The *Journal of Cotton Science 15:274–281 (2011)*
http://journal.cotton.org, © The Cotton Foundation 2011

ENGINEERING AND GINNING

Cotton Revenue Apportioned between Lint Yield and Fiber Quality: A Precision Agriculture Perspective

Yufeng Ge, J. Alex Thomasson*, Cristine L.S. Morgan, Scott M. Stanislav, and Ruixiu Sui

ABSTRACT

Cotton fiber quality has been emphasized by breeders, ginners, and textile processors but not among growers as an in-season crop-management consideration. Whereas many studies have shown in-field cotton fiber-quality variation, the amount observed is usually small compared to that of lint yield, casting doubt on the usefulness of site-specific crop management for fiber-quality improvement. The goal of this study was to elucidate the inter-related effects of lint yield and fiber quality on in-field revenue variation. With more clarity in this regard, growers can better understand how to improve revenue and potentially profit, and determine whether it would be worthwhile for them to manage fiber quality on a site-specific basis. Field studies were conducted in two cotton fields near College Station, Texas. Lint yield and fiber quality data were collected. Loan-rate maps were produced by integrating fiber-quality parameter maps with the USDA-CCC Loan Schedules, and gross revenue maps were produced by combining lint-yield and loan-rate maps. In-field variation of revenue was separated into two components: one associated with in-field variation of lint yield and the other associated with in-field variation of fiber quality. The results showed that, for the first field, the standard deviation (SD) of revenue was \$181 ha^{-1} (\$73.2 ac.$^{-1}$), with fiber quality variation being about 13% as important as yield variation. In the second field, the SD of revenue was \$216 ha^{-1} (\$87.4 ac.$^{-1}$), with fiber quality variation being about 31% as important. While lint yield was the primary factor in determining overall revenue, the contribution of fiber quality was substantial and should not be overlooked, especially when high input costs and small profit margins are considered.

Precision agriculture (also known as site-specific crop management) is based on the idea that in-field variation exists in soils and crops (Pierce and Nowak, 1999). Opportunities exist for growers to vary in-field inputs accordingly in an effort to increase profitability and improve environmental stewardship. Precision-agriculture research has generally focused on crop yield, partly due to the advent of yield monitors for various crops, which have enabled yield mapping within fields. Recently, interest has grown in site-specific management for crop quality, which is important in increasing growers' revenue and profits (Huang et al., 2008). McBratney et al. (2005) listed "assessment of crop quality" as a critical issue that needs to be addressed in future precision-agriculture research. Some researchers have quantified in-field variation of quality indices for various crops such as soybean (Kravchenko and Bullock, 2002), wheat (Stewart et al., 2002), and sugar cane (Johnson and Richard, 2005). *In-situ* crop quality sensors that can be mounted on harvesters and produce high-resolution crop-quality maps have also been researched (Taylor et al., 2005; Montes and Paul, 2007; Sui et al., 2008).

The importance of cotton fiber quality has been emphasized among breeders, ginners, and textile processors, but it has generally not been critical to growers while their crop is growing in the field. Yield has been the main issue for growers, and fiber quality has influenced only their variety selection prior to planting. A grower's view of cotton loan rates (determined by several fiber quality parameters, such as color and micronaire) is mostly in terms of a price adjustment applied to a cotton bale, rather than as a revenue component that may be spatially variable in the field. High quality bales are sought through improved harvest, storage, and ginning and handling methods, but the potential for optimizing fiber quality during production through field management has been largely overlooked. Many believe that cotton fiber quality is determined by genetics (e.g., Bradow and Davidonis, 2000), but a number

Y. Ge and J.A. Thomasson*, Biological & Agricultural Engineering Department, Texas A&M University, College Station, TX 77843; C.L.S. Morgan and S. M. Stanislav, Soil & Crop Sciences Department, Texas A&M University, College Station, TX 77843; and R. Sui, USDA/ARS Cotton Ginning Research Unit, Stoneville, MS 38776
*Corresponding author: thomasson@tamu.edu

of recent studies have shown that in-field variation of cotton fiber quality exists and is significantly related to soil properties, pointing to the possibility of site specific management for fiber quality improvement (Elms et al., 2001; Johnson et al., 2002; Ping et al., 2004).

One critical question that has not been answered by these studies is as follows: is it economically advantageous for cotton growers to consider fiber-quality variability during crop production? Unlike lint yield, which is directly proportional to a grower's revenue, fiber quality parameters have a rather complex and non-linear relationship with revenue. It is thus useful to convert fiber-quality variation into economic terms ($ ha^{-1} or $ ac.$^{-1}$) so that the importance of fiber quality can be directly compared with that of lint yield. Such a comparison would help growers to understand the factors affecting their revenue, and whether it would be worthwhile to implement site-specific management inclusive of fiber quality. In a recent study, Ge et al. (2008) found that loan rate varied as much as $0.2 kg^{-1}($0.09 lb^{-1}) in a 12-ha (30-ac.) cotton field in Texas. They concluded that fiber-quality variability can have a large impact on growers' revenue, and they recommended a site-specific management system encompassing both yield and fiber quality. Their analysis, however, did not quantify the contributions that variability in yield and fiber quality make to revenue variability. The overall goal of this research is thus to build upon the previous work by elucidating in-field variation of revenue in cotton fields in terms of how it can be apportioned to lint yield and fiber quality. The specific objectives are (1) to map overall revenue of example cotton fields including both lint yield and fiber-quality information, and (2) to separate the variation of overall revenue into lint-yield and fiber-quality components.

MATERIALS AND METHODS

A field experiment was conducted in two cotton fields on a Texas AgriLife Research farm near College Station, Texas in 2007 and 2008. The first field, referred to as the 2007-river field, consists of 14 ha (35 ac.) of dryland farm in a cotton-corn rotation. Dominant soil types in this field include Ships clay (very-fine, mixed, active, thermic Chromic Hapluderts) and Weswood silt loam and silty clay loam (fine-silty, mixed, superactive, thermic Udifluventic Haplustepts). A mixture of several FiberMax varieties (Bayer CropScience, Research Triangle Park, N.C.) was planted at a uniform rate of 100,000 seeds ha^{-1}(40,000 seeds ac.$^{-1}$) with a row spacing of 1.0 m (40 in.). The second field (also in a cotton-corn rotation), referred to as the 2008-I3 field, is about 12 ha (30 ac.) in size and under a center-pivot irrigation system. The soil in this field is predominantly Belk clay (fine, mixed, active, thermic Entic Hapluderts), with a small area of Weswood silty clay loam and Yahola fine sandy loam (coarse-loamy, mixed, superactive, calcareous, thermic Udic Ustifluvents). The cotton variety, DPL 164B2RF (Delta Pine & Land Company, Scott, Miss.), was planted in this field at an average rate of 100,000 seeds ha^{-1} (40,000 seeds ac.$^{-1}$) with a row spacing of 0.76 m (30 in.). Field management practices including seed bed preparation, fertilization, and applications of chemicals (herbicides, insecticides, growth regulators, and defoliants) followed recommendations made by Texas AgriLife Extension Service.

The 2007-river field was harvested with a John Deere six-row picker, and cotton yield information was recorded with its onboard GreenStar yield-monitor system. The raw seed cotton yield data were calibrated with a module-specific post-calibration method (Ge et al., 2009), adjusted to lint yield, and cleaned by following steps suggested by Sudduth and Drummond (2007) for yield and gross revenue mapping. To quantify the spatial variation of fiber quality, 51 sampling points were laid out on a 50.0 x 50.0m (164 x 164 ft) regular grid (Fig. 1). A total of roughly 0.45 kg (1.0 lb) of seed cotton was hand-harvested from at least eight plants at each sampling location. The bulk samples were ginned with a laboratory-scale saw gin at Texas A&M University's Cotton Improvement Lab.

In the 2008-I3 field, stratified sampling was applied (three strata developed from an EM38 soil apparent electrical-conductivity map) to select 36 sampling locations (12 random locations in each stratum) for seed cotton sampling (Fig. 1). At each location, a 4-m^2 (0.001 ac.) area was designated, and all cotton bolls within the area were hand-picked three days after defoliants were applied. Seed cotton was separated from bolls, ginned with the same laboratory saw gin, and weighed for lint yield determination. For each lint sample, a subsample (around 150 g, or 0.33 lb) was separated for fiber quality determination. In addition, another 18 sampling locations (six random locations in each stratum) were selected and sampled with the same hand harvesting method as in 2007 for quality measurement only (Fig. 1). Therefore, a total of 54 (36 + 18) fiber quality samples were obtained in 2008. It should be noted that a variable-rate seeding trial was also being conducted in this field (Stanislav et al., 2009), and the samples were thus also being collected to investigate the effects of seeding rate on lint yield and fiber quality. No statistically significant differences in either lint yield or fiber quality were found with respect to seeding rate, so it is reasonable to assume that in-field variation of cotton was due to natural soil-plant-microclimate interactions and not experimentally imposed seeding rates.

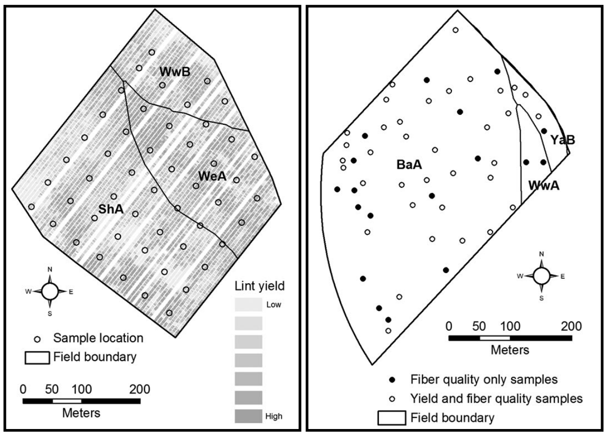

Figure 1. The 2007-river (left) and the 2008-I3 (right) study fields. For the 2007-river field, the calibrated and cleaned yield monitor data were overlaid with fiber quality sampling locations. Major soil types are ShA (Ships clay), WeA (Weswood silt loam), and WwB (Weswood silty clay loam). For the 2008-I3 field, sample locations for both lint yield and fiber quality determination and those for fiber quality determination only were distinguished. Soil types are BaA (Belk clay), WwA (Weswood silty clay loam), and YaB (Yahola fine sandy loam).

In both years lint samples were sent to the Fiber and Biopolymer Research Institute (Lubbock, Texas) for High Volume Instrument (HVI) fiber-quality measurement. The HVI parameters relevant for loan-rate and revenue mapping are micronaire, fiber length, length uniformity, fiber strength, reflectance (Rd), and yellowness (+b).

Loan rate and gross revenue mapping. Lint-yield and fiber-quality data were first summarized in terms of minimum value, mean, maximum value, standard deviation (SD), and coefficient of variation (CV). Fisher's protected least significant difference (LSD) test was applied to compare HVI fiber-quality parameters between the years. A common grid of 6.0 x 6.0 m (20 x 20 ft) was used to produce lint-yield and fiber-quality parameter (e.g., micronaire, fiber strength) map layers for both fields. For cases in which a variable exhibited apparent spatial correlation, ordinary kriging was used to interpolate the sample data; otherwise, the inverse distance weighted (of order two) method was used.

The final cotton loan rate is equivalent to the base loan rate (\$1.14 kg^{-1}, or \$0.52 lb^{-1}, in 2007 and 2008) adjusted by premiums or discounts. According to the USDA-CCC Loan Schedule (USDA, 2007 and 2008), premiums and discounts are determined with four loan-rate components: (1) length and color and leaf grade (LCL, jointly determined by fiber length, Rd, +b, and leaf grade), (2) micronaire, (3) fiber strength, and (4) length uniformity. Therefore, fiber-quality parameter map layers were converted to respective loan-rate component map layers based on the Loan Schedule. The Loan Schedules of 2007 and 2008, which differed slightly from one another, were used to create the loan-rate layers of their respective crops years for loan-rate mapping. The loan-rate layers were then overlaid with the base loan to produce the final loan-rate map.

Once the lint-yield and loan-rate maps were produced, the gross revenue map was calculated with the following equation.

$$GR = LY \times LR \tag{1}$$

where GR is gross revenue (\$ ha^{-1}or \$ ac.$^{-1}$); LY is lint yield (kg ha^{-1} or lb ac.$^{-1}$); and LR is loan rate (\$ kg^{-1} or \$ lb^{-1}).

Revenue decomposition. The following equation was used to decompose the overall gross revenue into different components.

$$GR = (LY_m + \Delta LY) \times (LR_m + \Delta LR) \tag{2}$$

where LY_m is the field mean of lint yield; ΔLY represents the offset of lint yield at each grid cell from the field mean; LR_m is the field mean of loan rate; and ΔLR is the offset of loan rate at each grid cell from its field mean.

Eq. 2 can be expanded and rearranged as:

$$GR - LY_m \times LR_m = \Delta LY \times LR_m + LY_m \times \Delta LR + \Delta LY \times \Delta LR \tag{3}$$

where

- the left hand side of the equation is field-mean-adjusted gross revenue
- the first term on the right hand side – yield offset times mean loan rate – can be regarded as the portion of gross revenue variation attributable to lint yield
- the second term – loan rate offset time mean yield – can be regarded as the portion of gross revenue attributable to loan rate (or fiber quality)
- the last term – yield offset times loan rate offset – reflects the interaction between lint yield and loan rate, and presumably its amplitude is negligible compared to the first two components.

Again, Eq.3 decomposes the in-field variation of gross revenue (mean centered) into two primary components: one associated with in-field variation of lint yield, and the other associated with in-field variation of loan rate (or equivalently, fiber quality). By comparing maps of these components (particularly their magnitudes of spatial variation), one can determine to what extent each component contributes to the overall variation of gross revenue in the field. The last term on the right hand side of equation 3 accounted for very little variability and was thus neglected, so the separation of gross revenue is approximate. However, it is a very useful estimate for disentangling the inter-related lint-yield and fiber-quality effects on overall revenue and allowing a direct comparison between them.

Summary statistics and spatial-correlation modeling were performed with the R statistical software package (R Development Core Team, 2008). Mapping of lint yield, loan rate, and revenue were performed with ArcMap9.2 (ESRI, Redlands, Cal.), along with raster analysis for revenue decomposition.

RESULTS AND DISCUSSION

Table 1 gives the minimum value, mean, maximum value, SD, and CV for lint yield and six HVI fiber-quality parameters for both study fields. Lint yield in 2007 was much lower than in 2008. Fiber quality parameters in 2007 had significantly higher micronaire, uniformity, strength, and Rd than in 2008, but significantly lower +b and comparable fiber length. These differences indicated more mature fibers in 2007, which contributed to superior overall fiber quality and higher loan rate. It is important to note that, because the lint yield information in 2007 was from yield monitor data calibrated to the gin bale weight, there was likely some yield loss due to mechanical picking and ginning. In addition, different cotton varieties were planted in the two fields. Therefore, it is difficult to make inferences from agronomic and growing-environment perspectives as to why cotton had higher lint yield in one year but superior fiber quality in the other.

The CV for fiber quality parameters was much smaller than that of lint yield, a finding that is consistent with several other studies (Elms et al., 2001; Johnson et al., 2002; Ping et al., 2004; Ge et al., 2008). The relatively low level of fiber quality variation is a possible reason that cotton fiber quality is not given much consideration for site-specific crop management. However, due to the nonlinear relationship between loan premiums (or discounts) and fiber quality parameters, and the fact that loan premiums (or discounts) are applied to entire bales, CV is not exactly a straightforward indicator of the importance of fiber quality to gross revenue. The lowest micronaire found in 2008 was 2.96. Compared to the field average of 3.78, this low value results in a discount of nearly \$0.09 kg^{-1} (\$0.04 lb^{-1}) (USDA, 2008). Applying this value to the average lint yield of 1173 kg ha^{-1} (1047 lb ac.$^{-1}$), a revenue loss of \$106 ha^{-1}(\$42.9 ac.$^{-1}$) would result. The lowest fiber length found in 2007 was 26.7 mm (34/32 in.), while the field average was 29.1 mm (37/32 in.), indicating a discount of over \$0.09 kg^{-1} (\$0.04 lb^{-1}) (USDA, 2007), assuming color and leaf grade of 31-2. Applying this value to the average lint yield of 822 kg ha^{-1} (733 lb ac.$^{-1}$), a revenue loss of \$74 ha^{-1} (\$30 ac.$^{-1}$) would result. Therefore, even though the in-field variation of fiber quality parameters appears small, it may have a strong influence on the growers' revenue.

Table 1. The minimum value, mean, maximum value, standard deviation (SD), and coefficient of variation (CV) of lint yield and high volume instrument fiber quality parameters for the two study fields.

	2007-River					2008-I3				
Variables	Min.	Mean[z]	Max.	SD	CV (%)	Min.	Mean	Max.	SD	CV (%)
Yield (kg ha^{-1}) [y]	392	822	1184	138	16.7	596	1173	1797	246	21.0
Micronaire	3.76	4.51 [a]	5.00	0.25	5.6	2.96	3.78 [b]	4.88	0.40	10.6
Length (mm)	26.7	29.1 [a]	31.2	1.1	3.7	27.4	29.3 [a]	31.8	1.1	3.8
Uniformity	80.5	82.6 [a]	84.6	1.0	1.2	79.1	82.1 [b]	84.6	1.2	1.4
Strength (g tex^{-1})	26.3	30.0 [a]	34.6	1.7	5.6	23.2	26.8 [b]	29.9	1.8	6.8
Rd	75.6	79.4 [a]	83.8	1.8	2.3	67.2	71.3 [b]	80.0	2.7	3.8
+b	6.2	7.4 [b]	8.7	0.6	7.9	7.6	8.8 [a]	9.8	0.5	6.0

[z] **Fisher's protected Least Significant Difference was implemented to compare the mean of fiber quality parameters in different years. Values followed by different letters (a and b) are significantly different from each other at 0.01 level.**

[y] **Lint yield in the 2007-river field was based on data from the John Deere GreenStar yield monitor system, and lint yield in the 2008-I3 field was estimated from 36 hand harvested cotton samples.**

Figures 2 and 3 show the spatial variation of cotton lint yield, loan rate, and gross revenue for both study fields. In the 2007-river field, the loan rate ranged from less than \$1.19 kg^{-1}(\$0.54 lb^{-1}) to greater than \$1.32 kg^{-1}(\$0.60 lb^{-1}). The field average loan rate was \$1.26 kg^{-1} (\$0.57 lb^{-1}), or \$0.12 kg^{-1}(\$0.05 lb^{-1}) greater than the base loan of \$1.14 kg^{-1}(\$0.52 lb^{-1}), and the SD was \$0.027 kg^{-1}(\$0.012 lb^{-1}). In the 2008-I3 field, the loan rate ranged from less than \$1.07 kg^{-1}(\$0.49 lb^{-1}) to greater than \$1.19 kg^{-1}(\$0.54 lb^{-1}). The field average was \$1.12 kg^{-1} (\$0.51 lb^{-1}) – \$0.02 kg^{-1}(\$0.01 lb^{-1}) less than the base loan rate – and the SD was \$0.047 kg^{-1}(\$0.021 lb^{-1}). The 2007-river field had a much higher average loan rate (or higher average quality), but the 2008-I3 field had greater loan rate variation (or greater quality variation). Micronaire and LCL combined contributed most to the variation of loan rate in the 2008-I3 field. In the 2007-river field, more mature fibers meant that micronaire tended to fall into the same price categories (base rate and a premium of \$0.0044 kg^{-1}, or \$0.002 lb^{-1}), and LCL became the major contributor to loan rate. The greater micronaire variation, and the fact that its cotton falls into several loan-rate discount categories, are the main reasons why the 2008-I3 field had greater in-field variation of loan rate.

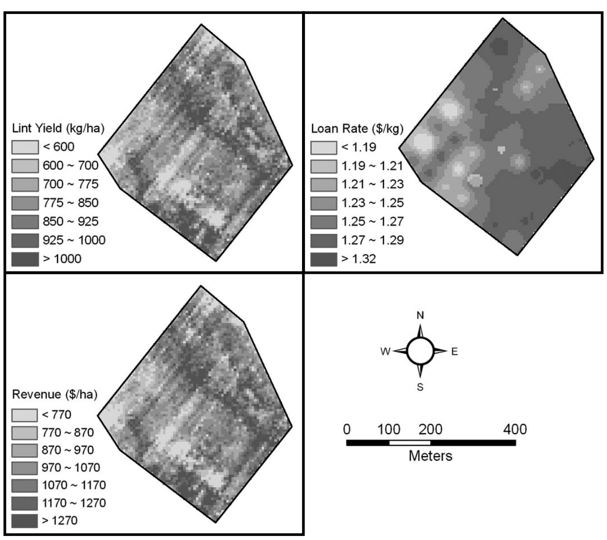

Figure 2. Spatial maps of lint yield, loan rate (determined by fiber quality parameters), and gross revenue for the 2007-River field.

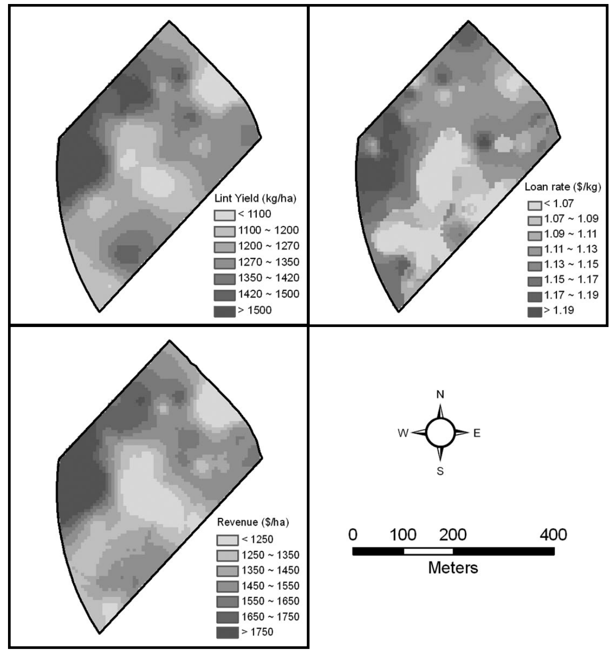

Figure 3. Spatial maps of lint yield, loan rate (calculated from fiber quality parameters), and gross revenue for the 2008-I3 study field.

Lint yield in the 2007-river field exhibited a somewhat less structured pattern. High yield areas were in the southwestern and northeastern portions of the field (shown as two transects running NW to SE in Fig 2.); and low yield areas were in the western and northern corners and a patch near the southwestern edge. However, the loan-rate map in this field exhibited a remarkably different pattern, with values increasing gradually from west to east. In 2008-I3, high lint yield was found primarily in the western corner and a small patch near the southern corner, and yield was low in the central portion and a small patch at the northeastern edge of the field. The spatial pattern of loan rate was somewhat similar to that of lint yield in this field, with high loan rate values also found in the western corner and low values in central portion of the field. The main difference was in the southern corner where lint yield and loan rate patterns were reversed (high yield but low loan rate). The dissimilarity between lint yield and loan rate maps (particularly in the 2007-river field) indicated that lint yield and fiber quality can respond differently toward environmental and agronomic factors. This fact provides growers some incentive to formulate specific strategies to manage lint yield and fiber quality.

Gross revenue in the 2007-river field ranged from less than \$770 to greater than \$1270 ha^{-1} (\$312 to greater than \$514 ac.$^{-1}$), with a mean revenue of \$1038 ha^{-1} (\$420 ha^{-1}). In 2008-I3, gross revenue ranged from less than \$1120 to greater than \$1520 ha^{-1} (\$453 to greater than \$615 ac.$^{-1}$), with a mean revenue of \$1315 ha^{-1} (\$532 ac.$^{-1}$). It is notable that in both fields, the spatial patterns of revenue were similar to those of lint yield, indicating that in-field variation of lint yield is the dominant factor determining the overall variation of gross revenue.

The lint yield and fiber quality contributions to overall gross revenue in the 2007-river and 2008-I3 fields, as calculated from Eq. 3, are shown in Figs. 4 and 5. As expected, the interaction term on the right side of Eq. 3 is essentially zero, and the corresponding maps were not shown. The color maps in Figs. 4 and 5 are drawn at the same scale so that a visual comparison can be made. The contribution from lint yield is clearly larger than that from fiber quality (loan rate) for both fields. Table 2 gives the range and SD of both components. In the 2007-river field, the SD of gross revenue, yield contribution, and fiber quality contribution were \$181, \$173, and \$23 ha^{-1} (\$73.2, \$70.0, and \$9.3 ac.$^{-1}$), respectively. In the 2008-I3 field, the SDs were \$216, \$178, and \$55 ha^{-1} (\$87.4, \$72.0, and \$22.3 ac.$^{-1}$), respectively. These numbers reconfirm the dominance of lint yield in determining gross revenue. However, the fractions attributable to fiber quality are larger (particularly for the 2008-I3 field) than may have been expected when considering the small CVs for all the fiber quality parameters (Table 1). Particularly interesting, the SDs of yield contributions were quite comparable to each other in 2007 and 2008 (\$173 vs. \$178 ha^{-1}, or \$70.0 vs. \$72.0 ac.$^{-1}$), and the larger in-field variation of revenue in 2008 could clearly be attributed to the greater in-field variation of fiber quality.

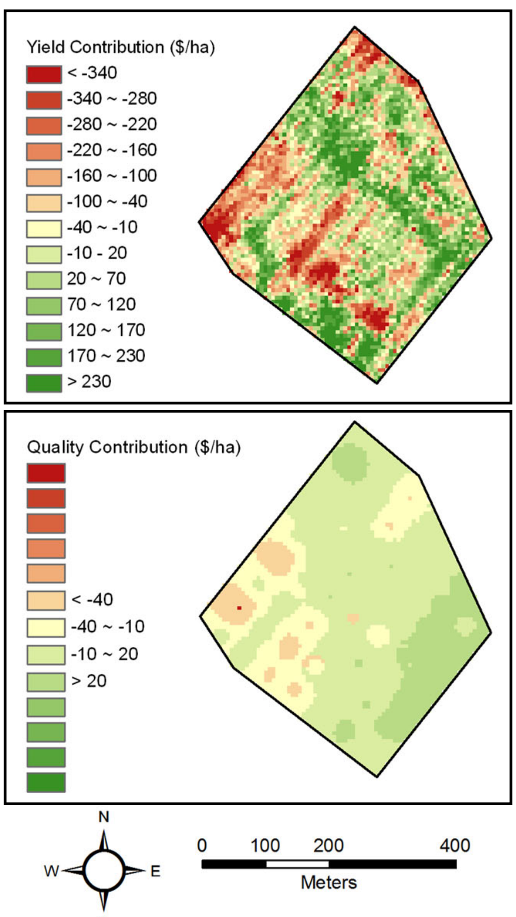

Figure 4. Maps based on revenue decomposition, elucidating the lint yield and fiber quality contributions to the overall field variation of gross revenue in the 2007-River study field. Color maps are drawn at the same scale so that a direct visual comparison can be made.

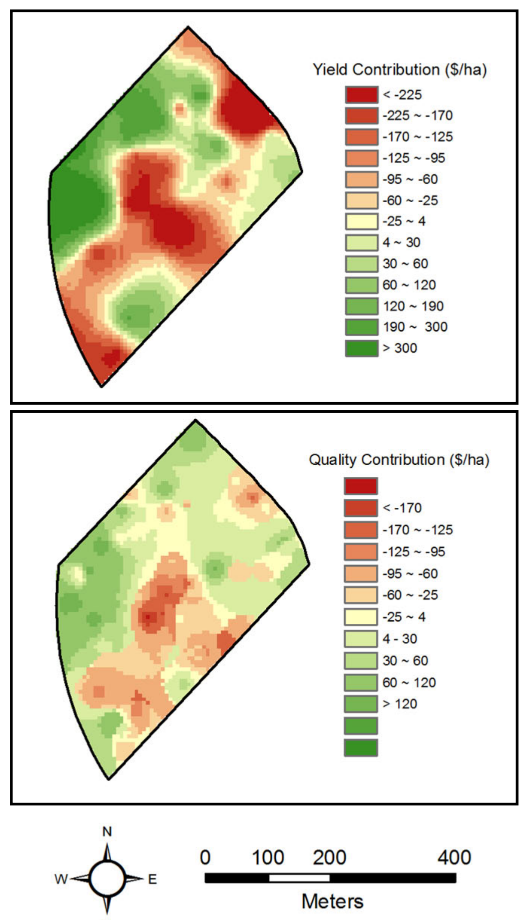

Figure 5. Maps based on revenue decomposition, elucidating the lint yield and fiber quality contributions to the overall field variation of gross revenue in the 2008-I3 study field. Color maps are drawn at the same scale so that a direct visual comparison can be made.

Table 2. Summary of in-field range and standard deviation (SD) of overall revenue, lint yield contribution, and fiber quality contribution in the study fields.

	2007-River		2008-I3	
	Range	SD	Range	SD
Overall revenue ($ ha^{-1})^{z}	-534 to 455	181	-638 to 794	216
Yield contribution ($ ha^{-1})	-542 to 456	173	-628 to 680	178
Fiber quality contribution ($ ha^{-1})	-101 to 43	23	-174 to 168	55

^{z} The range of overall revenue was adjusted from its field mean as in the left hand side of Eq. 3.

From a site specific management standpoint, if the areas in the lower half of fiber quality could have been improved to match the higher half, the potential economic return would have been roughly \$15 ha^{-1} (\$6.1 ac.$^{-1}$) for 2007 and \$40 ha^{-1} (\$16 ac.$^{-1}$) for 2008. These figures were calculated based on the inter quartile ranges (\$30 and \$80 ha^{-1}, or \$12 and \$32 ac.$^{-1}$, for 2007 and 2008, respectively) of the fiber quality contribution (to overall revenue) as shown in Figs. 4 and 5. Such numbers become particularly important when considering the high production cost and low profit margins typical for cotton growers. Field records in this study showed an average production cost of \$1000 ha^{-1} (\$405 ac.$^{-1}$) for the 2007-river field (disregarding labor, equipment depreciation, crop insurance, and general farm overhead, which are difficult to estimate on a research farm). An average production cost of \$1300 ha^{-1} (\$526 ac.$^{-1}$) was estimated in the same way for 2008-I3, including an extra \$265 ha^{-1} (\$107 ac.$^{-1}$) for irrigation and \$35 ha^{-1} (\$14 ac.$^{-1}$) for increased harvesting costs. Therefore, the profit margin was \$38 ha^{-1} (\$15 ac.$^{-1}$) in 2007-river and \$15 ha^{-1} (\$6.1 ac.$^{-1}$) in 2008-I3. It is clear that potential fiber-quality-management-based profit improvements on the order of \$15 ha^{-1} (\$6.1 ac.$^{-1}$) and \$40 ha^{-1} (\$16 ac.$^{-1}$), respectively, are significant and should not be overlooked.

Hand-picked cotton samples were used in this study for fiber-quality and loan-rate mapping. Hand-picked cotton usually has superior fiber quality and higher loan rate than cotton that is machine-harvested and processed in commercial gins. In both 2007 and 2008, nearly half of the samples in this study had fiber-length from 29.4 to 31.8 mm (37/32 to 40/32 in.), all of which fell into the same length-price category. Records from this study indicated an average fiber-length reduction of 1.2 mm (1.5/32 in.) between hand-picked plus lab-ginned cotton and machine-picked plus commercially ginned cotton. Thus, it is to be expected that commercially produced cotton will have lower fiber length, possibly causing a wider variation in price. For example, if the length variation were from 26.2 to 28.6 mm (33/32 to 36/32 in.), four length-price categories would be covered. In other words, the same level of fiber-length variability with a lower average value has a greater effect on price. Therefore, it is reasonable to expect that in-field variation of fiber quality, and thus its contribution to overall revenue variation, would be greater if post-harvest fiber quality (which is more realistic) were considered. In addition, the two cotton fields in this study were relatively small (14 and 12 ha, or 35 and 30 ac.) and had moderate variation in fiber quality (e.g., micronaire from 3.76 to 5.00 in 2007). As larger fields are considered, the degree of variation in soil types and fiber quality (and thus its contribution to overall revenue) could increase.

CONCLUSION

A two year field study was conducted (1) to map overall revenue (considering lint yield and fiber quality) in cotton fields and (2) to separate the variation of revenue into lint-yield and fiber-quality components. In both years, the CV of HVI fiber quality parameters was lower than that of lint yield. While lint yield was higher in the 2008 field (average yield of 1173 kg ha^{-1}, or 1047 lb ac.$^{-1}$) than in the 2007 field (average yield of 822 kg ha^{-1}, or 733 lb ac.$^{-1}$), fiber quality in the 2007 field was superior (average loan rate of \$1.26 kg^{-1}, or \$0.57 lb^{-1}) to that of the 2008 field (an average loan rate of \$1.12 kg^{-1}, or \$0.51 lb^{-1}).The average revenue was \$1038 ha^{-1} (\$420 ac.$^{-1}$) in the 2007 field and \$1315 ha^{-1} (\$532 ac.$^{-1}$) in the 2008 field. In both fields, the spatial patterns of lint-yield maps and revenue maps were similar, meaning that yield dominated revenue relative to fiber quality. However, an approximate decomposition of revenue variation showed that, in 2007, fiber quality was 13.3% as important in determining total revenue as yield (\$23 ha^{-1} / \$173 ha^{-1}, or \$9.3 ac.$^{-1}$ / \$70 ac.$^{-1}$). In 2008, fiber quality was 30.9%

as important in determining total revenue as yield. Such numbers indicate a smaller but economically important contribution of fiber quality to the overall revenue for cotton growers. Adding fiber quality to yield as another parameter to be optimized during cotton production appears to have merit, as it has the potential to substantially improve overall profit.

ACKNOWLEDGEMENTS

The authors would like to thank Texas AgriLife Cropping Systems Program for funding this project.

REFERENCES

Bradow, J.M., and G.H. Davidonis. 2000. Quantitation of fiber quality and the cotton production-processing interface: A physiologist' perspective. J. Cotton Sci. 4:34-64.

Elms, M.K., C.J. Green, and P.N. Johnson. 2001. Variability of cotton yield and quality. Commun. Soil Sci. Plant Anal. 32:351–368.

Ge, Y., J.A. Thomasson, R. Sui, C.L. Morgan, S.W. Searcy, and C.B. Parnell. 2008. Spatial variation of fiber quality and associated loan rate in a dryland cotton field. Precis. Agric. 9:181-194.

Ge, Y., J.A. Thomasson, R. Sui, and C.L.S. Morgan. 2009. A module-specific post-processing calibration method to improve cotton yield mapping. Comput. Electron. Agric. 68:61-167.

Huang, H., H. Yu, H. Xu, and Y. Ying. 2008. Near infrared spectroscopy for on/in-line monitoring of quality in foods and beverages: A review. J. Food Eng. 87:303-313.

Johnson, R.M., R.G. Downer, J.M. Bradow, P.J.Bauer, and E.J. Sadler. 2002. Variability in cotton fiberyield, fiber quality, and soil properties in a southeastern coastal plain. Agron. J.94:1305–1316.

Johnson, R.M., and E.P. Richard, Jr. 2005. Sugarcane yield, sugarcane quality, and soil variability in Louisiana. Agron. J. 97:760-771.

Kravchenko, A.N., and D.G. Bullock. 2002. Spatial variability of soybean quality data as a function of field topography: I. Spatial data analysis. Crop Sci. 42:804-815.

McBratney, A., B. Whelan, and T. Ancev. 2005. Future directions of precision agriculture. Precis. Agric. 6:7-23.

Montes, J.M., and C. Paul. 2007. Near infrared spectroscopy on agricultural harvesters: Technical aspects. NIR News 19:10-12.

Pierce, F.J., and P. Nowak. 1999. Aspect of precision agriculture. Advances Agron. 67:1-47.

Ping, J.L., C.J. Green, K.F. Bronson, R.E. Zartman, andA.D. Doberman. 2004. Identification of relationships between cotton yield, quality, and soil properties. Agron. J. 96:1588–1597.

R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL: http://www.R-project.org.

Stanislav, S., C. Morgan, A. Thomasson, R. Sui, and T. Cothren. 2009. Implementing soil-specific seeding rates to increase field-scale cotton lint quality. p. 1249-1254. *In* Proc.Beltwide Cotton Conf., San Antonio, TX. 5-8 Jan. 2009. Natl. Cotton Counc. Am., Memphis, TN.

Stewart, C.M., A.B. McBratney, and J.H. Sherritt. 2002. Site-specific durum wheat quality and its relationship to soil properties in a single field in northern New South Wales. Precis. Agric. 3:155-168.

Sudduth, K.A., and S.T. Drummond. 2007. Yield Editors: Software for removing errors from crop yield maps. Agron. J. 99:1471-1482.

Sui, R., J.A. Thomasson, Y. Ge, C.L. Morgan. 2008. Multispectral sensor for in-situ cotton fiber quality measurement. Trans. ASABE 51:2201-2208.

Taylor, J., B. Whelan, L. Thylen, M. Gilbertsson, and J. Hassal. 2005. Monitoring wheat protein content on harvester: Australian experiences. p. 369-375.*In* J.V. Stafford (ed.) Precision Agriculture '05: Proc. 5th European Conf. on Precision Agriculture, Uppsala, Sweden. 8-11 Jun. 2005. Wageningen Academic Publisher, Wageningen, The Netherlands.

USDA. Farm Service Agency. 2007. 2007 CCC loan schedule of premiums and discounts for upland and ELS cotton.

USDA. Farm Service Agency. 2008. 2008 CCC loan schedule of premiums and discounts for upland and ELS cotton.