FIELDPRINT® CALCULATOR: THE EFFECTS OF IRRIGATION AND TILLAGE PRACTICES ON SUSTAINABILITY IN THE TEXAS HIGH PLAINS

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Abstract

The Fieldprint® Calculator is an analytical tool that evaluates crop production operations and computes their sustainability and operational efficiency. The calculator was developed by Field to Market®: The Alliance for Sustainable Agriculture. The data used for this study was obtained from the Fieldprint® Calculator's data output for fields in the Texas Alliance for Water Conservation (TAWC) project located in the Texas High Plains region. The sites were evaluated across eight years from 2007 to 2014 and sustainability indexes were calculated for each field. The objective of the study was to evaluate the TAWC data and analyze the effects of irrigation and tillage practices on sustainability metrics found in the Fieldprint® Calculator. The goal of the study is to determine which production practices are efficient or inefficient in regards to sustainability in the Texas High Plains, so producers can make informed decisions about their crop production operations.

Background

Sustainability has become an important issue for many involved in the agricultural sector. One group, Field to Market®, is a collaboration of producers, agribusinesses, conservation organizations, universities, and public sector partners whose focus is defining, measuring, and advancing the sustainability of food, fiber, and fuel production (Field to Market®). They have several on-going projects including the Texas Cotton project, sponsored by the National Cotton Council and Natural Resource Conservation Service, which uses data from TAWC demonstration farms located in Castro, Crosby, Deaf Smith, Lamb, Lubbock, Parmer, and Swisher counties with the majority of farms located in Hale and Floyd counties. Field to Market® developed the Fieldprint® Calculator which computes the sustainability and operational efficiency of an operation so it can be evaluated by producers and researchers. The calculator is a valuable tool for producers and researchers to measure the sustainability of crop operations as well as analyze the effects of various management practices on sustainability and the environment (Field to Market®, 2015). In the calculator, a field is identified by spatial coordinates and soil and topographic information is automatically loaded for the given location. Operational information for a field such as crop rotation, tillage systems, fertilization, pesticides, transportation, drying, and other crop inputs are entered into the calculator. Field performance and sustainability is then assessed based on seven metrics in the calculator: land use, irrigation water use, energy use, greenhouse gas emissions, soil conservation, soil carbon, and water quality. Table 1 shows the metrics from the calculator and their unit of measure.

Table1. Metrics and Their Unit of Measure.

METRIC	UNIT OF MEASURE
Land use	ac/unit of production
Irrigation water use	in/unit of production
Energy use	gallons of diesel/unit of production
Greenhouse gas emissions	lbs of CO_2/unit of production
Soil conservation	tons of soil loss/ac/yr
Soil carbon	index
Water quality	index

Land use is directly related to yield and refers to the production efficiency of a particular field. A field that has higher levels of output per acre than another will have a lower land use index value. Irrigation water use refers to the amount of irrigation water applied per unit of crop production increase over rain fed crop production on the same land. Energy use accounts for direct and indirect energy involved in crop production for an operation. Direct energy use includes input applications such as irrigation, fertilizer, pesticides, etc. Indirect energy accounts for the manufacture and transportation of fertilizers, pesticides, and equipment. Greenhouse gas emissions refers to the amount of CO_2 produced from direct and indirect energy usage as well as non-energy elements like N_2O emissions from soil, based on fertilizer applications, or CH_4 emissions from rice cultivation. There is generally a high correlation between energy use and greenhouse gas emissions since the production of CO_2 is related to energy use. Soil conservation accounts for the soil erosion in a field due to wind and water. Soil carbon represents the levels of carbon present in the soil and water quality refers to the quality of runoff at the edge of a field. The sustainability metrics are constructed such that a lower value represents a more sustainable production system.

The calculator analyzes these metrics and allows a producer to visually and quantitatively compare their production operation to state and national averages. A producer enters information into the calculator each year and may have several fields with various management practices, allowing them to use the calculator to compare multiple sites across many years. The calculator presents the metrics in the form of a spidergram, seen in Figure 1, which compares a production operation (shaded purple region) to the local, state (orange), and national (green) averages. Currently, the calculator can generate sustainability metrics for corn, cotton, potatoes, rice, soybeans, and wheat. Alfalfa will be available in 2016.

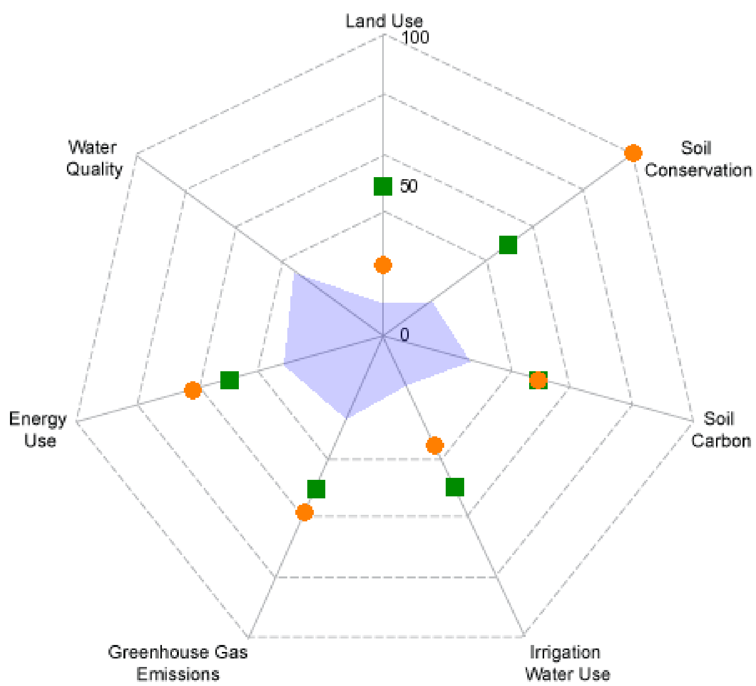

Figure 1. Spidergram representing a field that planted cotton in 2013.

Methods

The data used in this study was from the Texas Alliance for Water Conservation (TAWC) demonstration project with production operations in Castro, Crosby, Deaf Smith, Lamb, Lubbock, Parmer, and Swisher counties with the majority of producers located in Hale and Floyd counties. The focus of the TAWC is to conserve water for future generations while maintaining and improving agricultural production. The project has collected data from approximately 23 producers compiling a total of 181 cotton observations from 2007 through 2014. The fields range in size from 13 acres to 398 acres and consist of various irrigation practices (LEPA, LESA, MESA, subsurface drip, and furrow) and tillage practices (conventional, minimum, and no-till). The producers keep track of yields, costs, revenues, and timing and amounts of input applications (fertilizer, pesticides, harvest aides, etc.) and irrigation. For this study, irrigated cotton fields were analyzed. Only fields that harvested a crop were included, those that collected insurance for any given year were not included in the study.

The TAWC data was entered into the Fieldprint® Calculator for further analysis. Each field was spatially located then operational information was entered such as irrigation and tillage practices, chemical input applications, yields, and conservation measures. From the information given, the calculator evaluated each operation and produced results for each of the seven sustainability metrics. For cotton, the calculator computes values based on a lint equivalent yield (LEY). Given that cotton is a joint product comprised of lint and seed, seed revenues must be accounted for along with lint. The calculator assumes that seed provides approximately 17 percent of revenues. Therefore, in order to calculate the LEY, the lint yield is divided by 83 percent.

Results

For this project, four metrics were used in order to evaluate the effects of irrigation and tillage practices on producer sustainability: land use, irrigation water use, energy use, and soil conservation. Greenhouse gas emissions was eliminated as it is a direct product of energy use and is highly correlated to the metric. Soil carbon and water quality were also eliminated from the study as irrigation and tillage systems were not expected to have much, if any, effect on the metrics. The metrics from the calculator were converted into index values based on the mean value for each metric. The index values indicate the impact of the usage of that particular variable, so a smaller index value indicates a smaller carbon footprint. Therefore, a producer with a smaller index value is more sustainable than a producer with a larger index value. Four models were evaluated with land use, irrigation water use, energy use, and soil conservation as the dependent variables and irrigation systems (LEPA, LESA, MESA, furrow, and SDI) and tillage systems (conventional, minimum, and no-till) as the independent variables. Minimum tillage was defined as any operation that used only one invasive tillage practice (disc or lister) and three or fewer less invasive tillage practices (coulter, rodweeder, etc.), or any operation that used two invasive tillage practices only. Any operation that used more tillage than described above was classified as a conventional tillage system. The analysis allowed the impact of operational systems on the sustainability metrics to be evaluated. For tillage systems there were 108 convention tillage, 54 minimum tillage and 19 no-till observations. For the irrigation systems there were 23 furrow, 35 LEPA, 32 MESA, 47 LESA and 44 SDI observations. LESA was the base irrigation system and conventional tillage was the base tillage system. The results of the models are shown below.

Model 1

$$LU = f(LEPA, FUR, MESA, SDI, MIN, NT)$$

Where:
LU = Land use index
LEPA = Low energy precision application
FUR = furrow irrigation system
MESA = mid elevation spray application
SDI = subsurface drip irrigation
MIN = minimum tillage
NT = no tillage

Table 2. Parameter Estimates for Irrigation and Tillage Systems for the Land Use Index.

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	95.99878	6.88065	13.95	<.0001
LEPA	-6.79106	9.30962	-0.73	0.4667
FUR	28.66038	11.27394	2.54	0.0119
MESA	23.67502	9.51809	2.49	0.0138
SDI	-7.30667	8.74076	-0.84	0.4043
MIN	-3.99077	7.28041	-0.55	0.5843
NT	3.72620	10.73260	0.35	0.7289

The furrow and MESA variables were significant at the 90% confidence level. When compared to the base system LESA, furrow and MESA irrigation systems increase the land use index by 28.66 and 23.68, respectively. Given that a lower index value is more desirable, furrow and MESA irrigation systems are less sustainable than LESA irrigation systems for the land use index. The results of the t-tests indicate that conventional tillage systems had a negative effect on the land use index when compared to minimum and no-till systems. Furrow and MESA irrigation systems had a negative effect on the land use index when compared to LEPA, LESA, and subsurface drip irrigation systems.

Model 2

IRR = ƒ(LEPA, FUR, MESA, SDI, MIN, NT)

Where:
IRR = Irrigation water use index
LEPA = Low energy precision application
FUR = furrow irrigation system
MESA = mid elevation spray application
SDI = subsurface drip irrigation
MIN = minimum tillage
NT = no tillage

Table 3. Parameter Estimates for Irrigation and Tillage Systems for the Irrigation Water Use Index.

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	97.26029	10.85882	8.96	<.0001
LEPA	-5.08275	14.69214	-0.35	0.7298
FUR	38.49179	17.79216	2.16	0.0319
MESA	-3.05198	15.02114	-0.20	0.8392
SDI	-13.92217	13.79438	-1.01	0.3142
MIN	6.91319	11.48970	0.60	0.5482
NT	7.27112	16.93784	0.43	0.6682

The furrow variable was significant at the 90% confidence level. When compared to the base system LESA, furrow irrigation systems increase the irrigation water use index by 38.49. Given that a lower index value is more desirable, furrow irrigation systems are less sustainable than LESA irrigation systems for the irrigation water use index. The results of the t-tests indicate that furrow and LESA irrigation systems have a negative effect on the irrigation water use index when compared to subsurface drip (SDI) irrigation systems.

Model 3

ENG = ƒ(LEPA, FUR, MESA, SDI, MIN, NT)

Where:
ENG = Energy use index
LEPA = Low energy precision application
FUR = furrow irrigation system
MESA = mid elevation spray application
SDI = subsurface drip irrigation
MIN = minimum tillage
NT = no tillage

Table 4. Parameter Estimates for Irrigation and Tillage Systems for the Energy Use Index.

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE	PR > |t|
INTERCEPT	98.59168	9.24129	10.67	<.0001
LEPA	1.43611	12.50360	0.11	0.9087
FUR	29.92739	15.14185	1.98	0.0497
MESA	3.25776	12.78360	0.25	0.7991
SDI	-12.78550	11.73958	-1.09	0.2776
MIN	-3.71543	9.77820	-0.38	0.7044
NT	9.37918	14.41479	0.65	0.5161

The furrow variable was significant at the 90% confidence level. When compared to the base system LESA, furrow irrigation systems increase the energy use index by 29.93. Given that a lower index value is more desirable, furrow irrigation systems are less sustainable than LESA irrigation systems for the energy use index. The results of the t-tests indicate that furrow, LEPA, and LESA irrigation systems had a negative effect on the energy use index when compared to subsurface drip (SDI) irrigation systems.

Model 4

SC = ƒ(LEPA, FUR, MESA, SDI, MIN, NT)

Where:
SC = Soil conservation index
LEPA = Low energy precision application
FUR = furrow irrigation system
MESA = mid elevation spray application
SDI = subsurface drip irrigation
MIN = minimum tillage
NT = no tillage

Table 5. Parameter Estimates for Irrigation and Tillage Systems for the Soil Conservation Index.

VARIABLE	PARAMETER ESTIMATE	STANDARD ERROR	t VALUE	PR > |t|
INTERCEPT	106.87424	9.09922	11.75	<.0001
LEPA	-13.72133	12.31137	-1.11	0.2666
FUR	-19.63404	14.90906	-1.32	0.1896
MESA	39.07594	12.58706	3.10	0.0022
SDI	-19.25725	11.55909	-1.67	0.0975
MIN	-0.63667	9.62787	-0.07	0.9474
NT	-35.81298	14.19318	-2.52	0.0125

The MESA, SDI, and NT variables were significant at the 90% confidence level. When compared to the base system LESA, MESA irrigation systems increase the soil conservation index by 39.08 and SDI systems decrease the index by 19.26. Given that a lower index value is more desirable, MESA irrigation systems are less sustainable than LESA irrigation systems for the soil conservation index while SDI systems are more sustainable than LESA systems. When compared to the base conventional tillage, no-till systems decrease the soil conservation index by 35.81. Therefore, no-till systems are more sustainable than conventional tillage systems for the soil conservation index. The results of the t-tests indicate that conventional and minimum tillage systems had a negative effect on the soil conservation index when compared to no-till systems. MESA irrigation systems had a negative effect on the soil conservation index when compared to furrow, LEPA, LESA, and subsurface drip irrigation systems. In addition, LESA irrigation systems had a negative effect on the soil conservation index when compared to furrow and subsurface drip (SDI) irrigation systems.

Conclusions

The Fieldprint® Calculator is a valuable tool for producers as it allows them to visualize and quantify how changes in their management practices affect their sustainability footprint and operational efficiency. By improving agricultural sustainability and productivity, a producer can reduce their impact on the environment and reduce their overall carbon footprint. Agricultural sustainability is an important issue that can easily be improved by using tools such as the Fieldprint® Calculator. The calculator will be invaluable to producers as farming operations begin adopting more sustainable production practices.

References

Field to Market®: The Keystone Alliance for Sustainable Agriculture – Fieldprint® Calculator. Internet site: https://www.fieldtomarket.org/fieldprint-calculator/

Texas Alliance for Water Conservation (TAWC), Internet site: http://www.depts.ttu.edu/tawc/