COTTON YIELD PREDICTION IMPROVEMENT WITH REMOTE SENSING

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Abstract

Spatially variable yield estimates for cotton fields would be beneficial to farmers in terms of marketing their crops and optimizing input vs. output costs. Remote sensing may be useful in producing such estimates. Multispectral satellite images, acquired during the growing season in 1998, were examined for their relationship with cotton yield in a particular Mississippi-Delta cotton field. It was found that one infrared image of the field, acquired 3.5 months in advance of harvest, was a good predictor of cotton yield.

Introduction

Although cotton fiber production was valued at over $4 billion in 1998 (USDA - National Agricultural Statistics Service, 1999) significant problems with profitability currently exist. Two possible solutions are precision farming and improved marketing. Precision farming provides information to a producer about variability in field conditions. This allows management of crop inputs on a spatially variable basis so that costs of input vs. output can be optimized. Marketing can be improved with additional information about yield expectation, with which farmers can optimally sell contracts for their production to get the best price for the amount of cotton they expect to produce. Spatially variable yield estimates, as far in advance of harvest as possible, would allow better production and marketing decisions to be made.

Remote sensing fits into both of these possible solutions. As a precision-farming tool, remote sensing provides information about spectral reflectance of small land units within fields. Such data can give insight into the variability in soils and crop conditions. Remote sensing can possibly also provide information to give advance notice of problems and/or marketing opportunities. One example of this would be the use of remote sensing to predict the yield and associated variability of a cotton crop well in advance of harvest.

Literature Review

Huete and Jackson (1988) reported a study of canopy reflectance over differing levels of canopy coverage for cotton. They found that reflectance values in the red and near-infrared (NIR) bands were highly influenced by the type of underlying soil. However, Huete (1988) reported that, at high Leaf Area Index (LAI) values, there was not enough soil-reflected signal coming back through the canopy to be significant. Clevers et al. (1994), having found that efforts to tie remote sensing to yield were somewhat disappointing, pointed to the need to tie remote sensing information to crop growth models. Their hope was that remote sensing could be used to monitor the growth and development of cultivated plants. They stated that remote sensing can be used to detect amounts of chlorophyll and nitrogen in plant tissue and can provide feedback to crop models for checking the amount of biomass produced. They also stated that crop models can be used to predict plant architecture, leaf area index, leaf angle distribution, and optical properties. These values can in turn be used to predict reflectance. They used the feedback mechanism to improve the yield prediction of a sugar beet model in the Netherlands. This approach has a great deal of potential in cotton, because cotton is an indeterminate crop, and yield does not necessarily relate directly to biomass. Anderson and Yang (1996) demonstrated a correlation between remotely sensed images and biomass production that correlate to yield in cereal grains like wheat, sorghum, and rice. Shibayama and Akiyama (1991) reported that earlier work had been done to relate grain yield to remote sensing images. They noted work that related the NIR-to-red ratio to grain-yield forecasts by way of the relationship between dry matter and grain yield. They concluded that yield could not be predicted with multiple linear regression, but that regression on normalized differences of second derivatives of reflectance were useful, although still not reliable across years.

Objective

The objective of this study was to develop a useful early prediction of cotton yield with the aid of remote-sensing data.

Methods

Study Site

A field of approximately 275 acres in a cooperating producer's operation near Vance, Mississippi, was selected for study. The field was planted from year to year in a cotton/other rotation, but was in cotton in 1998.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:419-421 (2000)
National Cotton Council, Memphis TN

Remote-Sensing Data

Multispectral images of field 1, from the Landsat 5 satellite, were acquired at several dates in 1998. Landsat 5 data contain six spectral bands (0.45 to 0.515, 0.525 to 0.605, 0.63 to 0.690, 0.75 to 0.90, 1.55 to 1.75, and 2.09 to 2.35 µm) at roughly 30-m spatial resolution, and a thermal IR band (10.40 to 12.5 µm) at 120-m resolution. Figure 1 is a color-infrared composite image of the field in the study, based on Landsat bands 2, 3, and 4. The images were manually georectified with digital-orthoquad maps (DOQs) of the areas surrounding the fields. The DOQs are developed from scanned color-infrared photographs, and processed so that they are geographically very accurate with 1-m spatial resolution.

Yield Data

Yield data were collected with a Micro-Trak cotton yield monitor mounted on a John Deere four-row cotton picker. Figure 2 is a yield map for the field in the study.

Analysis

Data were analyzed as follows. For every pixel value in a Landsat image, all yield values within the boundaries of corresponding pixels were averaged. Then, for every pixel value, there was one corresponding average yield value. Linear regression was performed between the pixel values and the average yield values to determine the correlation between them. This analysis was conducted for each spectral band of each image collected during the growing season.

Results

After some testing, it was evident that the band-4 image acquired on June 22, 1988, was by far the most highly correlated ($R^2 = 0.77$) with yield, even more so that vegetation indices such as NDVI. Correlations between yield values and pixel values were linear. Figure 3 shows the data points and regression line relating yield to image pixel values. The relationship was highly significant and predominantly linear. It was noted that the pixels whose values were near the low and high ends were relatively few in number. Therefore, the regression was performed again with a weighting factor for the number of pixels at a given value. In this case (figure 4), the correlation appeared to be much stronger ($R^2 = -0.88$). It can be readily seen that, for pixel values from 101 to 122, which include almost all the data, the yield values fall very close to the regression line.

Conclusions

This work showed that in this particular case, one infrared image, acquired by a satellite sensor 3.5 months before harvest, was a good predictor of cotton yield. This conclusion at least gives strong evidence to the idea that remote sensing can provide important information to improve cotton growth models.

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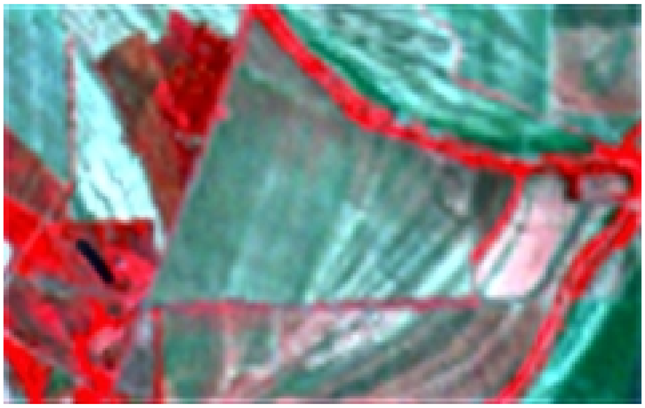

Figure 1. Infrared image of field from Landsat data.

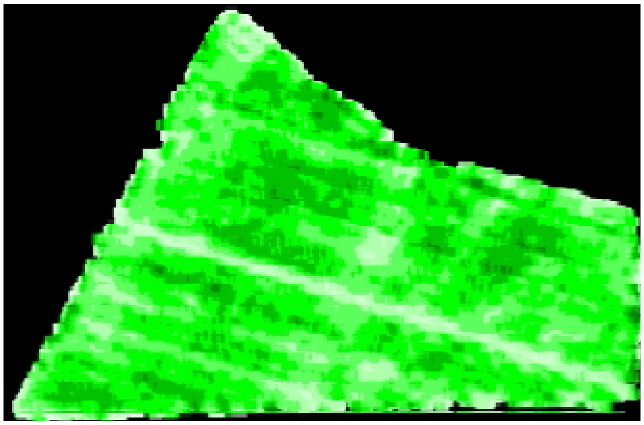

Figure 2. Cotton yield map of field. Darker areas are higher yielding.

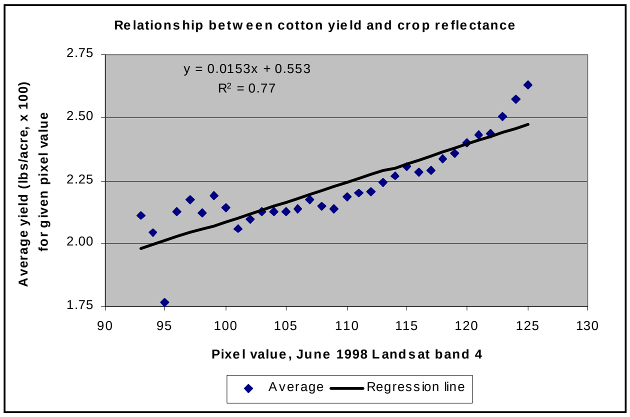

Figure 3. Plot of relationship and regression line between average yield and pixel value of Landsat band 4 image.

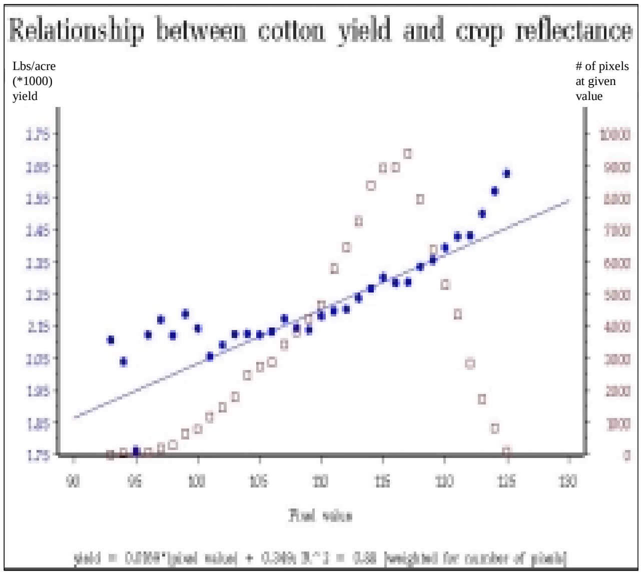

Figure 4. Plot of regression line, weighted according to the number of pixels at a given value within the image, between average yield and pixel value of Landsat band 4 image. Dots represent data points of yield vs. pixel value, while squares represent number of pixels at the given pixel value.