FIELDPRINT CALCULATOR: INFLUENCE OF MANAGEMENT PRACTICES ON COTTON SUSTAINABILITY

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Abstract

The Field to Market Fieldprint Calculator is an educational tool that provides producers with general information on which management strategies are most likely to improve or lessen their impacts, or 'Fieldprint', on energy use, climate impact, soil loss and water quality and use. The objective of this project is to collect cotton production data and to use the metrics provided by the Field to Market Fieldprint Calculator to compare traditional management strategies to newly adopted strategies, with the overall goal of increasing the sustainability of cotton production. By entering data from Tennessee cotton producers into the Fieldprint Calculator, several production factors were identified that heavily influenced overall sustainability including: yield, fertilizer application, irrigation, and various soil health related practices. The use on no-till substantially decreased the amount of soil loss and energy use as compared to conventional tillage practices. Cover crops decrease soil loss throughout the year by providing cover and root infrastructure for soil stability. The use of cover crops improved the water quality index metric in the Calculator, as well as reduced the energy use and greenhouse gas emissions because less synthetic nitrogen was required in fields with legume cover crop species. Data collected of irrigated fields showed that proper irrigation scheduling and management could have a significant impact on sustainability. In most fields, variable rate application (VRA) of fertilizers was found to reduce the amount of energy used and greenhouse gases emitted because less fertilizer, on average, was applied than the producer's traditional uniform rate. In turn, this reduces the amount of nutrients that could ultimately pollute surrounding waterbodies. Using the Fieldprint calculator to compare management practices demonstrates that being sustainable and reducing 'Fieldprints' can not only increase producers' profitability, but also reduce the impacts from agriculture on the environment.

Introduction

Cotton production is facing scrutiny by the public and changing consumer expectations on their perception that cotton is not sustainable. It is a common goal among commodity associations, federal and state departments of agriculture, and various others to take a proactive stance in defining sustainability and informing the public that agriculture has sustainability goals. Sustainability not only includes environmental goals, but should be economically and socially sound as well. This means that an unprofitable management practice that is environmentally beneficial is not necessarily sustainable, nor is a profitable management practice that negatively impacts the environment.

The Field to Market Fieldprint Calculator is a free, online resource for producers to see how sustainable their production system is and also identify ways it can be improved. To use the calculator, the field must be spatially located then information is entered pertaining to crop rotation, management system, transportation, and drying. The quantified output metrics and their corresponding units include: land use (derived from total land area used to produce the crop), soil conservation (tons of soil per year per pound of lint produced), soil carbon (soil conditioning index), irrigation water use (acre-inch of water applied per pound of lint produced), energy use (BTU per pound of lint produced), greenhouse gas emissions (pounds CO_2e per pound of lint produced), and a water quality index that estimates surface water quality. These metrics are then plotted on a spidergram, whose axes are relative indices representing the resource use per pound of lint produced in each of the resource metric areas. Lower values closer to the center of the spidergram indicate a lower impact on each resource.

The objective of this project is to collect actual production data and to use the metrics provided by the Fieldprint Calculator to compare traditional management strategies to newly adopted strategies, with the overall goal of increasing the sustainability of cotton production as well as public awareness. The calculator provides producers with general information on what management strategies are most likely to improve or lessen their impacts, or 'Fieldprint', on energy use, climate impact, soil health and water use and quality. By entering data from Tennessee cotton producers into the Fieldprint Calculator, several production factors were identified that heavily influenced overall sustainability including, but not limited to: tillage, fertilizer application, irrigation, and various soil health related practices. Economics of these management choices were also considered to further support adoption.

Materials and Methods

For a single field of interest, current production practices were entered into the Fieldprint Calculator as an original scenario. A duplicate scenario was created, and one management strategy was altered (fertilizer rate, use of cover crops, etc.) while keeping all of the other original data the same. Thus, there are two scenarios for a particular field: the real-world scenario (before management change) and that same scenario with one management change (after management change). The results from both of these scenarios can then be compared and any changes in sustainability can be attributed to that management change. Economics of the management change are also compared to further support adoption. Currently, data has been collected and analyzed for 83 fields, 7 of which have multiple years of production data, from 7 producers. These fields total approximately 5800 acres with 12 major cotton growing counties of Tennessee represented. The fields were used in the various analyses discussed below.

Tillage System

According to the National Agricultural Statistics Service, 70% of Tennessee's production acres are no-till. Comparing the sustainability metrics of our no-till systems to conventional tillage systems serves as additional proof that cotton production in Tennessee is sustainable. Fields were observed under no-till and conventional tillage systems while holding all other aspects constant. Soil loss and soil carbon, as well as overall energy usage and greenhouse gas emissions are compared.

Cover Crops

Cover crops were assumed on some of the fields in order to observe cover crop residue effects on sustainability metrics. Small plot research that is currently underway at the Research and Education Center at Milan provided information on species mixes, seed prices, available cost-share programs, and nitrogen credits provided from legume cover crops. In addition to the other well-known benefits of cover crops, current research is showing the benefit of weed suppression which is ever more important with the increase in herbicide-resistant weeds.

Using a crimson clover and cereal rye cover crop was assumed on several fields. As literature suggests, a 50-80 lb nitrogen credit should be used due to the legume species in the cover crop mix; for the purpose of this study, a 30 lb nitrogen credit was used as it more realistically represents what a producer would do. NRCS seeding rates, prices, and cost share information was used from 2014.

Irrigation

Because the calculator quantifies its sustainability indices on a per pound of lint produced basis, maintaining yield is an important factor. Fields with center pivot irrigation were analyzed and split into two scenarios (irrigated and dryland) for comparison. The average yield from the irrigated area was used and the average yield in the field corners was used in the dryland scenario. Irrigation and precipitation amount are reported alongside the data to further explain differences in sustainability metrics.

Precision Nutrient Management

Fields receiving an application of fertilizer(s) on a variable-rate basis were identified and an average application rate (lb/ac) was determined. The producer's blanket application rate used before adopting variable rate technology (VRT) was used for comparison. These two scenarios were entered in the Fieldprint calculator, with all other inputs held constant. Sustainability metrics were compared, as well as the reduction in applied nutrients. By reducing the amount of nutrients applied and/or increasing nutrient use efficiency, a producer will reduce their impact on surrounding waterbodies and will likely see financial savings in fertilizer costs.
For example, from a 66 acre cotton field in West Tennessee was used for analysis of fertilizer application methods. Traditionally, this producer applied a blanket rate of 90 lbs/ac N and 60 lbs/ac of P_2O_5. The producer began using a

site-specific soil sampling regime and chose to use variable rate application (VRA) of N, P, and K inputs. Average application rates based on acreage were calculated from the prescription maps and were 67 lbs/ac N and 12 lbs/ac of P_2O_5. Thus, there was a traditional scenario with the blanket rates and a variable rate scenario with the averaged application rates. All other management decisions remained the same for both scenarios. Energy use and greenhouse gas emissions were compared, as well as the other sustainability indices that make up the Fieldprint spidergram.

A marginal approach that utilizes a partial budgeting technique (Kay and Edwards, 1999) was used to ascertain changes in costs and revenues associated with the use of VRT. The following equation was developed to evaluate the change in costs and revenue associated with passing from blanket rate to variable rate application of fertilizer:

$$\Delta REV_j = a_j * (p_j \Delta y_j + \Delta fc_j) \quad (1)$$

where ΔREV_j is the change in net revenue ($/ac), a_j is planted area (ac) in cotton, p_j is the price for cotton ($/lb), Δy_j is yield gain (lb/ac) from adopting VRT, and Δfc_j is the change in fertilizer cost ($/ac) due to VRT use.

Using Equation (1), estimated changes in net revenue were evaluated for four yield changes scenarios for cotton: (1) no change, (2) 25 lb/ac increase, (3) 100 lb/ac increase, and (4) 200 lb/ac increase. These scenarios were selected based on results of the 2013 Southern Cotton Farm Survey. According the 2013 Southern Cotton Farm Survey results, from the 117 respondents form Tennessee, 22% reported perceiving an increase in yield from variable rate input application. The best estimate they provide for yield increases per acre ranged between 25 lb/ac to 200 lb/ac, with 100 lb/ac being the most frequent increased yield reported. About 22% of all Tennessee respondents reported no changes in yield after using variable technologies for input application. None of the respondents reported a decrease in yield after using VRT. A limitation of these assumption rely on the fact that the reported changes in yield by respondents are not associated with a particular input, so these scenarios may not represent actual changes in yield associated to the inputs evaluated in this analysis. A price of $0.77/lb lint from the 2014 University of Tennessee Crop Budgets (University of Tennessee, Agricultural & Resource Economics, 2014) was used to estimate changes in net revenue associated with VRT use. The most up-to-date fertilizer product costs from the USDA Economic Research Service were used.

Results and Discussion

Tillage System

Several fields were analyzed under both no-till and conventional tillage and analyzed for energy use (Figure 1) and soil loss (Figure 2). As shown in these figures energy use (BTU/lb lint) and soil loss (T) are always reduced by the use on no-till. Depending on slope, slope length, soil type, and other factors, some fields are more likely to erode than others, as seen by the differences in soil loss between conventional and no-till scenarios in Figure 2.

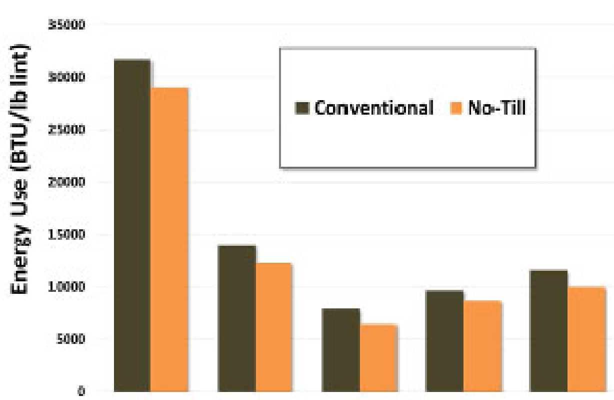


Figure 1. Energy use (BTU/lb lint) for 5 fields under conventional tillage scenario and no-till scenario

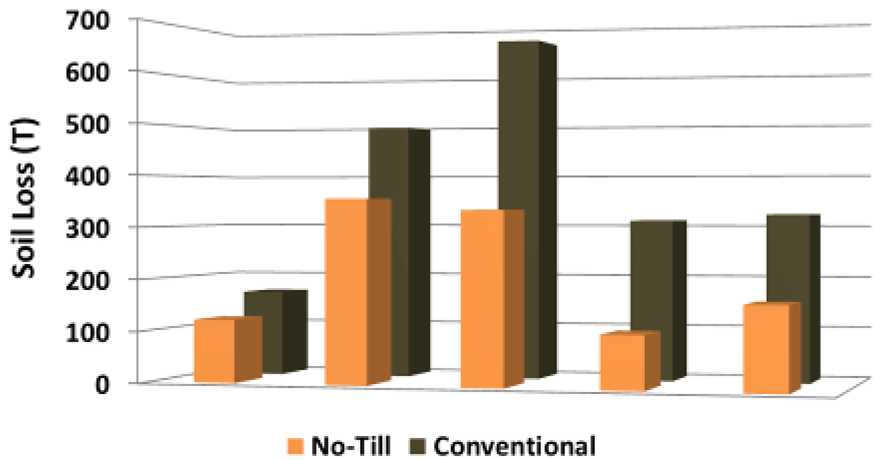


Figure 2. Soil loss (tons) for 5 fields under conventional tillage scenario and no-till scenario

By converting to no-till management, one field in particular reduced its soil loss by approximately 3 tons/ac/year, or a total savings of 142 tons of soil in 2013. Figure 3 displays the spidergrams for this field under (a) conventional tillage and (b) no-till. Note the reduction in the Fieldprint on the water quality axis. This is due to the reduction in soil loss, as sediment is the most common polluter of surface water which causes turbidity and can also be a carrier for phosphorus.

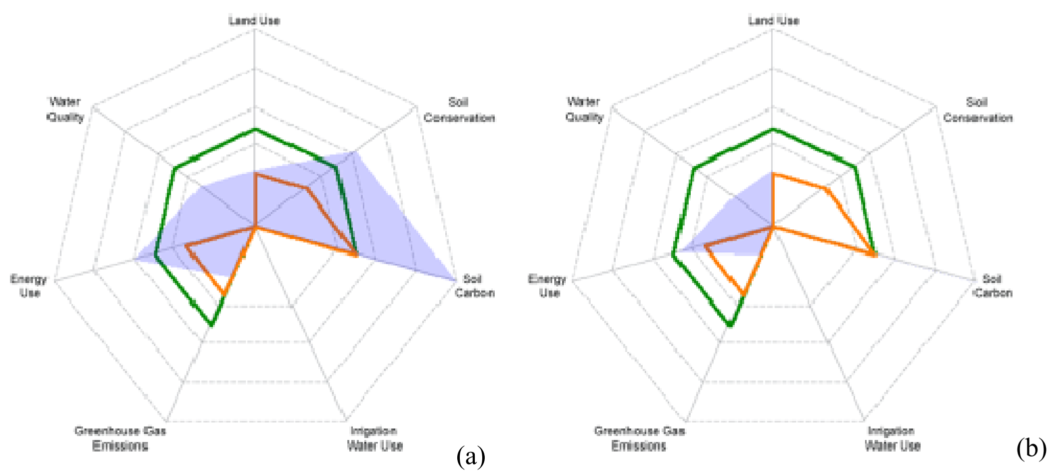


Figure 3. Spidergrams for field under (a) conventional tillage and (b) no-till

Cover Crops

Cover crops were assumed on several fields and energy usage compared (Figure 4). Energy use was consistently reduced by the use of cover crops, due to the reduction in synthetic nitrogen fertilizers used.

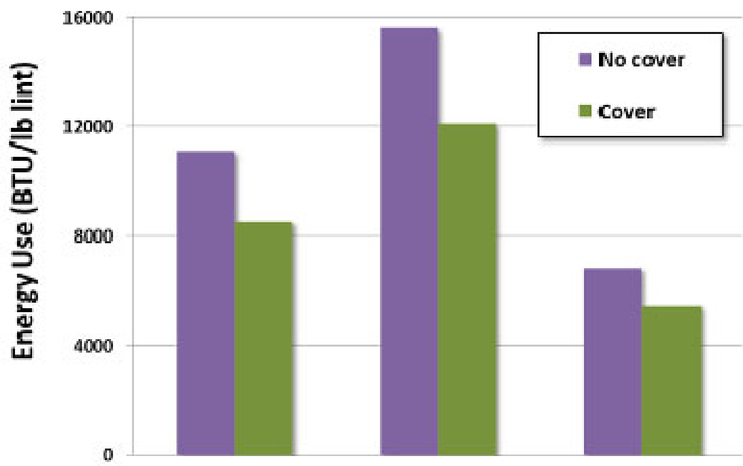


Figure 4. Energy use (BTU/lb lint) for 3 fields with and without cover crops

The use of cover crops one field in particular field improved energy usage by 2575 BTU/lb lint and approximately 0.3 lb CO2e/lb lint because of the reduction in chemical nitrogen fertilizers used due to the nitrogen credit taken. The water quality index was also improved by over 1 index point. These values are represented in Figure 5.

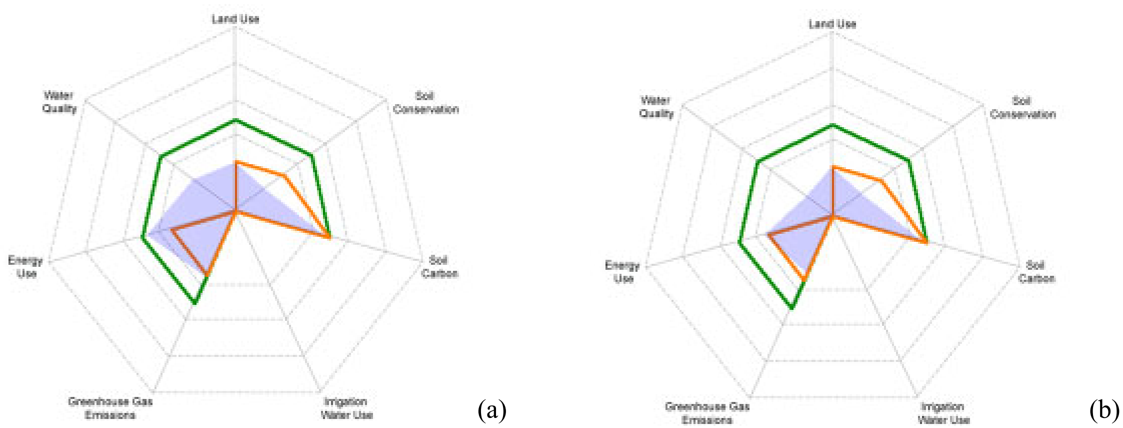


Figure 5. Spidergram for the field (a) without cover crops and (b) with cover crops

NRCS will cost share a two-species cover crops at \$38/ac for up to 200 acres through their EQIP program. The crimson clover/cereal rye seed cost is \$36/ac at the seeding rates specified by the NRCS cost share program. A 30 lb nitrogen credit was taken for this field, resulting in \$24.38/ac savings in chemical fertilizer (assuming UAN, prices from March 2014) costs for the subsequent cotton crop. New, promising research is underway investigating the role cover crops can play in early season weed suppression, specifically with herbicide-resistant weeds. If no cost share is involved and a 30 lb nitrogen credit is taken, cover crops cost this producer about \$12/ac, not including any benefit seen in reducing chemical costs in the producer's herbicide program. This benefit will vary from field to field, so the use of EQIP cost share should be used to investigate the specific benefit a producer could see from the use of cover crops.

Irrigation
Several fields are reported here for irrigated and dryland yields, along with precipitation data (Figure 6). Figure 7 shows the breakdown of energy use for the same 4 fields shown in Figure 6. Notice the largest increase in yield by irrigating is on the field that only received 17 in of precipitation; in Figure 7, this same field used more energy to produce one pound of lint under dryland production rather than by irrigating. The fourth field in Figures 6 and 7 shows that if yield is not substantially increased by irrigating then it is likely not sustainable. From the authors' knowledge of the production in this field, it was most likely over-irrigated and timed improperly. From this example, the conclusion can be drawn that as long as irrigation best management practices such as irrigation scheduling are used to optimize yields, they can potentially be a more sustainable practice in terms of energy usage and greenhouse gas emissions than dryland cotton.

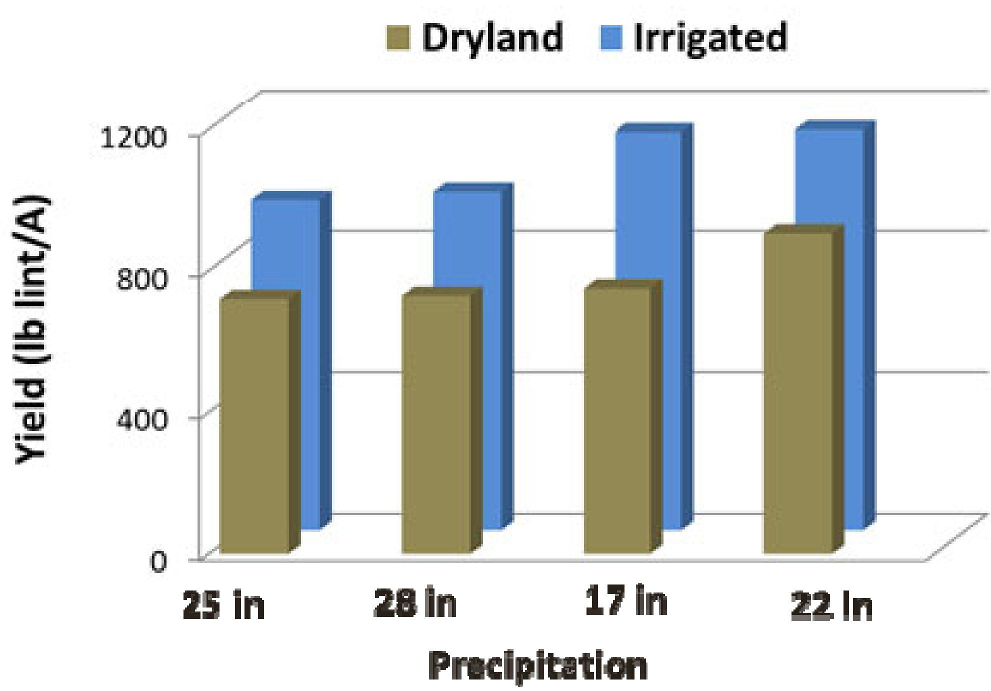


Figure 6. Dryland and irrigated lint yields (lb/A) and precipitation amounts for 4 fields

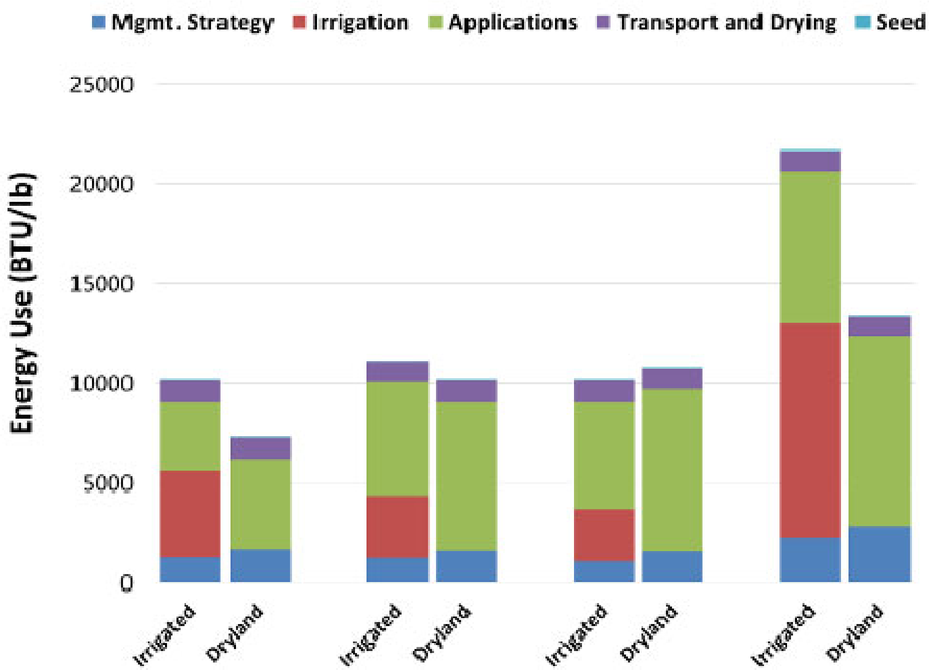


Figure 7. Energy use (BTU/lb lint) for the irrigated and dryland scenarios for 4 fields

Precision Nutrient Management

Fields with VRA of fertilizers consistently used less energy than their traditional, uniform rates (Figure 8). This is because these fields, on average, use less total fertilizer.

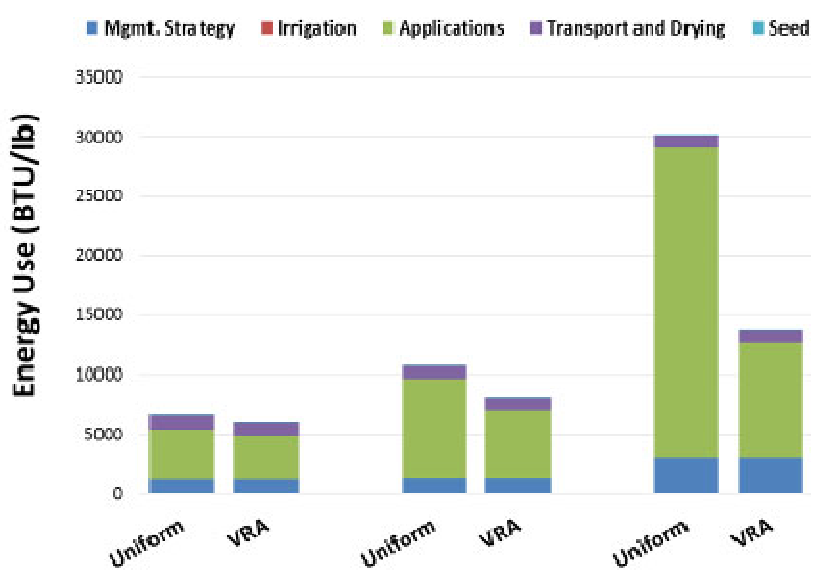
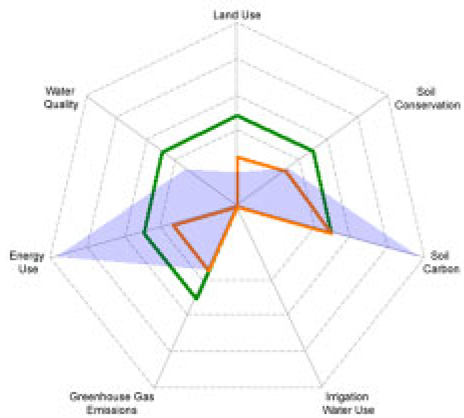
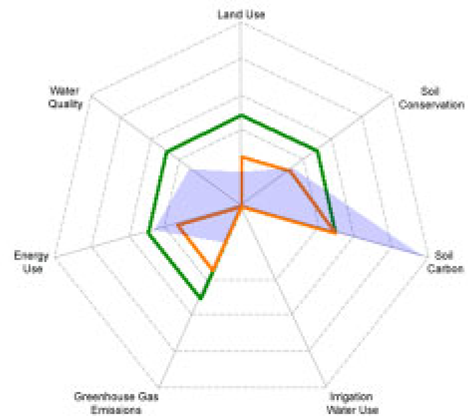


Figure 8. Energy use (BTU/lb lint) for the uniform and VRA scenarios for 3 fields

By using VRA of N, P, and K, the production in this field used 11,784 BTU/lb lint less energy and emitted 0.9 lb CO2e/lb lint less greenhouse gas than the traditional blanket rates in 2013. This reduction in energy use and greenhouse gas emissions can also be seen in the spidergrams for the two scenarios (Figure 9).



(a)



(b)

Figure 9. Spidergram for the (a) traditional rates scenario and (b) VR scenario.

On this field alone, the producer saved around $81/ac/yr in fertilizer costs and reduced the amount of N applied by approximately 1500 lbs and P_2O_5 applied by approximately 3100 lbs. Approximately 1500 acres covering 25 fields in 2013 were analyzed in the calculator for this producer. By site-specific soil sampling, using University soil fertility recommendations, and using VRA of fertilizer, the producer reduced:

- greenhouse gas emissions by 1.4 million lb CO2e
- energy usage by 18 billion BTU
- the amount of N applied by 28.7 tons
- the amount of P_2O_5 applied by 36.9 tons and
- input costs by over $127,000

Changes in net revenue for individual fields by using VRA of fertilizers as opposed to uniform application range from a loss of $1254 to an increase of $53,000, depending on field size and yield increase scenario. Table 1 includes average changes in net revenue for all yield scenarios described in Materials and Methods.

Table 1. Whole farm average changes in net revenue ($/A) for various yield change scenarios by using VRT

Average Changes in Net Revenue			
No Change in Yield	**+25 lb/A Increase in Yield**	**+100 lb/A Increase in Yield**	**+200 lb/A Increase in Yield**
$89.21/A	$108.46/A	$166.21/A	$243.21/A

Summary

In order to meet our food and fiber demand while reducing environmental impacts, producers need to be reconsidering management strategies they have traditionally used. Nutrient management is one area that could strongly influence reduction of nutrients moving off-site, optimizing yields, and profitability. Site-specific soil sampling is possibly the most simple, yet beneficial precision agriculture management strategy. It provides information on the spatial variability within a field, which can then be addressed by technologies such as VRA of input products. Proper irrigation scheduling and management also appear to be very important from an agronomic, as well as environmental standpoint. Soil health management practices, such as cover crops and no-till, can be significantly beneficial to water quality.

By analyzing fields with the Fieldprint Calculator, sustainability of production systems can be quantified. Because the Calculator defines it's metrics on a per unit of crop produced basis, it can be demonstrated that practices that are generally considered energy-intensive, expensive, and/or having negative impacts on the environment can actually be used in a sustainable manner. Using the Fieldprint Calculator to quantify how changes in management practices influence production sustainability will provide the cotton industry with the necessary information to demonstrate to producers that being sustainable and reducing their 'Fieldprints' can not only increase their profitability, but also reduce the impacts from agriculture on the environment. This data can also be used to document progress in the sustainability arena and give the cotton community quantified metrics to show the non-ag public that agriculture is working towards overall sustainability.

Acknowledgements

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References

Kay, R. D. and W.M. Edwards. 1999. Farm Management. McGraw-Hill, Boston, MA, Fourth Edition.