INFLUENCE OF VARIABLE RATE FERTILIZATION AND COVER CROPS ON COTTON SUSTAINABILITY USING THE FIELD TO MARKET FIELDPRINT CALCULATOR

Lori A. Duncan
Michael J. Buschermohle
Margarita Velandia
University of Tennessee
Knoxville, TN
Janet Reed
Cotton Inc.
Cary, NC

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 baseline 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. 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 water bodies. Cover crops decrease soil loss throughout the year by providing cover and root infrastructure for soil stability. The use of cover crops substantially improved the water quality index metric in the Calculator. The RUSLE2 model also showed that cover crops on the analyzed fields can substantially decrease the amount of soil loss. 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

Row crop production has recently come under scrutiny by the public for being “non-sustainable”, which has led to many regulatory issues as well as changing consumer expectations. 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 CO2e 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 baseline 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 as well as public awareness in Tennessee. 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: yield, 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 particular 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 51 fields from 5 producers. These fields total approximately 4000 acres with 6 of the 15 major cotton growing counties of Tennessee represented. The fields were used in the various analyses discussed below.

**Variable Rate Application of Fertilizers**

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 VRA 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 water bodies and will likely see financial savings in fertilizer costs.

For example, two years of data from a 92 acre cotton field in West Tennessee was used for analysis of fertilizer application methods. Traditionally, this producer applied a blanket rate of 120 lbs/ac N and 30 lbs/ac of P2O5. The producer began using zone management as a site-specific soil sampling regime and chose to use VRA of N and to reduce his P and K inputs. An average N application rate based on acreage was calculated from the prescription maps (Figure 1) in both 2011 (104 lbs/ac) and 2012 (71 lbs/ac). 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.

![Figure 1. VR N prescription maps for (a) 2011 and (b) 2012.](image-url)
For this producer, about 500 acres in 2011 and 2012 were analyzed using the Fieldprint Calculator. Monetary savings/losses by using VRA were calculated using current market fertilizer prices. The amount reduced/added of nitrogen and phosphorus by using VRA compared to blanket rate application was also calculated. Data was combined to give a whole farm analysis.

**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 good 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 the same 92 acre field used in the VR N example, a wheat and Austrian winter pea cover crop was assumed (Figure 2). As literature suggests, a 50 lb nitrogen credit was taken due to the legume species in the cover crop mix. NRCS seeding rates, prices, and cost share information was used from 2013.

**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 is possibly the most influential factor in the Fieldprint calculator, thus comparisons of different scenarios and metrics can illustrate to producers the importance of proper irrigation. A 200-acre cotton field under center pivot irrigation was analyzed and used in two different scenarios (irrigated and dryland) for comparison. From a yield map (Figure 3), the average yield from the irrigated area was determined as 1125 lb/ac for the regular scenario and the average yield in the field corners was determined as 750 lb/ac to be used in the dryland scenario. All other field management was held constant.
Figure 3. Yield map from an irrigated field to determine irrigated and dryland (corners) yield.

**Tillage Systems**
Fields using different tillage systems were compared for soil loss and soil carbon, as well as overall energy usage and greenhouse gas emissions. 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.

**Results and Discussion**

**Variable Rate Application of Fertilizers**
By using VRA of N and reducing the amount of P and K applied, the production in this field used 2955 BTU/lb lint less energy and emitted 0.32 lb CO2e/lb lint less greenhouse gas than the traditional blanket rates in 2012 (Figure 4).

Figure 4. Energy use (BTU/lb) and greenhouse gas emissions (lb CO2e/lb) for traditional rates and a VR scenario for the same field.
This reduction in energy use and greenhouse gas emissions can also be seen in the spidergrams for the two scenarios (Figure 5).

![Spidergram](image)

Figure 5. Spidergram for the (a) traditional rates scenario and (b) VR scenario.

On this field alone, the producer saved around $50/ac/yr in fertilizer costs and in two years reduced the amount of N applied by almost 3 tons and P$_2$O$_5$ applied by around 2 tons. Approximately 500 acres covering 5 fields in 2011 and 2012 were analyzed in the calculator for this producer. By site-specific soil sampling and switching to VRA of N and reducing the amount of P and K fertilizer, the producer reduced:

- greenhouse gas emissions by 425,000 lb CO2e
- energy usage by 4.2 billion BTU
- the amount of N applied by 19 tons
- the amount of P$_2$O$_5$ applied by 15 tons and
- input costs by $60,000

Currently, 46 cotton fields employing VRA of N, P, and/or K fertilizers have been analyzed. On average, these producers reduced their energy use by 1400 BTU/lb lint and their greenhouse gas emissions by 0.2 lb CO2e/lb lint respectively by using VRA as opposed to their traditional blanket rates. With a total lint yield from all fields being almost 3 million lbs, Table 1 shows the total energy and greenhouse gas emission reductions and real-world equivalents.

<table>
<thead>
<tr>
<th>Total Savings of VRA vs Blanket</th>
<th>Equivalents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Usage (BTU)</td>
<td>4.7 billion</td>
</tr>
<tr>
<td></td>
<td>Providing power to 118 households annually</td>
</tr>
<tr>
<td>GHG Emissions (lb CO2e)</td>
<td>536,000</td>
</tr>
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<td></td>
<td>Burning 94 tons of coal</td>
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Cover Crops
The use of cover crops on this field improved energy usage by 2863 BTU/lb lint and approximately 0.1 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 (Figure 6).

Figure 6. Spidergram for the (a) field without cover crops and (b) with cover crops.

NRCS will cost share cover crops at $59/ac for up to 200 acres through their EQIP program. The wheat/Austrian winter pea seed cost is $62.80/ac at the seeding rates specified by the NRCS cost share program. A 50 lb nitrogen credit was taken for this field, resulting in $31.92/ac savings in chemical fertilizer (assuming UAN, prices from March 2012) costs for the subsequent cotton crop. This results in a profit of over $28/ac for the acreage under cost share. 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, cover crops cost this producer about $31/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
By irrigating, the production in this field resulted in 2837 BTU/lb lint less energy used and 0.28 lb CO2e/lb lint less greenhouse gas emitted than if it had not been irrigated (Figure 7). Again, this is because the irrigated field yielded 1125 lb/ac, while the hypothetical dryland situation was assumed to yield 750 lb/ac as discussed in Materials and Methods. 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 7. Energy use (BTU/lb) and greenhouse gas emissions (lb CO2e/lb) for a dryland and an irrigated scenario for the same field.
Tillage Systems
By converting to no-till management, one field in particular reduced its soil loss by approximately 2 tons/ac/year, or a total savings of 420 tons of soil in 2011. According to the Soil Conditioning Index the calculator uses, no-till management is building this field's soil carbon by +0.21, while conventional tillage was depleting soil carbon by -0.57. Figure 8 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 8. A field under (a) conventional tillage and (b) no-till.

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.

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. Adopting precision agriculture technologies such as site-specific soil sampling and variable rate application of fertilizer also has the potential to reduce the ‘Fieldprint’ from cotton production systems. 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.

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