# Estimating Cotton Defoliation with Reflectance Indices

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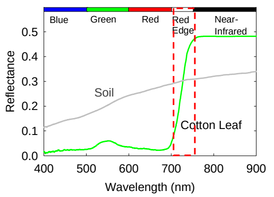
UNIVERSITY OF GEORGIA COTTON PHYSIOLOGY

## Objective

Compare spectrometry with visual estimates of cotton defoliation to identify consistent methods for estimating defoliation.

## Background

Cotton defoliants facilitate machine harvest, and can also reduce weather-induced yield and fiber quality losses. Estimates of defoliation rate allow producers to monitor harvest readiness and make further defoliation decisions as necessary. However, visual estimates are subjective and may differ among reviewers.
Crop reflectance has been used to estimate growth for several decades and could potentially improve defoliation estimates.




Soil and cotton leaf reflectance

- Chlorophyll absorbance dominates visible plant reflectance (e.g. Sims and Gamon, 2002)
- Near-infrared (NIR) plant reflectance is higher than soil reflectance.
- Many vegetation indices use combinations of visible and near-infrared reflectance to estimate leaf area index (LAI).

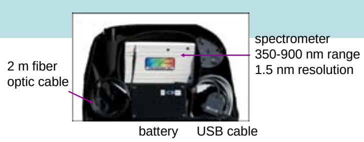
The normalized difference vegetation index (NDVI), as defined by Rouse *et al.* (1973), is

$$NDVI = (\lambda_2 - \lambda_1)/(\lambda_2 + \lambda_1)$$

where $\lambda_1$ and $\lambda_2$ are wavelengths in nanometers.
*In this study, $\lambda_2$ was drawn from the average reflectance in the broad chlorophyll-insensitive 800-900 nm range, unless otherwise specified.*

## Materials and Methods

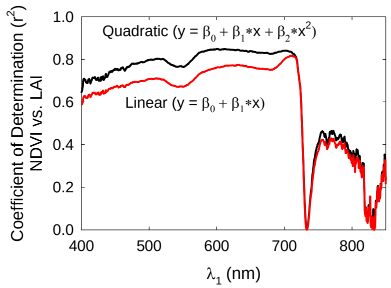
At 4 locations in 2003-2004, visible and NIR reflectance was measured on 0.91 m sections of cotton (*Gossypium hirsutum* cv. Delta&Pineland 555 and Stoneville 4892) row using a SPEC-PAR/NIR narrow-band spectrometer (Apogee Instruments, Inc., Logan, UT).
Leaves were removed by hand, and LAI was measured with a LI-3100 leaf area meter (LI-COR, Lincoln, NE)
NDVI models composed of reflectance at all wavelengths were regressed against LAI to determine which wavelengths most accurately estimated changes in LAI.
Both linear and quadratic models were tested for their usefulness in estimating LAI.
LAI was also compared with visual defoliation estimates by four reviewers.




LI-COR LI-3100 leaf area meter

Apogee SPEC-PAR/NIR spectrometer components. Photos courtesy Apogee Instruments, Inc.

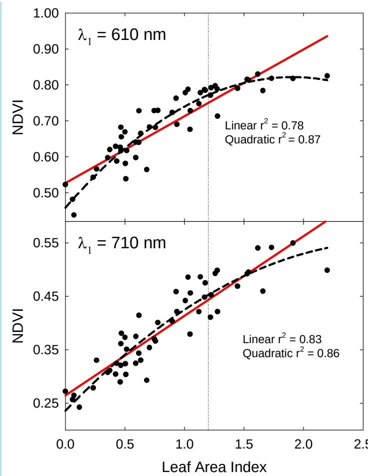
## Results



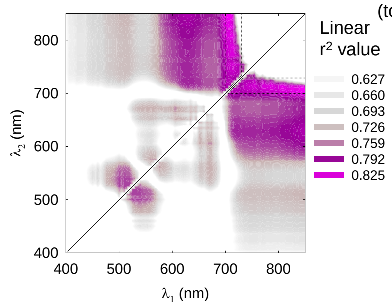

Linear and quadratic $r^2$ of NDVI with LAI based on $\lambda_1$

NDVI was observed to have the highest linear coefficient of determination ($r^2$) with LAI at wavelengths between 700-715 nm. The quadratic $r^2$ values were highest throughout the red and red edge regions of the spectrum.

Although the NDVI based on red wavelengths had a high quadratic correlation with LAI, much of this correlation was explained by the saturation of red reflectance and the high chlorophyll contents and the resultant flattening of NDVI at high LAI levels. As shown in the figure to the right, NDVI based on red reflectance ($\lambda_1$ = 610 nm) did not increase significantly above an LAI of 1.2. Despite the high correlation, the index based on red reflectance was not suitable for discriminating moderate to high LAI levels.
The linear and quadratic NDVI models based on red edge wavelengths had high correlations with LAI, including an upward trend with LAI well above that associated with red reflectance.




Linear and quadratic relationship of NDVI with LAI at $\lambda_1$ = 610 nm (top) and $\lambda_1$ = 710 nm (bottom)

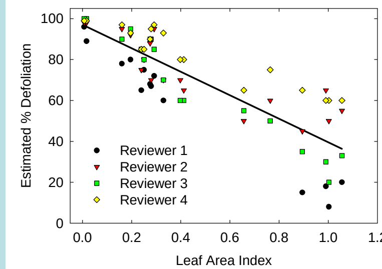



Coefficient of determination ($r^2$) of NDVI $_{\lambda 1, \lambda 2}$ vs. LAI

Additionally, each wavelength from 400-850 nm was compared with all other wavelengths to determine the combination of wavelengths with the highest linear LAI correlation. The highest correlations were found for combinations of red edge and near-infrared reflectance bands.
The graph is symmetrical, because interchanging $\lambda_1$ and $\lambda_2$ in the equation results in the same $r^2$ value.

## Results (continued)

NDVI was compared with visual estimates of cotton defoliation by 4 experienced defoliation reviewers as estimators of LAI over a three day period. Reviewer 1 was absent for one of the estimate days. All of the estimates showed a high correlation with overall LAI ($r^2$ ranged from 0.73-0.96). However, interesting trends were observed.




Estimates of defoliation at LAI levels greater than 0.5 were not significant for one reviewer did not follow a negative estimated defoliation: LAI trend for another reviewer.
In addition, estimates of percent defoliation between reviewers varied widely as LAI increased, despite an initial "calibration" procedure, in which the reviewers agreed on general defoliation levels at high, medium, and low levels of defoliation.

| Reviewer | $r^2$ (all LAI) | $r^2$ (LAI<0.5) | Slope (LAI<0.5) | $r^2$ (LAI>0.5) | Slope (LAI>0.5) |
|---|---|---|---|---|---|
| $NDVI_{710\ nm}$ | 0.90 | 0.87 | 0.50 | 0.50 | 0.17 |
| 1 | 0.96 | 0.87 | -92.8 | 0.54 | 18.2 |
| 2 | 0.73 | 0.64 | -78.9 | 0.03 | NS |
| 3 | 0.94 | 0.76 | -94.1 | 0.81 | -75.7 |
| 4 | 0.90 | 0.55 | -40.4 | 0.48 | -26.0 |

## Discussion

In this study, NDVI based on red edge and NIR wavelengths was highly correlated with LAI of cotton plants undergoing defoliation. Other issues can affect these estimates, including solar angle, atmospheric conditions, scaling issues, and the influence of leaf color.
The use of a spectral system for estimating defoliation would advance defoliation work in several areas. First, standardized estimates based on spectral changes would allow consistent estimates of defoliation both spatially and temporally. This might help quantify the effects of different conditions on defoliation rates. Defoliation estimates could also be performed on a larger scale, and defoliation might be performed as a variable rate application based on georeferenced LAI estimates. This could potentially improve efficiency of defoliant applications, as well as decrease application rates.

## References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