Using Multispectral Aerial Imagery to Estimate the Growth of Cotton Fertilized With Poultry Litter and Inorganic Nitrogen

Javed Iqbal E-mail: jiqbal@purdue.edu
Postdoc, Dept. of Agronomy, Purdue University

Phillip R. Owens
Assistant Professor, Dept. of Agronomy, Purdue University

H. Tewolde
USDA-ARS, Mississippi State

D. E. Rowe
USDA-ARS, Mississippi State

Bruce Erickson
Visiting Assistant Professor, Department of Agricultural Economics, Purdue University

INTRODUCTION

The poultry industry of Mississippi produces approximately 730 million broiler chickens each year. Environmentally safe disposal of poultry litter as a plant nutrient and soil amendment without affecting the water quality is a concern in Mississippi. Much of that poultry litter is applied to cotton, and remote sensing techniques can be used early in the growing season to assist growers in making nitrogen management decisions that affect profitability and environmental stewardship. A poultry litter (PL) application study was conducted during 2002 near Macon, Mississippi to determine the potential of aerial imagery to estimate and discriminate growth of the cotton crop.

RESEARCH STUDY

Treatments

Poultry litter (PL) and inorganic N treatments were organized in a randomized complete block design with four replications. Inorganic N fertilizer was applied (knifing-in 2 in deep and 30 in each side of the row) as urea-ammonium nitrate solution (UAN) at the rate 0 30, 60 and 120 lb/A (0, 33, 67 and 134 kg N ha^{-1}). Poultry litter was applied at 0, 1, 2, and 3 T/A (0, 2.2, 4.5 and 6.7 Mg ha^{-1}). Each treatment plot had a dimension of 20 ft (6 m, 8 rows) wide by 300 ft (91 m) long rows. Cotton (cultivar Sure Grow 501 B/R) was planted on April 25, 2002 and picked on September 24, 2002. Farmer conventional crop management practices were applied throughout the season. Data on cotton plant growth variables and lint yield were collected on July 2, July 22, August 14, and September 3, 2002.

Multispectral Aerial Imagery

Aerial images were collected with a GeoVantage™ digital camera system that acquired four bands (NIR=850, Red=650, Green=550, Blue=450) with a 0.5-m spatial resolution. The bandwidths for each band were 10 nm for Red, Green, Blue and 20 nm for NIR. The average digital numbers (DN) value of each plot area of interest (AOI) was used to study temporal trends in the cotton crop and for derivation of vegetation index. A widely used vegetation index is the normalized difference vegetation index (NDVI). NDVI is an indicator of crop biomass production and canopy vigor. The basis of this spectral index is the strong absorption at R_{650} by chlorophyll and low absorption at NIR_{850} by green leaves. As a result, healthy and dense vegetation produces a high NDVI, while less vigorous and sparse vegetation produces a low NDVI. Values for NDVI were calculated as NDVI = (*NIR-Red/NIR+Red).*

Statistical Analysis

The data collected on cotton plant growth variables were statistically analyzed in SAS for overall main effects of PL and inorganic N factors using GLM procedures. Contrast analysis procedure was used to determine PL rate differences within each rate of inorganic N and vice versa. Mean values were calculated and compared on least significant difference (LSD) at the 0.05 probability level. Simple regression analysis was also performed to quantify various plant growth variables and yield relationships with digital data derived from multispectral imagery on different dates.

RESULTS AND DISCUSSION

Significant ($P < 0.05$) differences were found in leaf N, leaf area index, total dry weight, and yield due to overall effects of different rates of inorganic N application (UAN-N) and PL. Table 1 shows the results of the analysis of variance for PL and inorganic N effects on leaf N concentration, leaf area index, total dry weight, normalized vegetation index for samples collected at different dates and yield for 2002 growing season. The overall effects of the UAN-N treatment produced the highest F-values (11.46 and 11.02) for leaf N sampled on July 2 and September 3 compared to overall effects of PL that resulted in lower F-values (3.36 and 4.68). This suggest that PL releases N slowly. The same pattern was observed in other variables. Significant ($P < 0.05$) differences were found in cotton lint yield and total dry weight in treatments that received different PL rates within different rates of UAN-N. However, no significant ($P < 0.05$) differences were found in leaf N, total dry weight, leaf area index and NDVI across different dates in different PL rates within different levels of UAN-N. Highly significant ($P < 0.02$) differences were found in all variables means due to different rates of UAN-N within each level of PL. The t-test (LSD) of cotton lint yield means suggest an application rate of 2 T/A of PL in combination with 60 lb/A of UAN.

Table 1 .F-values of cotton growth characteristics at different dates (probability values in parenthesis) fertilized with poultry litter (PL) and inorganic nitrogen (UAN) during 2002.

Trt	Leaf_N	LAI	TDW	LAI	TDW	NDVI
	July_02			July_22		
PL	3.36(0.03)	3.94(0.02)	3.86(0.02)	1.65(0.20)	4.21(0.01)	2.59(0.07)
PL(UAN)	1.35(0.27)	1.60(0.18)	1.22(0.32)	2.11(0.08)	2.43(0.05)	1.55(0.19)
UAN	11.46(0.00)	7.88(0.00)	7.61(0.00)	13.90(0.00)	13.65(0.00)	21.22(0.00)
UAN(PL)	5.40(0.00)	3.57(0.00)	3.10(0.02)	8.24(0.00)	7.15(0.00)	10.87(0.00)

Trt	LAI	TDW	NDVI	Leaf_N	LAI	TDW	NDVI	Yield
	August_14			September_3				
PL	1.04(0.39)	3.22(0.04)	0.71(0.55)	4.68(0.01)	1.66(0.21)	0.87(0.48)	1.97(0.16)	2.59(0.07)
PL(UAN)	0.66(0.68)	1.53(0.21)	0.65(0.69)	1.44(0.25)	1.71(0.17)	0.76(0.61)	1.73(0.17)	2.73(0.03)
UAN	12.25(0.00)	5.86(0.00)	6.17(0.00)	11.02(0.00)	10.03(0.00)	5.87(0.00)	21.17(0.00)	11.82(0.00)
UAN(PL)	6.27(0.00)	2.85(0.03)	3.38(0.01)	4.61(0.00)	5.90(0.00)	3.26(0.02)	11.33(0.00)	7.34(0.00)

Multi-Spectral Aerial Imagery

Canopy based reflectance in the visible (400 – 700 nm) and NIR (700-1200 nm) has been related to crop N status, leaf area index, and yield. Leaves with higher N content have higher spectral reflectance in the NIR waveband and lower reflectance in Red waveband. Figure 1 shows the regression plots of digital numbers (DN) averaged over each plot at blooming stage vs. leaf N, leaf area index, total dry weight, and yield. Significant ($P < 0.05$) relationships were found between the NIR band, Red band and derived NDVI values with leaf N concentration, total dry weight, leaf area index, and cotton lint yield. The highest variation in leaf N concentration, total dry weight, leaf area index, and cotton lint yield was explained by NDVI followed by NIR band and Red band.

Figure 1. Linear regression between cotton canopy reflectance and crop growth variables.

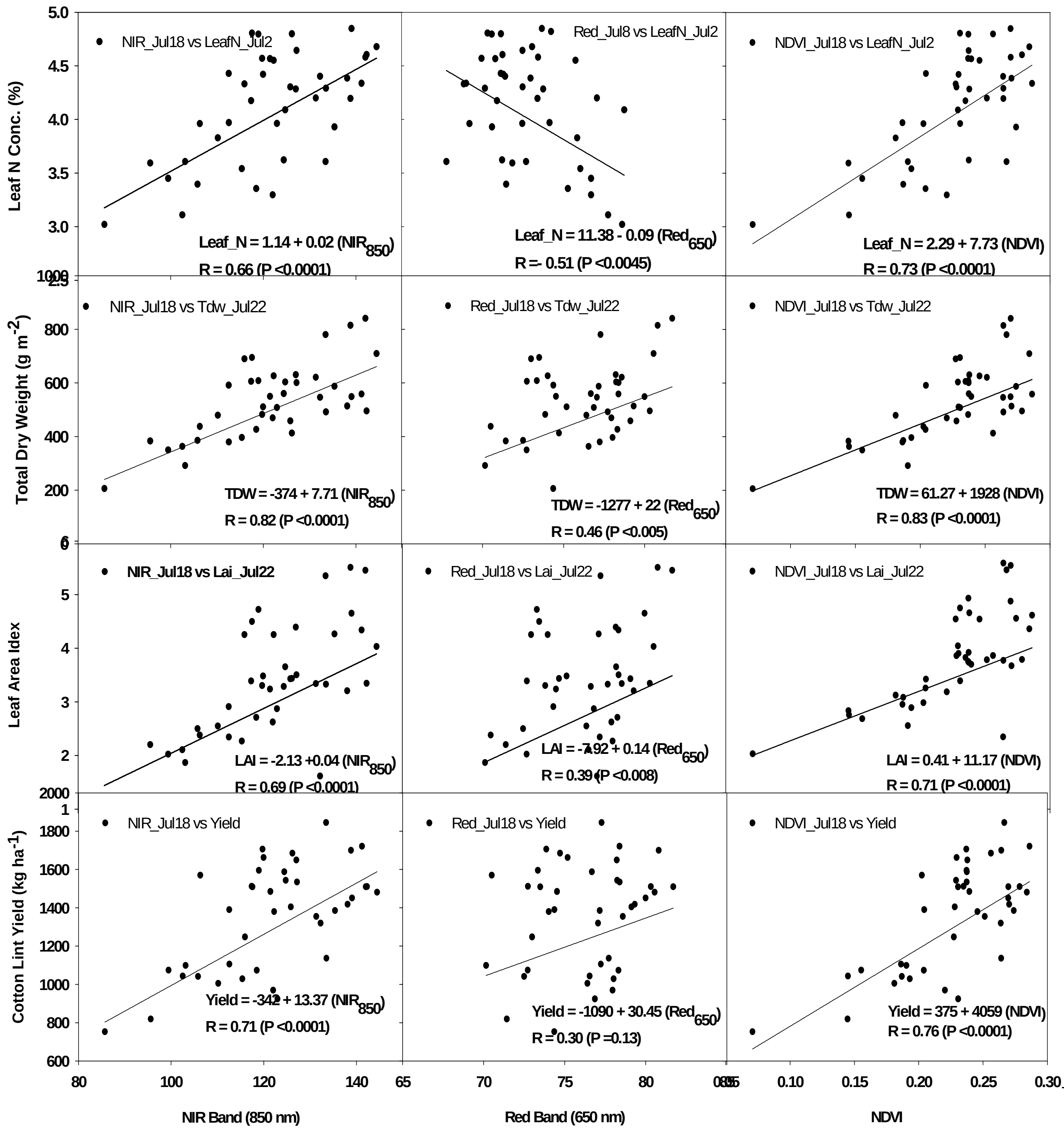

Figure 2 shows a temporal comparison of NDVI response curves derived from different flight dates under different rates of PL and UAN-N. Highest NDVI values were obtained from plots that received 120 lb/A as UAN while the lowest NDVI values were obtained from plots receiving no fertilizer. Overall, treatments under PL without UAN-N (portrayed in dark red, red, orange, and yellow) had lower NDVI than treatments that received PL in combination with UAN.

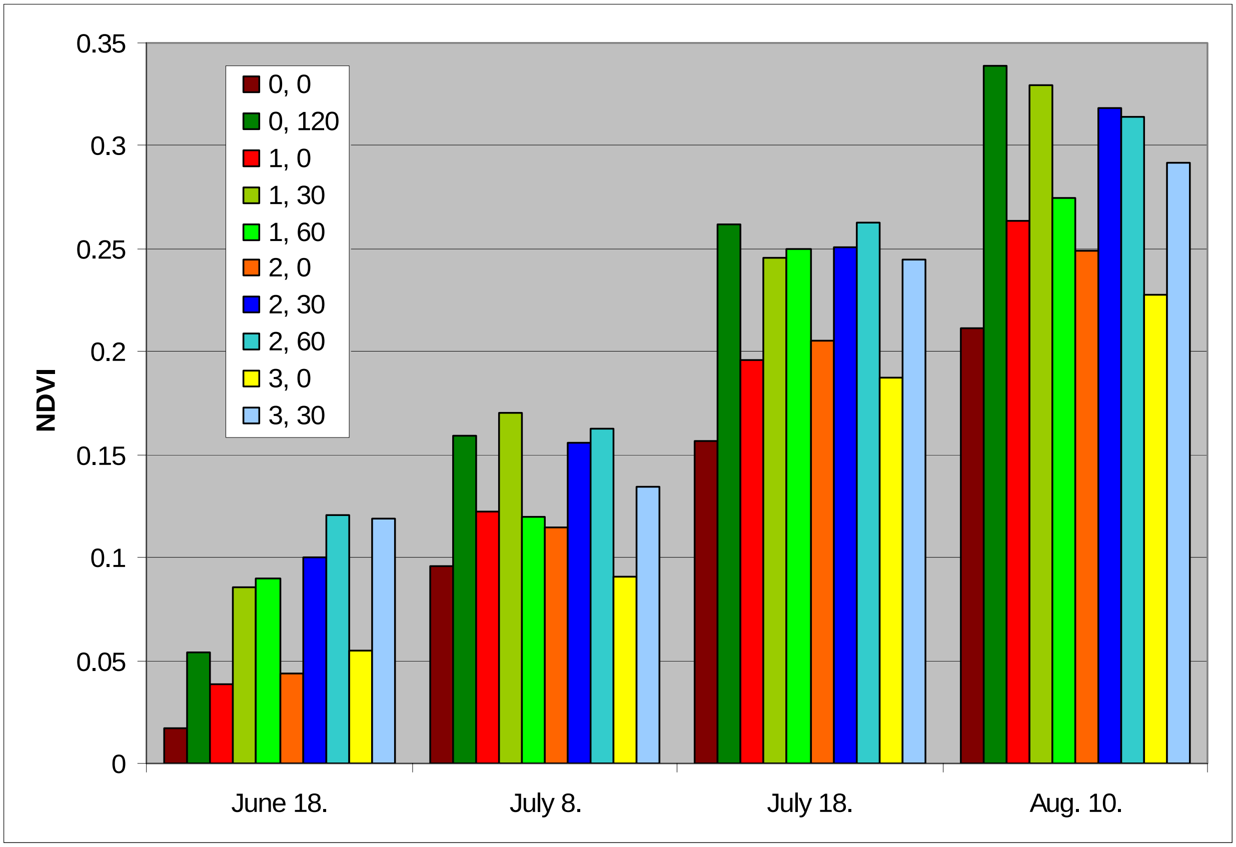

Figure 2. Temporal relationships between NDVI at different dates and various rates of PL and UAN (PL, T/A, UAN, lbs/A).

Figure 3 shows false color imagery, derived NDVI map and predicted thematic maps of canopy N concentration and cotton lint yield. In the imagery each plot can be distinctively identified—plants that received UAN and/or in combinations with PL show an intense reddish-magenta tone, compared to plots without any fertilizer treatment. The site-specific regression equations between NDVI and leaf N concentration, and yield were used to generate the canopy based thematic maps for NDVI, canopy N concentration and yield. The NDVI map shows strong spatial similarities with canopy N concentration and yield maps. Areas in the field that had higher NDVI values show a higher canopy N concentration with a high cotton lint yield and vice versa. This suggests that NDVI can be used early in the growing season to adjust the crop management decisions, especially N management.

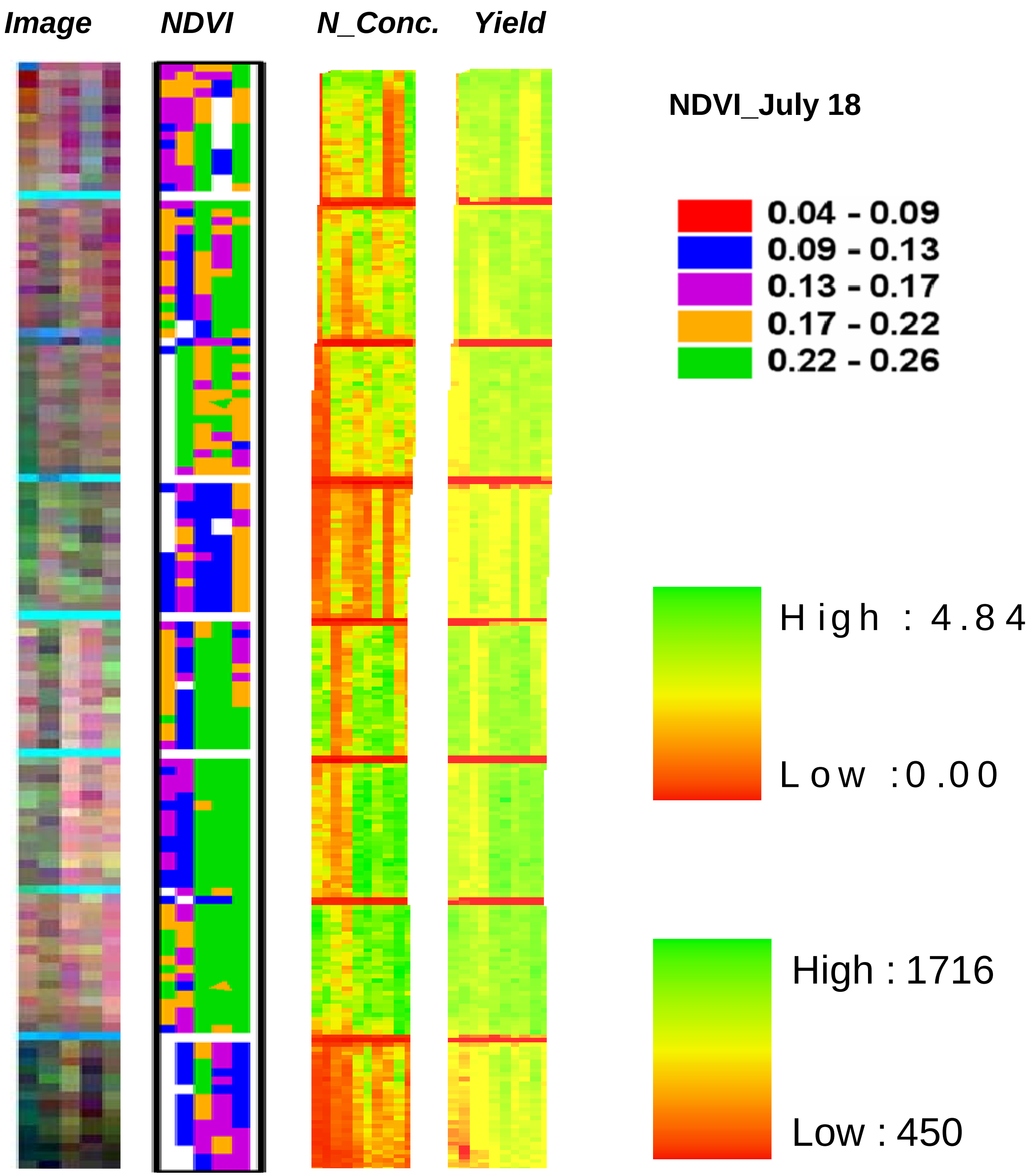

Figure 3. Images of plots fertilized with different rates of PL and UAN. From left, an RGB representation from data collected July 18, 2002, NDVI, and thematic maps of canopy N concentration and lint yield estimated from NDVI.

SUMMARY AND CONCLUSIONS

Different rates of PL and inorganic N fertilizer significantly affected the leaf N content, leaf area index, total dry weight, and NDVI as compared to the control. Canopy based reflectance in the visible (650 nm) and NIR (850 nm) was significantly related to crop N status, leaf area index, total dry weight and yield. Temporal patterns of NDVI throughout the growing season distinctively discriminated different levels of PL and inorganic N fertilizer. Spatial similarities were found between canopy-based thematic maps of NDVI, N concentration and cotton lint yield. With a reliable relationship between remote sensing information and field management practices, remote sensing could be used as a tool to better manage cotton nutrient inputs.

FOR MORE INFORMATION

Dinku, M.E., Cabrera, M.L., Steiner, J.L., Radcliffe, D.E., Vencill, W. K., Schomberg, H.H., and Lhr, L. 2002. Impact of conservation tillage and nutrient management on soil, water and yield of cotton fertilized with poultry litter or ammonium nitrate in the Georgia piedmont. Soil and Tillage Research 66: 55-68. doi:10.1016/S0167-1987(02)00013-2

Moore Jr., P.A., Daniel, T.C., Sharpley, A.N. Wood, C.W., 1995. Poultry manure management: environmentally sound options. J. Soil water conserve. 50:321-327.

Perkins, H.F., Parker, M.B., and Walker, M.L. 1964. Chicken manure-its production, composition and uses as fertilizer. Georgia Agric. Exp. Stn. Bull. No. 123. University of Georgia, Athens, GA.