REMOTE SENSING FOR PREDICTING COTTON YIELD

J. Alex Thomasson, Jian Chen and James R. Wooten
Department of Agricultural and Biological Engineering,
Mississippi State University
Starkville, MS
Scott A. Shearer
Department of Biosystems and Agricultural Engineering,
University of Kentucky
Lexington, KY

Abstract

Maps of predicted yields could help cotton farmers better manage and market their cotton crops. Remote sensing has the potential to supply current information on crop status that could make possible the creation of estimated yield maps during the growing season. Multispectral satellite images, acquired during the growing seasons in 1998 and 1999, were examined for their relationships with cotton yield in two irrigated Mississippi-Delta cotton fields. It was found that one infrared image of each field, acquired in advance of harvest, was well correlated with cotton yield.

Introduction

Remote sensing offers cotton producers information with which they can possibly improve crop management and crop marketing. Remote sensing can give insight into the variability in soils and crop conditions, and as such is a precision-farming tool. It can also give advance notice of problems and/or marketing opportunities. If a producer had a predicted profit map at the beginning of the season, with improved prediction accuracy as the season progressed, there are many management and marketing improvements that he could make.

Literature Review

Pierce et al. (1998) stated that, because crop yield is the basis for input recommendations and a determinant of farm profitability, yield mapping is essential to the success of precision agriculture. The state of the art in yield monitoring has progressed slowly in cotton as compared to grain and bulk crops. However, it appears that cotton yield monitors are nearing the point at which their data will be reliable for management decisions and verification of remote-sensing based yield estimates.

Several researchers have attempted yield estimation with remote sensing data. According to Wiegand and Richardson (1990) and Wiegand et al. (1991), vegetation indices (e.g., normalized differential vegetative index, NDVI) calculated from remote spectral observations are good yield predictors. Yang and Anderson (1999) reported strong correlation (R^2 = 0.90) between red band reflectance and yield of a grain sorghum crop. Wiegand et al. (1991) reported fairly strong linear correlations between satellite-based spectral vegetation indices and cotton boll counts (R^2 = 0.76). Further, Thomasson et al. (2000) reported strong correlations between infrared remote-sensing data and cotton yield. It is partially on this basis that cotton yield estimates are expected to be possible from remote sensing data. Other significant relationships have been discovered between yield and soil fertility and texture, and between Landsat images and soil fertility and texture. Therefore, it appears reasonable that a combination of remote-sensing data and soil-property data could enable reasonable predictions of cotton yield, particularly in irrigated fields where soil-moisture content is relatively controlled. It is also expected that multi-temporal spectral reflectance data taken throughout the growing season will enhance the accuracy of crop yield estimates. In fact, Yang et al. (2000) reported that the correlations between multi-temporal remote-sensing data and grain sorghum yield steadily increased from the beginning of the growing season to the end.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:317-319 (2001)
National Cotton Council, Memphis TN

Another promising technology for improving agricultural management is that of crop-growth models. Development of physiological crop-growth models has been taking place for many years, and some of these models have found practical application in agricultural production. For example, Gossym-Comax (Baker et al., 1983) is a tested and widely accepted physiological cotton-growth model. Linkage with GIS has allowed crop models to be applied to regional studies (Lal et al., 1993) and field studies (Akins et al., 1999). Since crop-growth models and remote-sensing data can be linked with GIS, it is reasonable to consider incorporating remote-sensing data as input into crop-growth models. This has been done to a very limited extent in yield monitoring and forecasting; e.g., Potdar (1993) used the change in NDVI over time to calibrate a simple crop-growth equation.

Objectives

The objectives of this study were to investigate the possibility of predicting cotton yield in advance of harvest with the aid of remote sensing, and to consider the possible benefit of incorporating remote sensing in cotton growth models.

Methods

Study Site

In 1998, a field (field 1) of approximately 275 acres in a cooperating producer's operation near Vance, Mississippi, was selected for study. In 1999, a different field (field 3) of the same producer was selected. Both fields were planted from year to year in a cotton/other rotation, but were in cotton during their respective year of study.

Remote-Sensing Data

A multispectral image of field 1, from the Landsat 5 satellite, was acquired for June 20, 1998. Multispectral images of field 3, from the Landsat 7 satellite, were acquired for July 20 and September 6, 1999. Both Landsat 5 and 7 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 (Landsat 5) or 60-m (Landsat 7) resolution. 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. No attempt was made to atmospherically correct the image data.

Yield Data

In 1998, yield data were collected with a Micro-Trak cotton yield monitor mounted on a John Deere four-row cotton picker. In 1999, yield data were collected with a Zycom cotton yield monitor on the same picker.

Analysis

Every pixel in each Landsat image was overlaid with yield data in such a way that each yield data point was associated with a certain pixel. Since there were more yield data points than pixels, each pixel was associated with a group of yield data points. All groups of yield values associated with a pixel were averaged such that each pixel corresponded to one yield average. Then, for every pixel value within a given band, the yield averages were further averaged, such that for every pixel value represented in an image, there existed on overall yield average. Weighted linear regression was performed between pixel values and overall yield averages to determine the correlation between them. The regression was weighted on the number of pixels at a given value. This analysis was conducted for each spectral band and NDVI of each image collected during a growing season.

Results

After initial analyses, it was evident that band-4 images were the most highly correlated with yield, even more so than the vegetation index, NDVI. Weighted correlations between overall yield averages and pixel values were highly significant and predominantly linear. Figure 1 shows the data points and regression line ($R^2 = 0.88$) relating overall yield average to band-4 pixel values for field 1 in late June 1998. For pixel values from 101 to 122, which include almost all the data, the yield averages fall very close to the regression line. This implies that, within the range of most of the remote-sensing data, the relationship is very strong. Figure 2 shows the data points and regression line ($R^2 = 0.44$) relating overall yield average to band-4 pixel values for field 3 in late July 1999. The reason that the relationship is not as strong in this case is not obvious, but again the data points near the center of the pixel-value data (values of 208 to 231) do fit the regression line very well. Figure 3 shows the data points and regression line ($R^2 = 0.81$) relating overall yield average to band-4 pixel values for field 3 in early September 1999. The relationship exhibited here is very similar to that for field 1 in June 1998. Further, the improvement in the relationship from late July to early September, 1999, falls in line with earlier research suggesting that remote-sensing data correlate better and better with eventual yield as the season progresses.

Two things must be pointed out with respect to these analyses: (1) there is a large amount of scatter in the original data prior to averaging, and (2) the slopes and intercepts of the regression lines are quite different in each case. This means that, while there is a strong general relationship between remote-sensing data and yield in these examples, remote-sensing data by themselves could not have been used to predict yield with a reasonable degree of accuracy. If atmospheric correction had been performed, it is very possible that the slopes and intercepts would have been more similar. All things considered, it is more likely that remote-sensing data can be used in cotton yield prediction as a feedback mechanism to improve estimates made by crop-growth models.

Conclusions

This work showed that, in this particular case, infrared images acquired by a satellite sensor in advance of harvest were reasonably well correlated with cotton yield. It also appears that the correlation improves as the growing season progresses, and this idea is in line with previous research. These conclusions lend strong evidence to the idea that remote sensing can provide important information to improve cotton growth models.

References

Akins, D. C., J. L. Willers, J. M. McKinion, S. B. Turner, F. D. Whisler, and J. Varco. 1999. Integrating GIS into precision crop management. In *Proc Beltwide Cotton Conf.*, P. Dugger and D. Richter, eds., 395-399. Memphis, Tenn.: National Cotton Council of Am.

Baker, D. N., J. R. Lambert, and J. M. McKinion. 1983. GOSSYM: a simulation of cotton growth and yield. Technical Bulletin 1908. Clemson, S.C.: S.C. Agric. Experiment Station.

Lal, H., G. Hoogenboom, J. P. Calixte, J. W. Jones and F. H. Beinroth. 1993. Using crop simulation models and GIS for regional productivity analysis. *Trans. ASAE* 36:175-184.

Pierce, F. J., D. D. Warncke, and S.M. Swinton. 1998. Evaluation of site-specific management technology for sustaining and enhancing Michigan agriculture. Special Research Report 99. E. Lansing, Mich.: Mich. Agric. Exp. Sta.

Potdar, M. B. 1993. Sorghum yield modeling based on crop growth parameters determined from visible and near-IR channel NOAA AVHRR data. *Intl. J. Remote Sensing* 14(5):895-905.

Thomasson, J. A., J. Chen, J. R. Wooten, S. A. Shearer, and D. A. Pennington. 2000. Cotton yield prediction improvement with remote sensing. In *Proc. Beltwide Cotton Conf.*, P. Dugger and D. Richter, eds., 419-421. Memphis, Tenn.: National Cotton Council of Am.

Wiegand, C. L., and A. J. Richardson. 1990. Use of spectral vegetation indices to infer leaf area, evapotranspiration and yield. II. Results. *Agron. J.* 82(3):630-636.

Wiegand, C. L., A. J. Richardson, D. E. Escobar, and A. H. Gerbermann. 1991. Vegetation indices in crop assessments. *Remote Sensing Environ.* 35(2/3):105-119.

Yang, C., and G. L. Anderson. 1999. Airborne videography to identify spatial plant growth variability for grain sorghum. *Precision Agric.* 1(1):67-79. Boston: Kluwer Academic.

Yang, C., and J. H. Everitt. 2000. Relationships between yield monitor data and airborne multispectral digital imagery. In *Proc. 5th Int. Conf. on Precision Agric. (in press).* Bloomington, Minn.: Univ. of Minnesota Precision Agric. Center.

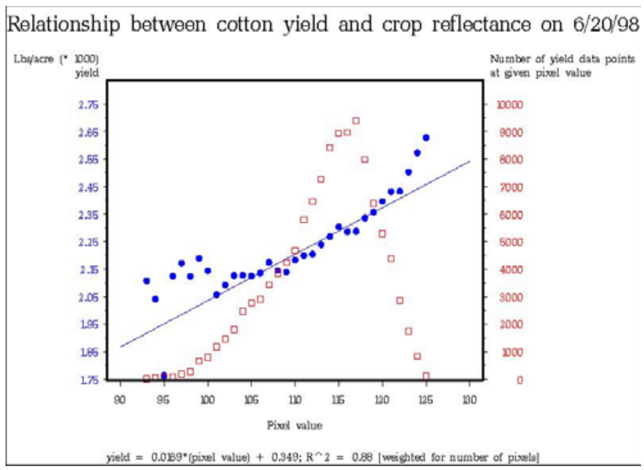

Figure 1. Plot of relationship and regression line between overall yield average and pixel value of Landsat band 4 image, field 1, June 20, 1998.

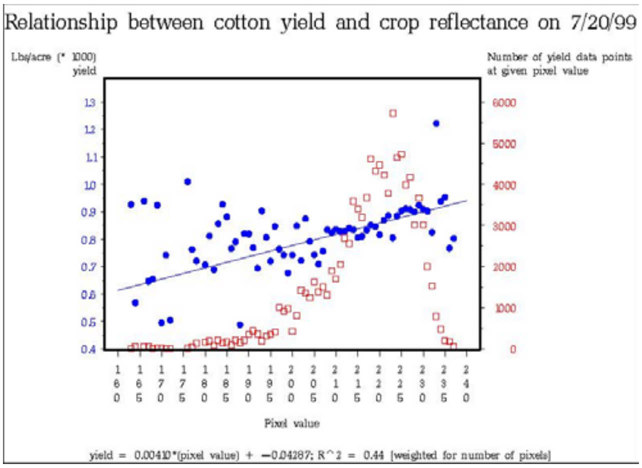

Figure 2. Plot of relationship and regression line between overall yield average and pixel value of Landsat band 4 image, field 3, July 20, 1999.

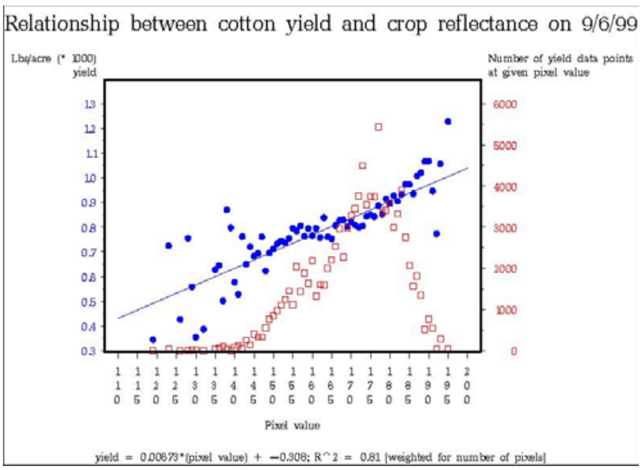

Figure 3. Plot of relationship and regression line between overall yield average and pixel value of Landsat band 4 image, field 3, September 6, 1999.