QUANTIFYING COTTON SUSTAINABILITY AND EXPLORING OPPORTUNITIES FOR GROWTH USING FIELD TO MARKET

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Abstract

Sustainable agriculture has become an increasingly popular subject across all levels of the supply chain as producers, companies, and consumers have implemented sustainability goals. Despite each having goals, difficulty in reaching them has arisen as there are discrepancies in the definition of and how best to quantify sustainability as it applies to production methods. Field to Market provides an interesting opportunity to gather producer data by using the Fieldprint Calculator to analyze and calculate a sustainability score for an individual field based on the following metrics: biodiversity, energy use, greenhouse gas emissions, irrigation water use, land use, soil carbon, soil conservation, and water quality. The focus of this project was divided into three sub-goals: creating long-term baseline sustainability data for cotton, the design and facilitation of educational events, and the creation of long-term sustainability benchmarks. This paper will focus on the first two goals of the project. With the agricultural industry looking for continuous improvement in levels of sustainability, an explanation of project research concerning the Theory of Diffusion of Innovation will be explained as feedback is provided back to growers about the adoption of precision agriculture techniques, sustainable agricultural practices, and conservation techniques. By using feedback from growers, an internal evaluation can be performed into how the extension components of the project can use current producer perceptions, to inform the next steps of the project. These next steps could include possible partnerships that can be created to assist producers with private cost-sharing opportunities or current programs available for producers to enroll in for the adoption of sustainable agriculture practices.

Introduction

Historically, agriculture has been more impactful on society and the environment than any other industry. In recent years, the idea of sustainability and sustainable agriculture has become more popular (Minarovic & Mueller, 2000). Even more so in the last few months as many activists have taken to the media to speak their opinions on the state of our environment and what will be left for future generations. As the activists have come forward, more issues have arisen as each individual has their ideas of and definitions for sustainability and how best to move forward towards a more sustainable future. Previous research has shown that despite the differences, definitions generally tend to have characteristics that fall within the boundaries of the "three pillars" of sustainability–those being social, environmental, and economic (Bruulsema, 2009; Jayaratne et al, 2001; Minarovic & Mueller, 2000).

As observed from those previous studies, we cannot solely focus on the environmental aspects of sustainability, we must also keep in mind the economic inputs to keep producers afoot. Past research studies have shown that conventional agriculture systems have not been reaching their ultimate levels of efficiency and given the economic capacity agriculture plays, efficiency is only becoming more important (Smith & McDonald, 1998; Tey & Brindal, 2012). When the system is not reaching its ultimate efficiency, the producers in the system often seem to find many barriers to their production and decisions to adopt sustainable practices, not only environmentally and economically, but socially. Many of the challenges tend to come from a lack of knowledge or support in the steps they are taking to become more sustainable. With the existence of barriers to adoption and challenges to diffusing the information to producers, a need for research into sustainability levels of current production practices and the identification of new and improved technologies that can be implemented has now been established (Tilman et. al, 2002). Finding this need to be evident in the research as well as felt throughout the supply chain, this project sought to create a baseline of sustainability data for cotton producers as well as provide educational events for the producers as well as extension agents using the Field to Market Fieldprint Platform.

Since Field to Market was the primary research platform used in this study, the metrics of observation were adopted as this study's metrics. These metrics were given a definition and explanation by Field to Market and will be summarized in the following paragraphs.

Biodiversity
The biodiversity metric measures the ability of the entire farm to support an ecosystem. The score given by this metric includes both plant and animal life and is the only metric that is an overview of the farm, all other metrics are specific to either the management practice, location, or the crop being grown. It is the hope of this metric to inspire management decisions that will maximize the farm potential to support wildlife and plants. This metric is impacted by the location of the farm, the management practices, and land history. Many of the input calculations used to determine Biodiversity are also used to determine Water Quality just in a different way which is more specific to water quality.

Energy Use
The energy use metric is an efficiency metric used to calculate all the energy used in a single crop production cycle from the pre-planting activities to the first point of sale. This metric has seven subcategories: management energy, application energy, manure loading energy, seed energy, irrigation energy, post-harvest treatment energy, and transportation energy. This metric is dependent on the tillage practices, crop, fertilizer and chemical applications, and irrigation decisions, thus it is directly related to the soil conservation, irrigation water use, water quality, and greenhouse gas emissions metrics.

Greenhouse Gas Emissions
The greenhouse gas emissions metric is an efficiency metric used to calculate the emissions from sources identified to be the most influential: energy use, nitrous oxide emissions from soil, methane emissions, and the emissions from burned residue. For this project, the main emissions used in calculations are energy use, nitrous oxide, and residue burning. It should be noted that residue burning is only calculated if it has been noted that previous crop residues had been burned. Energy use is pulled directly from the inputs for the energy use metric. Emissions from soils are based on the fertilizers and chemicals applied to the soil. As previously stated, the greenhouse gas emissions metric is related to the energy use metric.

Irrigation Water Use
The irrigation water use metric is another efficiency metric used to account for water applied to induce a measurable change in crop yield for a given cycle. To calculate the metric amount of irrigation applied in acre/inches over the entire growing season is required in addition to the expected yield of the crop if no amount of irrigation was used. It is best to have a dryland comparison field or yield to input into this metric. The metric is related to energy use, greenhouse gas emissions, biodiversity, and water quality metrics.

Land Use
The most straightforward metric, this efficiency metric uses the amount of land used to produce a given yield. This metric is related to energy use, greenhouse gas emissions, irrigation water use, and soil conservation metrics.

Soil Carbon
While soil carbon is important to the production of crops as it aids in water and nutrient uptake, water holding capacity, and overall carbon storage, it is often difficult to accurately calculate the amount of carbon in the soil/ due to this, Field to Market decided to adopt a calculation system directly from the USDA NRCS, known as the Soil Conditioning Index. This index looks directly into three components, existing organic matter, soil erosion, and field operations related to soil. This metric is related to soil conservation and greenhouse gas emissions.

Soil Conservation
The soil conservation metric is also an efficiency metric that is used to calculate the amount of soil lost to both wind and water erosion and is reported as tons of soil lost per acre per year. The calculations are based on the USDA NRCS tool known as the Integrated Erosion Tool which takes into account water and wind erosion predictions. The soil conservation metric is related to soil carbon, energy use, greenhouse gas emissions, and water quality.

Water Quality
The water quality metric is a calculation made to determine the quality of surface water as it leaves a given field. This qualitative metric also uses a USDA-NRCS platform known as the Water Quality Index to determine the quality of water. This index determines the risk of loss of fertilizer and chemical sediments from water runoff. This metric is related to biodiversity, irrigation water use, energy use, and soil conservation metrics.

Objectives

The main objective of this paper was to collect and analyze data from producers within the cotton producing counties of Georgia. The sub-objectives of this project were: creating long-term baseline sustainability data for cotton, the design and facilitation of educational events, and the creation of long-term sustainability benchmarks.

Materials and Methods

Following the agreements between the partnering organizations, the project began by setting the number of participants for the beginning year of 50 cotton producers from within the state of Georgia. Knowing that bias exists the researchers put procedures in place to ensure that the sample of producers was representative.

The researchers were initially provided a list of producers by commodity commissions in the state of Georgia and proceeded to contact extension agents from the counties the producers reside in, and the extension agents served as liaisons throughout the project. The agents contacted growers and assisted the researchers in setting up meetings and were present during the interviews. Agents also assisted researchers in identifying potential participants and contacting them in place of the researchers with information about the study. This decision was made to ensure that the sample remained representative of all growers in Georgia.

Data collection followed a qualitative method in which in-person interviews were used. Participants were briefed on the purpose of the study, the research methods, and the storage of all information at the beginning of each interview and were allowed to ask any questions of the researcher. Following this, an at-most hour-long interview was conducted with the producers to ask them specific questions from a survey. The topics in the survey included crop residues, cover crops, tillage methods, irrigation nutrient management, pest management, conservation practices, and chemical applications. The survey was developed based on Field to Market's Fieldprint Calculator to ensure data were easily entered into the calculator. Producers were allowed to share any additional information they wanted at this point.

The Field to Market Fieldprint Calculator supported all of the data analysis from the surveys. The calculator is a service offered by Field to Market an agricultural supply chain alliance. The calculator uses the information input to assess a sustainability score based on the metrics of biodiversity, energy use, greenhouse gas emissions, irrigation water use, land use, soil carbon soil conservation, and water quality. The survey format used during the interviews followed the exact format of the Fieldprint Calculator, thus ensuring that researcher error in data collection and entry was limited. Following each interview, survey information was entered in the Fieldprint Calculator for each field individual field that information was collected.

Analysis of the data continued as the Fieldprint Calculator exported the given data into a spidergram and chart which provided an assessment score for each of the sustainability metrics. The scores of each field were analyzed to interpret the sustainability level of each metric. Three primary metrics for each field were chosen in the study and used to create a summary of the metrics and listed the field characteristics and management practices which had the greatest impact on sustainability scores. From this, extension and precision agriculture information was gathered to return to producers to educate on their current sustainability levels and possible adoptions that could be made to reduce environmental impact.

Results and Discussion

Tables 1 and 2 are summaries of the benchmarks from the growers within our irrigated and dryland projects along with the state and national benchmarks for the irrigated and dryland crops, respectively. The data for our project benchmark is based on field data collected from growers in our program from 2016-2018. The data used to generate the state and national benchmarks was collected from USDA regional data from the past 5 years. The following discussions will compare our project benchmarks to the state and national benchmarks and seek to provide insight into the differences in results.

Table 1. Irrigated Cotton

Metric	Project	State	National
Land Use (ac. /lb.)	0.0010	0.0010	0.0010
Soil Conservation (ton/ ac. /yr.)	5.4	10.3	12.9
Irrigation Use (ac.-in./lb.)	0.020	0.014	0.027
Energy Use (btu/ lb.)	6,291	7109	9427
Greenhouse Gas (lbs. - CO_2e/ lb.)	1.6	1.7	2.0
Water Quality	7.59	N/A	N/A
Biodiversity (%)	67.4	N/A	N/A

Table 2. Dryland Cotton

Metric	Project	State	National
Land Use (ac. /lb.)	0.0010	0.0012	0.0019
Soil Conservation (ton/ ac. /yr.)	3.7	10.3	12.9
Energy Use (btu/ lb.)	4,854	5947	6881
Greenhouse Gas (lbs. - CO_2e/ lb.)	1.1	1.7	2.1
Water Quality	7.87	N/A	N/A
Biodiversity (%)	68.6	N/A	N/A

Land Use

The land use metric for our project for both the dryland and irrigated crops was calculated to be 0.0010(ac./lb.), respectively. Which is equal to the state and national benchmarks for the irrigated cotton but was lower than the state and national benchmarks from the dryland crop perspective. This benchmark explains that our producers are becoming more efficient with their production in both categories from the past years as they are continuing to increase or maintain yields on the same or less amount of land. This could be due to improved seed quality or management practices.

Soil Conservation

The benchmarks from the state and national data for both dryland and irrigated cotton were calculated to be 10.3(tons/ac/yr.) and 12.9(ton/ac/yr.), respectively. The benchmark for irrigated cotton was 5.4(tons/ac./yr.) whereas the dryland cotton benchmark resulted in a calculated loss of 3.7(tons/ac/yr.). The reduction in the scores for soil conservation from the state and national benchmarks to the levels of our project could be due in part to the switch from conventional high disturbance tillage to strip-tillage methods as well as the addition of cover crops which help to hold nutrients, moisture in the soil, but also hold the soil together due to the root systems. When evaluating the differences in our project benchmarks for the dryland and irrigated cotton, we see the main factor affecting the score was due to water erosion, which was elevated for all growers in our project.

Irrigation Use

The irrigation use metric was the only metric for this project benchmark which was higher than one of the state or national benchmarks. The project irrigation use benchmark was 0.020(ac.-in./ lb.) higher than the state benchmark of 0.014(ac.-in./ lb.) but still lower than the national benchmark, which was calculated to be 0.027(ac.-in./ lb.). When analyzing the irrigation data, the data was collected for 2016-2018; two of those three years had natural disasters occur during harvest in Georgia that severely impacted the yields of producers despite the efficient use of irrigation previously during the season. Evaluating the other benchmarks, the state benchmark had information from growing seasons which were not impacted by weather to average into the score and the national benchmark takes into account growing regions where the use of water is required to produce any yield resulting in a very high-water use efficiency and low metric score.

Energy Use

Following the trend for the majority of the metrics, the project benchmarks for energy were lower than the state and national benchmarks in both categories. For irrigated cotton, the average energy was calculated to be 6,291(btu/lb.) whereas the state benchmark was 7,109(btu/lb.), and the national data resulted in 9,427(btu/lb.). For the dryland crop, the project resulted in a calculation of 4,854(btu/lb.) lower than the state and national benchmarks, which were 5,947(btu/lb.), and 6,881(btu/lb.), respectively. When evaluating the information gathered from growers, some growers from this project had individually elevated energy use scores on an, due in part to an average of 8-10 trips to the field for fertilizer and chemical sprays in addition to the irrigation water applied to the fields.

Greenhouse Gas

Similarly, the Greenhouse Gas metric benchmark was lower than the state and national benchmarks for both irrigated and dryland cotton. The scores for irrigated cotton were 1.6(lbs. - CO_2e/ lb.) for this project, 1.7(lbs. - CO_2e/ lb.) for the state and 2.0(lbs. - CO_2e/ lb.) for the national score. Similar to the irrigated score, the dryland scores followed the same pattern, this project score was 1.1, the state was 1.7(lbs. - CO_2e/ lb.), and the national benchmark was 2.1(lbs. - CO_2e/ lb.). It was interesting to note that the benchmarks for the state and national data were higher than the scores for irrigated cotton. The reduction in greenhouse gas scores could be a result of the decreased scores for this project in the energy use metric as well as a reduction in nitrous oxide emission.

Other Metrics

The Fieldprint Calculator was not able to provide a state and national benchmark score for the Soil Carbon, Water Quality and Biodiversity metrics. While the benchmarks are not available, some level of comparison can be made between the dryland and irrigated scores. The dryland Water Quality score was 7.87 whereas the irrigated score was 7.59, respectively. Soil texture, tile drainage, irrigation, fertilizer, and chemical applications impact water quality and the adoption of conservation practices. The difference in the scores for dryland and irrigated crops can be explained by the disturbance of the soil from being conventionally tilled, followed by applications of chemicals and irrigation that could result in soil erosion into waterways without conservation techniques in place to filter the water. The presence of conservation methods within the producer's fields could also be an explanation for the differences in Water Quality scores. The Biodiversity metric is impacted by many of the same items as the Water Quality metric. The score of the Biodiversity metric represents the ability of the entire farm to support a diverse ecosystem, the score for the irrigated score was lower than that of the dryland score those being, 67.4 for irrigated and 68.6 for the dryland. These differences can be explained by the differences in water quality scores between the growing methods as water quality impacts the living capabilities of plants and in turn wildlife.

Summary

As only one full year of data collection and analysis has occurred in this four-year project, a final conclusion cannot be determined. However, it is easy to see that both the dryland and irrigated the metrics are trending downward to a more sustainable level. A side by side comparison of the dryland and irrigated benchmarks from this project have shown that the dryland benchmarks are consistently on the more desirable side based on specific metrics being analyzed. In the following years of the study, it will be interesting to monitor the land use scores between dryland and irrigated as they are currently the same. When analyzing the data at the individual field level, there are different concerns which are specific to each field, but for many of the growers, Energy Use and Greenhouse Gas emissions are elevated and will be metrics to be more closely monitored as more data is collected and analyzed.

Data collection will continue adding five to ten growers every subsequent year. Educational events will be planned with participating growers on the results of their data and opportunities for individual growth. Extension Agents and Specialists will be provided with educational opportunities on the Field to Market Platform, this project, as well as sustainable and precision agriculture practices than can be enacted by producers in their communities. An additional economic analysis will be completed on the current practices of producers based on Field to Market information and enterprise budgets produced by the University of Georgia. This economic analysis will be provided to producers to inform them on their management decisions.

Acknowledgments

This project would not have been possible without the funding of Cotton Incorporated for the cotton research as well as the National Peanut Board and Georgia Peanut Commission for the peanut research. Additionally, we would like to acknowledge the American Peanut Council and Lexi Clark from Field to Market for their assistance in the development and direction of the project.

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