ENERGY ANALYSIS OF COTTON PRODUCTION ON THE SOUTHERN HIGH PLAINS OF TEXAS

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Abstract

The cotton producing region of the Southern High Plains of Texas is an input intensive agricultural region. The use of irrigation, fertilizer, and other inputs makes this region a large consumer of both direct and indirect energy. Increasing energy costs have affected farm profitability and are predicted to increase in the future. Energy consumption from fossil fuels either directly through fuel consumption in mechanical operations and irrigation application or indirectly through the production of fertilizer and chemicals varies greatly at the farm level based on irrigation systems, crop selection, and management decisions. The objective of this study was to evaluate energy use in irrigated cotton production systems on the Southern High Plains of Texas. Results indicate that in terms of energy use efficiency the subsurface drip irrigation system (SDI) was the most efficient. The low energy spray application pivot system (LESA) was the most efficient with regard to profitability per unit of water applied.

Introduction

Energy from fossil fuels is a major input in agricultural production on the Southern High Plains of Texas (SHP). The region is characterized by the intensive use of inorganic fertilizers, pesticides and irrigation; which are inputs that are dependent on fossil fuels. The global dynamics of fossil fuel energy costs have significantly affected the input costs of crop production in the region and will be a major factor affecting production costs in the future.

Energy costs have been increasing faster than other input costs. Over the past 10 years, prices of diesel fuel and natural gas have increased at an annual rate of 8.2% and 8.3%, respectively (Energy Information Administration, 2007). Over the same period, the annual increase in the Index of Prices Paid for Agricultural Production Items was 2.8% (NASS, various issues). Although increasing fuel prices have affected producers across the nation, irrigated farmers on the SHP face the situation of reliance on energy to pump irrigation water in addition to other energy intensive inputs. Input costs for fuel and energy related inputs for cotton production in the region increased at a 12% annual rate between 1995 and 2005, while the cost of non-energy related inputs increased at a 4% annual rate (Johnson, Yates and Smith, 2006).

While there is some literature on how different agricultural systems consume energy, the specific needs of the producers in the SHP must be addressed in accordance with their dependence upon primary inputs such as irrigation. It is crucial to understand and analyze the potential of sustainable agricultural systems in this region and comprehend how they may aid in the conservation of energy while maintaining yields, socioeconomic levels, and profits. The objective of this study was to measure the use of energy for cotton production in the SHP region. Specifically, energy budgets were prepared to measure energy use for cotton production across different irrigation systems using data from the Texas Alliance for Water Conservation project (TAWC, 2007)

Methods and Materials

Energy inputs can be categorized as direct, indirect, and embedded. Use of fuel for irrigation and mechanical operations is considered a direct energy input. Inputs that require energy or fossil fuel for manufacture of fertilizers, commonly nitrogen fertilizer, and chemicals represent indirect energy inputs into the production process. Embedded energy is categorized as energy required in manufacturing capital assets used on the farm, such as machinery, equipment, and irrigation systems. In this study, only direct and indirect energy are considered.

There are several methods of analyzing energy in agricultural production systems including statistical, input-output analysis, and process analysis (Fluck and Baird 1980). Each is either considered a measure of efficiency, how well energy is converted, or intensity which involves a macro-analysis of the industry as a whole. Both the process method and the input-output analysis are generally applied to the study of energy efficiency, while the statistical method is used to measure energy use intensity. Bullard et al. (1976) indicated that the process analysis is more suited to specific processes, products or manufacturing chains in which the flow of goods and services can be easily traced. In this study the process analysis method was chosen due to the suitability of this method to farm level analysis of production systems. This method is preferred when there is sufficient data available to fully understand the farm practices, operational methods, input quantities, and yield characteristics over several crops and or systems.

Energy coefficients (expressed as mega-joules/unit, see Appendix) were established for all inputs, and calculated based on the quantity of inputs used. Energy budgets were developed so that the amount of energy required by each system can be compared with profitability, production practice, and cropping system. The energy coefficients for the various inputs were obtained from a number of sources which included: Pimentel (1980), Fluck and Baird (1980), and Green (1987).

The data available for this study encompasses all aspects of the production model through individual producer records. The Texas Alliance for Water Conservation project has gathered data from 26 sites in Floyd and Hale Counties of Texas for the 2006 crop year (TAWC, 2007). Data for this study was from 25 cotton fields (1,603 acres) on 21. The cotton production systems analyzed were under irrigation systems that included subsurface drip (SDI), low energy precision application pivot (LEPA), mid-elevation spray application pivot (MESA), low elevation spray application pivot (LISA), and conventional furrow irrigation (CF).

The direct energy values are the summation of energy consumed in field operations, harvest, processing, and irrigation. In the case of field operations and harvest, the direct energy values represent the amount of diesel fuel consumed in the various mechanical operations. Processing or ginning includes the electricity and fuel used to transport and gin the seed cotton. Energy used in irrigation was calculated assuming electricity as the primary fuel source. Indirect energy calculations consisted of the energy used to manufacture and transport production inputs such as fertilizer and chemicals including harvest aids, herbicides, insecticides and seed production. The energy coefficients, particularly those for nitrogen fertilizer, are primarily driven by the amount of natural gas required in the production process.

Discussion and Results

The results of the energy analysis are summarized in Table 1. The values shown are weighted means by acres for each type of irrigation system. It is important to note that the focus of this study was to understand the energy efficiency, not total consumption, of different types of irrigation systems. In this particular case the efficiency measures are in three categories; 1) energy consumed to produce one bale of cotton, 2) energy consumed to generate one dollar of gross revenue, and 3) the energy consumed to generate on dollar of gross margin.

Table 1. Energy Summary by Irrigation System

	SDI	LEPA	MESA	LESA	CF
Yield (bale per acre)	3.89	2.39	2.58	3.04	2.48
Acre Inches Applied	19.92	11.35	14.48	12.77	15.71
Lbs per acre inch	93.71	101.18	85.54	114.05	75.64
Acres	242.20	394.00	318.60	488.90	159.60
Observations	6.00	5.00	4.00	7.00	5.00
	--------------------------------(MJ)----------------------------------				
Direct Energy per acre	5560.53	3501.50	3954.80	4058.71	4276.30
Indirect Energy per acre	5949.59	4834.58	5081.27	6438.01	3401.53
Total Energy per acre	11510.12	8336.08	9036.07	10496.72	7677.83
Energy per bale	2958.82	3485.54	3501.24	3458.33	3102.13
Energy per $ Gross Margin	28.88	36.68	38.59	33.65	32.75
Energy per $ Gross Revenue	9.42	11.03	11.09	11.09	9.88

The SDI system had a yield of 3.89 bales per acre which was the highest across irrigation systems. However, irrigation water applied for the SDI system was also the highest at 19.92 acre inches. Water use efficiency as measured by pounds of lint per acre inch applied varied from 114.05 lbs per acre inch for the LESA system to 75.64 lbs per acre inch for the CF system. While the SDI system had the highest yield, its water use efficiency was third highest at 93.71 lbs per acre inch. The LESA system had the highest water use efficiency while the CF system had the lowest water use efficiency.

Total energy used varied from a high of 11510.82 MJ per acre for the SDI system to 7677.83 MJ for the CF system. The SDI system had the highest level of direct energy use at 5560.53 MJ which was related to the level of water applied at 19.92 acre inches and the harvest and processing of 3.89 bales per acre. The LESA system had the highest level of indirect energy use at 6438.01 MJ which was related to higher levels of fertilizer application. The results indicate that the SDI and CF systems were the most efficient in terms of energy use per bale, 2958.82 MJ and 3102.13 MJ, respectively. The pivot systems (LEPA, MESA and LESA) were similar with a range of 3458.33 MJ to 3501.24 MJ per bale.

Energy use per dollar of gross revenue followed the same relationship as energy use per bale, with the SDI and CF systems being the most efficient at 9.42 MJ and 9.88 MJ per dollar of gross revenue, respectively. The pivot systems had a very small range from 10.92 MJ per dollar of gross revenue for the MESA system to 11.09 MJ per dollar of gross revenue for the LESA system.

Energy use per dollar of gross margin was 28.89 MJ for the SDI system, which was the lowest across all systems irrigation systems. The CF and LESA systems used 32.75 MJ and 33.65 MJ to generate a dollar of gross margin, respectively. The LEPA and MESA systems were least efficient with respect to energy use per dollar of gross margin. Gross margin which is gross revenues less variable expenses takes into account the costs of production inputs. Using gross margin as a measure of energy use efficiency reflects the efficiency of energy use from both direct and indirect sources to generate profitability. Additionally, the SDI system and CF system were the most efficient with respect to energy use efficiency as measured by yield and gross revenue.

Table 2 presents an economic summary for each irrigation system. The SDI system had the highest gross revenue, gross margin, and net returns, which is primarily due to the SDI system having the highest lint yield at 3.89 bales per acre. However, the LESA system had the highest profitability per acre inch of water applied with $24.42 of gross margin per acre inch and $18.27 of net returns per acre inch. This compares to the SDI system of $20.00 of gross margin per acre inch and $13.98 of net returns per acre inch. The CF system had the lowest profitability per acre inch at $14.93 of gross margin per acre inch and $10.47 of net returns per acre inch.

Table 2. Economic Summary by Irrigation System

	SDI	LEPA	MESA	LESA	CF
	($/Acre)				
Gross Revenue	1222.23	755.84	814.45	946.14	776.89
Pre Harvest Cost	420.77	302.85	332.77	339.49	309.09
Harvest Cost	388.48	215.33	237.51	283.06	222.79
Interest Cost	14.41	10.37	10.01	11.63	10.59
Total Variable Cost	823.65	528.55	580.29	634.18	542.47
Gross Margin	398.57	227.29	234.15	311.96	234.43
Fixed Cost	120.00	78.60	78.60	78.60	70.00
Total Cost	943.65	607.15	658.89	712.78	612.47
Net Returns	278.57	148.69	155.55	233.36	164.43
Gross Margin per Acre Inch Applied	20.00	20.03	16.17	24.42	14.93
Net Returns per Acre Inch Applied	13.98	13.11	10.74	18.27	10.47

Conclusions

Since only one year's data (2006) was analyzed, it is difficult to draw any definitive conclusions for the analysis. However, there are some interesting results that can be discussed. The SDI system was the most efficient with regard to energy use, however; the SDI system used the greatest amount of total energy. The CF system was the second most efficient system with respect to energy use, which was surprising given that the CF system is considered to be the least efficient with regard to water application efficiency. The center pivot systems (LEPA, MESA and LESA) were very similar with regard to energy use efficiency. However, the LESA system was the most efficient of the three with regard to energy use efficiency per dollar of gross margin.

The LESA system had the highest water use efficiency with regard to gross margin and net return per acre inch of water applied. The SDI system had the highest yields, but also had the highest amount of water applied. From a profitability standpoint the SDI system gave the highest total returns, however; its water use efficiency per dollar of return was not as good as the LESA system.

Yield levels for each system are an important variable in all aspects of the analysis. All calculations in this study are based on input quantity applied or consumed. In this respect, the more input applied the more potential output was produced. There is a direct correlation between total energy used and yield, thus comparisons between systems was based on energy efficiency and not the quantities of inputs or production.

Data from the Texas Alliance for Water Conservation project is available for 2005 and will be available for 2007. Further analysis is planned to look at the three years 2005, 2006 and 2007 with regard to energy use efficiency in cotton production across the irrigation systems.

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Appendix

Mega joule (MJ) – a joule is defined as a metric (SI) unit of work or energy. One mega joule, MJ, is one million joules.

The following table represents several common conversion factors and measurements related to the joule.

Common Conversions and Measurements of the Mega joule

Energy Measurement	Btu	MJ
1 Kilowatt hour of electricity	3,412	3.6
1 Gallon of Gasoline	115,400	131.9
1 Gallon of Diesel	128,700	135.8
1 Gallon of LP Gas	83,500	88.1
1 Mcf of Natural Gas	1,031,000	1,008.0
1 Barrel of Crude Oil	5,535,600	5,840.0