even though there appears to be a difference in the yearly average of VSM, placing the soil moisture sensors in the horizontal orientation verses the vertical may be more advantageous. Placing the sensors in the horizontal orientation would provide VSM at the 10 cm depth thereby allowing better irrigation management based on volumetric soil moisture in a horizontal zone verses an average over a vertical zone where the soil moisture could vary more.

From the digital values collected from the UAS, there appears to be lower soil temperatures where there is a good residue cover early in the season when the canopy has not fully matured. In the later part of the growing season when the canopy has matured, the difference in the digital values and therefore the heat reflectance of the measured surface is equal across treatments. With the VSM being greater that the level expected to cause stress there was no sign of stress in any plot. This would lead to a conclusion that the mechanism used for applying water should be changed to give a larger separation between plots in respect to plant response to lack of water.

LITERATURE CITED

Conservation Technology Information Center (CTIC). 2004. National Crop Residue Management Survey – 2004 Survey Results. CTIC, West Lafayette, IN.