Returns to Tillage Systems under Changing Input and Output Market Conditions

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Abstract

Costs and net returns for conventional tillage (CT), reduced-tillage (RT) and no-tillage (NT) are evaluated for five cropping systems: continuous soybean, a soybean-grain sorghum rotation, a soybean-wheat rotation, continuous grain sorghum and continuous wheat, over a period of increasing input and output prices, 2006-2008. NT had the highest net return for all of the systems with soybeans each year. NT also had the lowest energy use for all systems. The net returns of NT increased relative to CT and RT from 2006 to 2008 for all of the systems with soybeans. However, this increase in net returns was a result of increasing commodity prices rather than a slower increase in costs for NT.

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Introduction

It has been suggested that reducing tillage as a response to increasing energy prices may provide economic benefits to farm managers because cropping systems that use less tillage are believed to be less energy intensive even when herbicides used for weed control are accounted for. Langemeier and Weeden report that increases in energy related expenses (fertilizers and fuel) were a major contributor to increasing whole-farm production costs on Kansas farms in recent years (2008). Although changes in fertilizer prices may have little to no impact on what type of tillage system to use if fertilizer rates are not impacted by tillage, increasing fuel prices certainly affect costs more in systems using more tillage. Although herbicides can be energy intensive per pound of product, the total pounds of use are significantly less than fertilizers on a per acre basis, so rising energy prices should have a smaller impact on these costs per acre. From June 2006 to June 2008, USDA's price index for fertilizers showed a 122 percent increase, fuels a 63 percent increase, while the herbicide price index showed a 6.5 percent increase (USDA).

In addition, changes in relative output prices may influence cropping and tillage systems. High grain prices as well as increasing fertilizer, herbicide and energy costs may cause changes in crop rotation and tillage system selection. There have been some recent studies that have examined the economic feasibility of reducing tillage (Pendell et al.; Epplin et al.; Ribera, Hons and Richardson; Williams, Roth and Claassen). However, these studies did not consider the impact of changes in input and output price conditions, particularly the higher input and output prices currently affecting agricultural markets.

Nail, Young and Schillinger found that increases in diesel price and decreases in glyphosate price favor the profitability of herbicide-intensive conservation tillage systems versus fuel-intensive traditional tillage systems. Diesel fuel prices increased 72 percent from June 2006 to June 2008 (USDA), but glyphosate prices have also increased in recent years after several years of decline. Glyphosate has been popular because it has been relatively inexpensive, simple to use and effective. With more widespread adoption of glyphosate resistant crops, global demand has been increasing faster than supply, resulting in significant price increases. Glyphosate prices from input suppliers in northeast Kansas increased 64 percent from June 2006 to June 2008 ($33 to $54 for 4.5 lbs. effective ingredient per gallon for generic label glyphosate). How does profitability of reducing tillage fare under the changing input and output price conditions of recent years?

Few studies have evaluated the associated energy balance of various crop rotations and tillage systems. Rathke et al. assessed energy balances for continuous corn, continuous soybeans and a corn-soybean rotation using conventional tillage, ridge-till and no-till treatments in eastern Nebraska. They found that the no-till systems had the lowest energy inputs and energy input was lower for soybeans than for corn.

This study presents an economic analysis of using conventional tillage (CT), reduced-tillage (RT) and no-tillage (NT) in five cropping systems. The objectives include determining the change in relative costs, gross returns and net returns by tillage method for each cropping system during the most recent three years 2006, 2007 and 2008. This time period is selected as input and output prices increased significantly from 2006 to 2007 and continued to increase in 2008. The energy intensity of NT compared to RT and CT is also examined. The objectives also include determining the tillage system that has the highest net return for each cropping system, and the cropping system that has the highest overall net return of the 15 strategies.

Procedures and Data

Annual yield, input types and rates and field operations were obtained from twelve years of data (1996-2007) from an experiment field near Manhattan, Kansas. Production costs, gross returns, and net returns were determined for 2006, 2007 and 2008.

Study Region

Yields were obtained from the Kansas State University experimental field, located in the Kansas River Valley at Ashland Bottoms, nine miles south of Manhattan, Kansas. Field experiments were designed with the objective of evaluating the effects and feasibility of conservation tillage systems in northeastern Kansas. The soil at the research center is of two types: Muir silt loam (fine-silty, mixed, mesic Cumulic Haplustoll) and Reading silt loam (fine-silty, mixed, mesic Typic Arguidoll). Average annual precipitation was 34.1 inches with a standard deviation of 6.1 inches over the study period.

Production Systems

The study evaluated five different combinations of three crops under three different tillage systems: CT, RT and NT. The three crops in the study are soybean (S), grain sorghum (G) and winter wheat (W). The cropping systems include three continuous cropping systems (continuous soybean, continuous grain sorghum and continuous wheat) and two crop rotations (soybean-grain sorghum and soybean-wheat). The fifteen cropping systems studied consist of:

CTCS – CT for continuous soybean
RTCS – RT for continuous soybean
NTCS – NT for continuous soybean
CTSG – CT for soybean-grain sorghum rotation
RTSG – RT for soybean-grain sorghum rotation
NTSG – NT for soybean-grain sorghum rotation
CTSW – CT for soybean-wheat rotation
RTSW – RT for soybean-wheat rotation
NTSW – NT for soybean-wheat rotation
CTCG – CT for continuous grain sorghum
RTCG – RT for continuous grain sorghum
NTCG – NT for continuous grain sorghum
CTCW – CT for continuous wheat
RTCW – RT for continuous wheat
NTCW – NT for continuous wheat

The field operations varied according to tillage and cropping systems. In general, under CT a chisel plow, disk and field cultivator were used in all cropping systems with the exception of continuous soybeans, which did not use a disk. Post-emergence herbicides were used for soybean, grain sorghum and wheat production. A pre-emergence herbicide was also used on grain sorghum. The RT field operations were similar to CT except that a chisel plow was not used. Additional herbicides were applied in RTCS and RTSW. For NT, the crop residues were left on the surface and planting occurred directly into the residue. All weed control was accomplished with the use of herbicide applications.

NT planting equipment was used for all of the NT systems. Soybeans (glyphosate resistant variety) were planted at a rate of 150,000 seeds per acre. A post-emergence herbicide was applied to all soybeans. Grain sorghum seed treated with a seed safener (to protect the grain from herbicide injury) plus insecticide and was planted at a rate of 55,000 seeds/acre. Pre- and post-emergence herbicides were applied to grain sorghum in all tillage systems. Wheat seed was planted at a rate of 70 lbs. per acre and a general herbicide was applied in the continuous wheat systems. Grain sorghum and wheat crops were fertilized with a blend of urea (46-0-0) and diammonium phosphate (18-46-0) to provide a total of 100 lbs. of nitrogen and 23 lbs. of P205 per acre. Fertilizer in the NT wheat was applied at planting and as a separate operation in CT and RT wheat. Soybeans were fertilized with diammonium phosphate to provide 23 lbs. of P2O5 per acre.

Energy Use in Crop Production

Energy expenditures for agricultural crop production can be divided into those used on-site (e.g., within the field) and those used off-site for the manufacture of materials needed for production. On-site energies are typically referred to as direct energies and off-site are embodied or indirect energies. On-site energy use and emissions result from fossil-fuel combustion (i.e., primarily diesel fuel) occurring on the farm that is directly related to crop production. Off-site energy use are those energy expenditures from fuel oil, natural gas, electricity, etc. required to produce, manufacture, process and/or distribute the raw materials, machinery, fuels, and/or chemicals needed to produce agricultural commodities. Energy consumption in the form of diesel fuel combustion (direct energy) and that used in the manufacture and production of fertilizers, herbicides and machinery (embodied energy) was calculated for each field operation and input to determine if NT systems were less energy intensive. Diesel fuel contains about 138,700 Btu per gallon and N, P and K embodied energy values are approximately 24,700, 3,022 and 2,945 Btu/lb., respectively, while herbicide/pesticide embodied energy values range from roughly 9,000 Btu/lb. to over 250,000 Btu/lb. The value for glyphosate is 204,633 Btu/lb. Embodied energy values for machinery range from 16,000 Btu/acre for a single cultivator to over 71,000 Btu/acre for a combine. Energy consumption rates were obtained from West and Marland.

Yields, Prices, Costs and Net Returns

Yield data for the five cropping systems under the three tillage systems were obtained from the experiment field for 1996-2007 and used to calculate an average yield (Table 1). Glyphosate resistant soybeans were introduced in the U.S. in 1996. The 1996 Farm Bill decoupled subsidy payments from production of specific crops, resulting in more flexibility in choosing which crops to produce. The years 1996 through 1999 were wet years and the years 2000 through 2003 were dry years. For all systems, the average yields for 2000 through 2003 are lower than the average yield for 1996 through 1999. The average yields for 2004 through 2007 fell between the averages for 1996 through 1999 and 2000 through 2003, with the exception of wheat in the soybean-wheat rotation. They are somewhat lower. We wanted to include wet, dry and average years. The 1996 to 2007 averages were either very similar to, or greater than, the average of the last five years (2003 to 2007).

Annual average crop prices for northeast Kansas in 2006 and 2007 were obtained from the Kansas Agricultural Statistics Service. The commodity prices used to calculate the 2008 net returns were the average weekly Kansas cash prices over the period January 1 to December 10, 2008 (Table 2). Prices increased substantially from 2006 to 2008. Soybean price increased by 108 percent, grain sorghum price increased 97 percent and wheat price increased 79 percent.

Gross returns for each year are reported in Table 3 and were calculated by using average yields and an average price for each year. Costs for each field operation were based upon Kansas custom rates for 2006 and 2007 (NASS, 2007 and NASS, 2008). Therefore, fuel price does not enter directly into the cost analysis. Each field operation cost for 2008 was estimated by increasing the cost by the same percentage it increased from 2006 to 2007. This increase ranged from 2.3 percent to 7.4 percent with an average of 4.7 percent. Prices for herbicides were obtained from Kansas State University 2006, 2007 and 2008 and input suppliers. Prices for fertilizers were obtained from input suppliers each year. Experiment field application rates were used to calculate input costs. Seed prices were obtained from an annual Kansas State University publication which includes input prices for forward planning (Kastens et al., 2005; Kastens et al., 2006 and Kastens et al., 2007). These prices were also validated for accuracy with input supply firms.

Total costs for each year as well as the change in total costs from 2006 to 2007, 2007 to 2008 and 2006 to 2008 are reported in Table 3. Detailed costs for 2006, 2007 and 2008 are reported in Tables 4, 5 and 6, respectively. Changes in detailed costs from 2006 to 2008 are reported in Table 7. Net returns to land, management and risk for each production system were calculated by subtracting input costs, field operation costs and interest from gross returns. Government payments were not used in calculating net returns because they do not directly influence the cropping or tillage decision. Net returns are reported in Table 3.

Results

Energy Use

Energy intensity is reported in Table 1. Direct energy use (in-field diesel fuel consumption) was greatest for CT in all five cropping systems studied because there were more energy intensive field operations (disking, etc.) per acre versus RT and NT systems (Figure 1). The second highest direct energy use was from RT for each cropping system. Embodied energy from inputs, primarily the energy required to produce the herbicides used in crop production, is the highest in NT because more herbicides were used (Figure 2). Total energy use was greatest in the CT systems for all five cropping systems (Table 1). This was because there were more energy intensive field operations in CT. The smaller embodied energy from reduced use of herbicides in CT relative to RT and NT was outweighed by the impact of its larger direct energy use for field operations. These results are similar to those found by Rathke et al. for eastern Nebraska.

Tillage Impact on Yield

There was no statistically significant difference in crop yields due to tillage systems (Table 1). Soybeans yields were higher under NT in each cropping system they were included in, but there was no statistically significant difference between the three tillage systems. Grain sorghum yields were higher under NT in both the soybean-grain sorghum rotation and continuous grain sorghum; though again, there was no statistically significant difference between tillage systems. Wheat yields were similar among the CT and RT systems and higher than the NT systems, particularly in the CT continuous wheat. Continuous wheat yields were highest on average under the CT system, but there was no statistically significant difference between the tillage systems.

Crop Rotation Impact on Yield

There was no statistically significant difference in soybean yields between the soybean-wheat and soybean-grain sorghum rotations. However, soybean yields were higher in the crop rotations than continuous cropping (Table 1). The highest yields for soybeans were obtained with the soybean-wheat rotation and the second highest with the soybean-grain sorghum rotation. Yields for grain sorghum were higher in the soybean-grain sorghum rotation than continuous grain sorghum, although there was no statistically significant difference. Grain sorghum yields in continuous NT were likely suppressed compared to sorghum in other cropping systems due to increased weed pressure (fall panicum) and disease infestations. The yields for wheat were similar in the soybean-wheat system and continuous wheat system for CT and RT, although not statistically significant. The wheat yields in continuous NT were lower due to increased pest problems, notably cheatgrass and diseases. Williams, Roth and Claassen (2004) found similar results for continuous NT wheat in south-central Kansas.

Tillage Impact on Costs

Herbicide costs and planting costs were the highest for NT systems in each year. Tillage costs were highest for CT systems in each year. Planting costs were slightly higher for the NT systems because NT planting equipment was used. Fertilizer costs for NT wheat were slightly lower because fertilizer was applied at planting. This does not show up in the table due to rounding to the nearest dollar.

In 2006 and 2007, NT had the lowest total costs for the three systems containing soybeans. RT had the lowest total costs for continuous grain-sorghum and continuous wheat (Tables 4 and 5). Herbicide costs in NT were less than tillage plus herbicide costs in CT and RT in all systems with the exception of continuous wheat (Table 3). The increased herbicide costs in NT were more than offset by lower field operation costs, although this difference grew smaller over time due to increasing glyphosate prices. Taking planting costs into account, herbicide plus planting costs were higher in NT than the sum of tillage, herbicide and planting costs for RT in continuous grain sorghum and continuous wheat (Table 4). Figure 3 illustrates the pattern of costs for 2007.

In 2008, RT had the lowest cost in all systems except soybean-wheat (Table 6). Herbicide costs in NT were less than tillage plus herbicide costs for CT and RT in the three systems with soybeans, but not continuous grain sorghum as it had been in previous years (Table 3). The difference for the systems with soybeans was also smaller than in the previous years. These changes in NT relative to RT and CT were due to increasing glyphosate prices. Slightly lower planting costs and harvest costs for RT contributed to lower total costs. Figure 4 illustrates the pattern of costs for 2008.

Tillage Impact on Gross and Net Returns

NT had the highest gross return for the three systems with soybeans and continuous grain sorghum (Table 3). CT had the highest gross return for continuous wheat, followed closely by RT.

Net returns were highest for NT in the three systems containing soybeans in all three years due to both higher gross returns and lower costs with the exception of slightly higher total costs in 2008. Despite lower gross returns, RT had higher net returns than NT for continuous grain sorghum in 2006 and 2008 due to lower costs. RT also had higher net returns than NT for continuous wheat in all three years due to both higher gross returns and lower costs (Table 3). CT had the lowest net return for soybean-grain sorghum, soybean-wheat and continuous grain sorghum. In all three years, CT had the second highest net returns for continuous wheat, having the highest gross returns and continuous soybeans with the second highest gross returns.

Relative Cost Changes from 2006 to 2008

Fertilizer prices increased substantially from 2006 to 2008. Fertilizer and application costs increased $17.27/acre for continuous soybeans, $31.95/acre for soybean-grain sorghum and soybean-wheat and $46.62/acre for continuous grain sorghum and continuous wheat (Table 7). This is a 144 percent increase for continuous soybeans, 103 percent increase for soybean-grain sorghum and soybean-wheat and 93 percent increase for continuous grain sorghum and continuous wheat. Seed prices increased the most for wheat (47%) and the least for soybean (5%) and grain sorghum (5%). These changes did not affect the profitability of one tillage system versus another because the same fertilizer levels and seeding rates were used in each tillage system for a given cropping system. If all costs besides fertilizer and output prices remain constant, systems containing soybeans, regardless of tillage system, would have had their relative profitability increase compared to others, because these systems use relatively less fertilizer.

Tillage costs increased more in the CT systems than RT systems (Table 7 and Figure 5). Although planting costs were slightly higher in NT due to the use of NT planting equipment, the custom charge for planting increased more in the CT and RT systems than for NT. Herbicide costs, including application costs, increased in some cases and declined in others. The cost of herbicides (s-metolachlor and atrazine mix) used for grain sorghum production decreased each year resulting in a decline in cost in the CT and RT systems for continuous grain sorghum. Herbicide costs increased in the other systems from $0.08/acre for NTCG to $12.06/acre for NTCS, largely due to increasing glyphosate price. The increase in herbicide costs for NT, including application costs, was more than the increase in tillage costs in CT and RT for all cropping systems with the exception of continuous grain sorghum (Table 7). Herbicide and planting costs increased more in NT than tillage, herbicide and planting costs in CT and RT (Table 7).

Total costs increased from $0.07 (NTCG) to $5.30/acre (NTCW) more for NT than CT systems. CT costs increased from $0.91 (CTCS) to $1.64/acre (CTSG) more than RT with the exception of soybean-wheat where RT costs increased more.

Sensitivity Analysis

NT uses 0.75 lb. to 1.50 lbs./acre more glyphosate than CT and RT. CT and RT use the same amount for a given cropping system. From 2006 to 2008, the cost of glyphosate increased 64 percent in northeast Kansas. If the price of glyphosate continues to increase, then the net returns for the NT systems including soybeans would probably decrease compared to their CT and RT counterparts simply because of the higher reliance on glyphosate for NT systems. Of course, the relative net income also depends upon what happens to the cost of performing field operations, particularly with respect to fuel prices.

A sensitivity analysis was performed using the 2008 costs to determine the glyphosate price needed for the NT systems to have total cost equal to the CT and RT systems. For NT to have equivalent total costs to CT the price of glyphosate needs to fall from $54.00/gallon to $47.09/gallon for CTCW, and rise to $64.00/gallon for CTSW, $73.76/gallon for CTCS, $99.87/gallon for CTCG and $101.00/gallon for CTSG. For NT to be equivalent to the RT total costs, glyphosate prices need to decrease to $18.71 for RTCW, $36.84/gallon for RTCG, $42.46/gallon for RTSG, $50.54/gallon for RTCS and increase to $138.53/gallon for RTSW.

A sensitivity analysis was also performed to determine the glyphosate price needed for CT and RT systems to have equivalent net returns with the NT system. For CT to be equal to NT, glyphosate prices would need to rise to well over $100/gallon for all of the cropping systems with the exception of continuous wheat to have equivalent net returns. The price of glyphosate would have to rise to well over $250/gallon for three of the cropping systems using RT, RTSS, RTSG and RTSW to have net returns equivalent to their NT counterparts. The price would need to fall to $49.51/gallon to increase net returns by $0.78/acre, in NTCG resulting in equivalent net returns to RTCG. Even if glyphosate was free, the CT and RT system for continuous wheat would be more profitable than NT because of their higher gross returns and low herbicide costs.

Diesel prices increased 58 percent from May of 2007 to 2008 compared to a -3.5 percent reduction the previous year (Energy Information Administration). Therefore, the increase in field operation costs for 2008 based upon the change from 2006 to 2007, as previously described, may understate the actual 2008 costs for field-operations. We can't capture the impact of fuel prices directly because we use custom rates for field operation costs. As stated earlier, NT net returns are higher than other tillage systems with the exception of continuous grain sorghum where RTCG has higher returns than NTCG. NT systems had lower field operation costs with or without including harvest cost in all cropping systems; therefore, if field operation costs actually increased in 2008 in response to the rise in fuel prices, NT net returns would increase relative to other tillage-systems. Therefore, only the cost increase for each field operation that would make NTCG have equivalent net returns to RTCG in 2008 was derived. If the average increase in field operation costs was 9.8 percent rather than 4.7 percent as originally used, the NTCG system would have equivalent net returns to RTCG.

Relative Gross and Net Return Changes

The increase in gross returns due to rising commodity prices from 2006 to 2008 was greater for NT than CT and RT for the cropping systems containing soybeans and continuous grain sorghum because yields were higher in the NT systems. CT gross returns increased more than NT and RT gross returns for continuous wheat because yields were highest in the CT system (Table 3).

From 2006 to 2007 and 2007 to 2008, the results show that the net return of NT relative to CT and RT increased for the systems with soybeans due to higher gross rather than relative costs decreasing. Similarly, for continuous wheat, net returns increased the most for CT over the study period due to higher gross returns (Table 3). For continuous grain sorghum, NT net return increased the most from 2006 to 2007, but RT increased the most for continuous grain sorghum from 2007 to 2008 because of the decrease in herbicide costs for RT compared to the increase for NT.

Overall Results

Net returns of all systems increased from 2006 to 2007 and from 2007 to 2008 given average yields based on 1996-2007 (Table 3). In all years, the system with the highest net return was a NT crop rotation with soybeans. In 2006, the best performing system was NTSW and in 2007 and 2008 it was NTSG. The systems with the second highest net returns in 2006, 2007 and 2008 were also crop rotations with soybeans; RTSW, NTSW and NTSW, respectively. Therefore, with the exception of RTSW in 2006, a NT system with soybean had the highest and second highest net returns in all years.

Summary

The objectives of this study were first to compare the costs of production and net returns for three tillage systems with five cropping systems to determine whether or not NT had lower costs and higher net returns than either RT or CT. Next the study determined if the relative differences in net returns between NT and CT and RT were enhanced under increased input costs and output prices in agricultural markets. There was no statistically significant difference in crop yields due to tillage systems; however, for the purposes of the analysis we used the actual average yields which did show differences. NT consistently had the lowest net return for continuous wheat and its net return relative to CT for continuous wheat grew smaller each year. Therefore, the remaining discussion is limited to the other four cropping systems.

For the remaining systems that had soybean in continuous cropping or rotation, net returns for NT relative to CT and RT were higher and amplified under current input costs and market prices. Further, the most profitable system overall in each year was a NT rotation system (NTSW in 2006 and NTSG in 2007 and 2008). The increase in the difference in net returns was due to larger increases in gross returns for NT as a result of increasing commodity prices, given slightly higher average yields. With the exception of wheat, NT yields were higher than CT and RT yields. The increase in net returns occurred despite a greater increase in costs for NT compared to CT. Total costs increased from $0.07 (NTCG) to $5.30/acre (NTCW) more for NT than CT systems. RT also had smaller increases in costs than NT from 2007 to 2008. This was largely due to increasing glyphosate prices.

The results indicate that farm managers need to consider both the changing costs of field operations and herbicide costs when selecting a tillage practice. If the price of glyphosate continues to increase then the profitability of NT relative to systems using more tillage may decline. However, glyphosate prices would have to increase to over $100/gallon for CT to be preferred to NT with the exception of continuous wheat. If energy prices continue to rise, the increased cost of performing field operations may outweigh any cost increase in herbicides, since total energy use as well as direct energy use, is greatest in the CT systems and smallest in the NT systems. If herbicide prices hold steady or decrease as field operation costs increase due to rising diesel prices, then no-tillage will look very favorable. The increasing demand and price of glyphosate may provide incentive for construction of new glyphosate production facilities. This may stabilize and even cause the price of glyphosate to decrease. Substitute herbicides may also become available. Managers may also want to consider the use of pre-emergence herbicides instead of multiple glyphosate applications to complement post-emergence glyphosate applications. Further, no-tillage requires fewer field operations than conventional and reduced tillage. As a result, a manager may be able to farm more acres with no-tillage, leading to an increase in whole-farm net returns over time. There are also environmental benefits of no-tillage to consider. NT practices reduce soil erosion and nutrient run-off, thus improving and protecting water quality.

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Table 1. Average yields and energy intensity for each cropping system

	Continuous Soybean			Soybean-Grain Sorghum			Soybean-Wheat			Continuous Grain Sorghum			Continuous Wheat		
	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT
	CTCS	RTCS	NTCS	CTSG	RTSG	NTSG	CTSW	RTSW	NTSW	CTCG	RTCG	NTCG	CTCW	RTCW	NTCW
Average Yields[b]															
Soybeans	29.2	29.3	33.1	36.4	38.9	46.2	42.3	44.1	46.9						
Grain Sorghum				90.8	94.8	104.1				74.9	74.8	75.2			
Wheat							55.3	55.4	54.4				56.8	56.1	44.3
Energy Intensity															
Direct[c]	755	646	344	814	684	382	792	663	347	873	722	420	830	679	350
Embodied[d]															
Fertilizers	151	151	151	1,346	1,346	1,346	1,346	1,346	1,346	2,541	2,541	2,541	2,541	2,541	2,541
Chemicals	115	115	201	272	272	455	110	110	275	430	430	709	105	105	349
Seeds	276	276	276	173	173	173	222	222	222	69	69	69	168	168	168
Machinery	185	196	158	210	207	180	199	196	169	234	218	203	213	196	180
Total Embodied	727	738	786	2,000	1,998	2,154	1,877	1,874	2,012	3,274	3,257	3,522	3,027	3,010	3,237
Total	1,482	1,384	1,130	2,814	2,682	2,536	2,669	2,537	2,359	4,147	3,980	3,941	3,857	3,690	3,587

[a]
CTCS conventional tillage for continuous soybean
RTCS reduced-tillage for continuous soybean
NTCS no-tillage for continuous soybean
CTSG conventional tillage for soybean-grain sorghum rotation
RTSG reduced-tillage for soybean-grain sorghum rotation
NTSG no-tillage for soybean-grain sorghum rotation
CTSW conventional tillage for soybean-wheat rotation
RTSW reduced-tillage for soybean-wheat rotation
NTSW no-tillage for soybean-wheat rotation
CTCG conventional tillage for continuous grain sorghum
RTCG reduced-tillage for continuous grain sorghum
NTCG no-tillage for continuous grain sorghum
CTCW conventional tillage for continuous wheat
RTCW reduced-tillage for continuous wheat
NTCW no-tillage for continuous wheat

[b] Bu./acre

[c] 1,000 Btus/acre of on-farm fuel use

[d] 1,000 Btus per acre of energy used in the manufacture of fertilizers, herbicides, machinery, and other inputs

Table 2. Commodity prices ($/bu.)

	Soybean	Grain Sorghum	Wheat
2006[a]	5.51	2.32	4.38
2007[a]	7.84	3.52	5.92
2008[b]	11.48	4.56	7.83

[a] Annual average

[b] January 1 to December 10, 2008 average

Table 3. Gross returns, cost and net returns[a] ($/acre)[b]

	Continuous Soybean			Soybean-Grain Sorghum			Soybean-Wheat			Continuous Grain Sorghum			Continuous Wheat		
	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT
	CTCS	RTCS	NTCS	CTSG	RTSG	NTSG	CTSW	RTSW	NTSW	CTCG	RTCG	NTCG	CTCW	RTCW	NTCW
Gross Return															
2006	161	156	182	205	217	248	238	243	248	174	173	174	249	246	194
2007	229	222	260	303	320	365	329	337	345	264	263	265	336	332	262
2008	335	325	380	416	440	503	459	470	482	342	341	343	445	439	347
Total Costs															
2006	124	121	120	146	138	137	122	125	118	164	155	156	143	133	140
2007	133	130	128	159	150	149	136	140	132	181	170	172	164	154	162
2008	158	154	154	189	179	181	169	174	167	217	206	209	206	195	209
Tillage and Herbicide Costs[c]															
2006	44	41	37	54	46	42	34	36	26	65	56	56	47	38	42
2007	47	44	40	56	46	43	35	38	29	65	55	55	49	39	45
2008	55	51	50	60	49	49	39	44	36	65	54	56	51	41	52
Net Return															
2006	37	35	63	59	80	111	115	118	131	10	19	18	106	113	54
2007	96	92	131	144	170	215	193	197	213	83	93	93	172	178	101
2008	177	171	226	226	260	321	290	296	316	125	135	134	239	244	138
Gross Return Change															
2007-2006	68	66	77	97	103	117	92	94	97	90	90	91	87	86	68
2008-2007	106	103	121	113	120	138	130	133	137	78	77	78	109	107	85
2008-2006	174	169	198	210	222	255	222	227	234	168	168	169	196	193	153
Total Cost Change															
2007-2006	9	9	9	13	12	13	14	15	14	16	16	16	21	20	22
2008-2007	25	24	26	31	30	32	32	34	35	36	36	37	42	41	47
2008-2006	34	33	35	43	42	45	47	49	49	53	51	53	63	62	68
Tillage and Herbicide Cost Change[c]															
2007-2006	3	2	3	1	0	1	2	2	2	0	-1	-1	2	1	3
2008-2007	8	7	9	4	3	5	4	6	7	0	-1	1	3	2	8
2008-2006	11	10	12	5	4	7	6	8	9	0	-2	0	4	3	11
Net Return Change															
2007-2006	59	57	69	84	91	104	78	79	82	74	74	75	66	66	47
2008-2007	81	79	95	83	90	106	97	99	103	41	42	41	67	66	38
2008-2006	140	136	163	167	181	210	175	178	185	115	116	116	133	132	84

[a] Net returns are returns to land, management, and risk.
[b] The cropping systems are explained in Table 1 and described in the text.
[c] Herbicide costs include application costs.

Table 4. Costs (2006) for each cropping system ($/acre) [a]

	Continuous Soybean			Soybean-Grain Sorghum			Soybean-Wheat			Continuous Grain Sorghum			Continuous Wheat		
	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT
	CTCS	RTCS	NTCS	CTSG	RTSG	NTSG	CTSW	RTSW	NTSW	CTCG	RTCG	NTCG	CTCW	RTCW	NTCW
Costs[c]															
Tillage	23	14	**0**	27	19	**0**	23	15	**0**	32	23	**0**	32	23	**0**
Planting	**10**	**10**	12	**10**	**10**	12	**9**	**9**	12	**10**	**10**	12	**9**	**9**	13
Seeds	31	31	31	21	21	21	21	21	21	10	10	10	11	11	11
Herbicides [b]	**21**	27	37	**27**	**27**	42	**10**	21	26	**33**	**33**	56	**15**	**15**	42
Fertilizer [b]	12	12	12	31	31	31	31	31	31	50	50	50	50	50	50
Harvest	22	**22**	23	**24**	25	26	**23**	23	23	22	**22**	22	21	21	**19**
Interest	5	5	**5**	6	5	**5**	5	5	**5**	6	**6**	6	5	**5**	5
Total Cost[c]	124	121	**120**	146	138	**137**	122	125	**118**	164	**155**	156	143	**133**	140

[a] The cropping systems are explained in Table 1 and described in the text

[b] Includes input and application costs, 2006 fertilizer prices, 2006 herbicide prices

[c] $/acre. The lowest cost for each field operation by rotation is in bold.

Table 5. Costs (2007) for each cropping system ($/acre) [a]

	Continuous Soybean			Soybean-Grain Sorghum			Soybean-Wheat			Continuous Grain Sorghum			Continuous Wheat		
	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT
	CTCS	RTCS	NTCS	CTSG	RTSG	NTSG	CTSW	RTSW	NTSW	CTCG	RTCG	NTCG	CTCW	RTCW	NTCW
Costs[c]															
Tillage	24	15	**0**	29	19	**0**	24	15	**0**	33	23	**0**	33	23	**0**
Planting	**11**	**11**	12	**11**	**11**	12	**10**	**10**	12	**11**	**11**	12	**10**	**10**	14
Seeds	32	32	32	21	21	21	22	22	22	10	10	10	13	13	13
Herbicides [b]	**22**	29	40	**27**	**27**	43	**11**	23	29	**32**	**32**	55	**16**	**16**	45
Fertilizer [b]	15	15	15	39	39	39	39	39	39	63	63	63	63	63	63
Harvest	23	**23**	23	**25**	26	27	**24**	24	24	24	**24**	24	23	22	**21**
Interest	6	6	**6**	7	6	**6**	6	6	**6**	8	**7**	7	7	**7**	7
Total Cost[c]	133	130	**128**	159	150	**149**	136	140	**132**	181	**170**	172	164	**154**	162

[a] The cropping systems are explained in Table 1 and described in the text

[b] Includes input and application costs, 2007 fertilizer prices, 2007 herbicide prices

[c] $/acre. The lowest cost for each field operation by rotation is in bold.

Table 6. Costs (2008) for each cropping system ($/acre) a

	Continuous Soybean			Soybean-Grain Sorghum			Soybean-Wheat			Continuous Grain Sorghum			Continuous Wheat		
	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT
	CTCS	RTCS	NTCS	CTSG	RTSG	NTSG	CTSW	RTSW	NTSW	CTCG	RTCG	NTCG	CTCW	RTCW	NTCW
Costs[c]															
Tillage	26	16	**0**	30	20	**0**	25	16	**0**	35	24	**0**	35	24	**0**
Planting	**12**	**12**	13	**12**	**12**	13	**11**	**11**	13	**12**	**12**	13	**10**	**10**	14
Seeds	33	33	33	22	22	22	24	24	24	11	11	11	15	15	15
Herbicides [b]	**29**	35	50	**29**	**29**	49	**14**	28	36	**30**	**30**	56	**17**	**17**	52
Fertilizer [b]	29	29	29	63	63	63	63	63	63	97	97	97	97	97	97
Harvest	24	**23**	24	**26**	26	28	**25**	25	25	24	**24**	24	24	24	**22**
Interest	6	**6**	6	8	**7**	7	7	7	**7**	9	**8**	9	8	**8**	9
Total Cost[c]	158	**154**	154	189	**179**	181	169	174	**167**	217	**206**	209	206	**195**	209

[a] The cropping systems are explained in Table 1 and described in the text

[b] Includes input and application costs, 2008 fertilizer prices, 2008 herbicide prices

[c] $/acre. The lowest cost for each field operation by rotation is in bold.

Table 7. Change in costs for each cropping system from 2006 to 2008 ($/acre) a

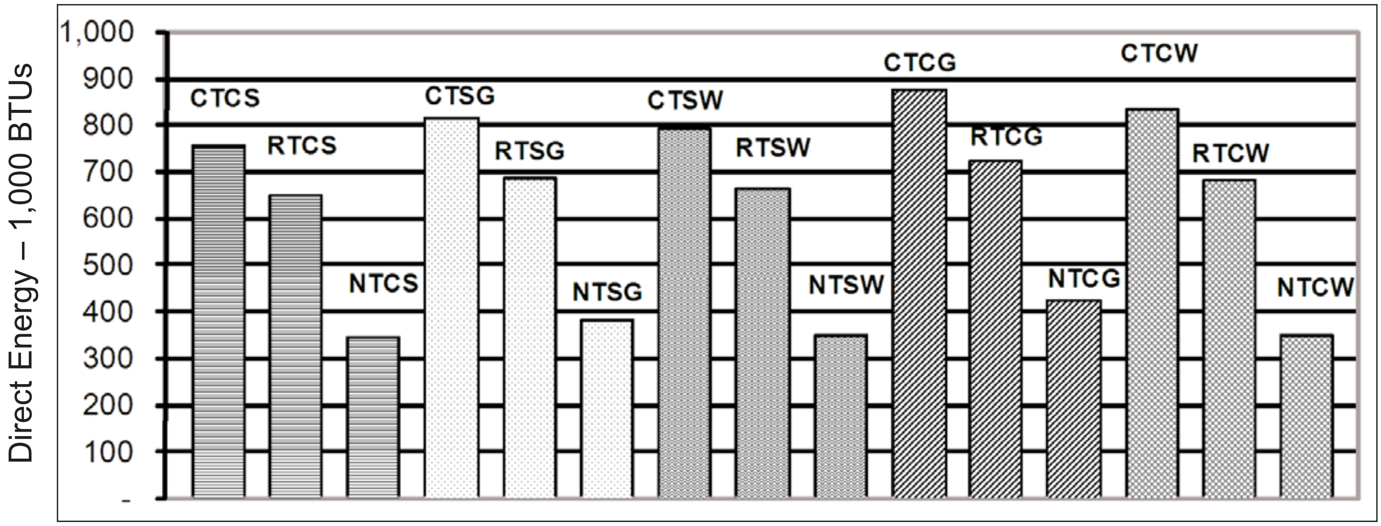
	Continuous Soybean			Soybean-Grain Sorghum			Soybean-Wheat			Continuous Grain Sorghum			Continuous Wheat		
	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT	CT	RT	NT
	CTCS	RTCS	NTCS	CTSG	RTSG	NTSG	CTSW	RTSW	NTSW	CTCG	RTCG	NTCG	CTCW	RTCW	NTCW
Costs															
Tillage	3	2	**0**	3	1	**0**	2	1	**0**	3	1	**0**	3	1	**0**
Planting	1	1	**1**	1	1	**1**	2	2	**1**	1	1	**1**	2	2	**1**
Seeds	2	2	2	1	1	1	3	3	3	0	0	0	5	5	5
Herbicides[b]	**8**	8	12	**2**	**2**	7	**4**	7	9	**-3**	**-3**	0	**1**	**1**	11
Fertilizer [b]	17	17	17	32	32	32	32	32	32	47	47	47	47	47	47
Harvest	1	1	**1**	**2**	2	2	2	2	**2**	**2**	**2**	2	3	3	**2**
Interest	2	**2**	2	2	**2**	2	**2**	2	2	3	**2**	3	3	**3**	3
Total Cost	34	**33**	35	43	**42**	45	**47**	49	49	53	**51**	53	63	**62**	68

[a] The cropping systems are explained in Table 1 and described in the text

[b] Includes input and application costs

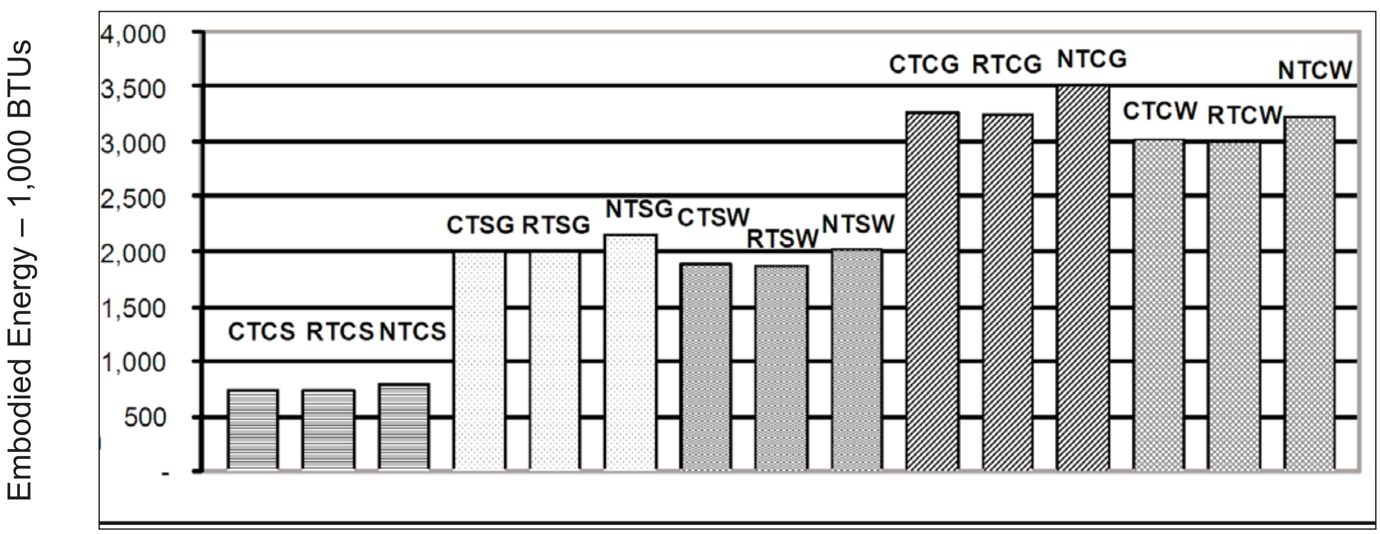
[c] $/acre. The lowest increase in cost for each field operation by system is in bold.

Figure 1. Direct energy use by cropping system [a]



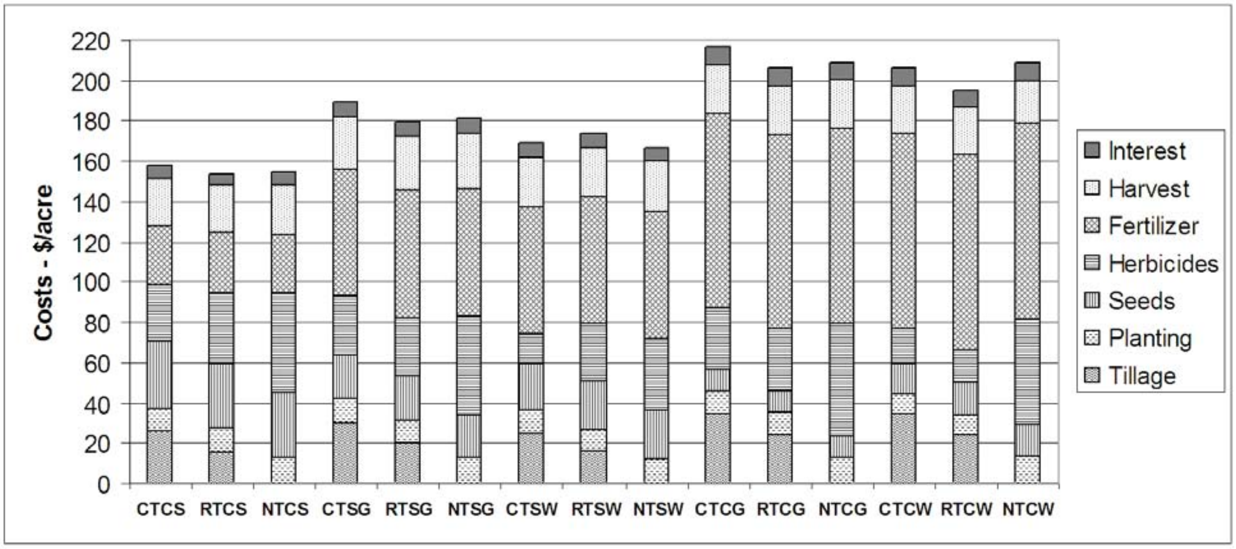
[a] The cropping systems are explained in Table 1 and described in the text.

Figure 2. Embodied energy use by cropping system [a]



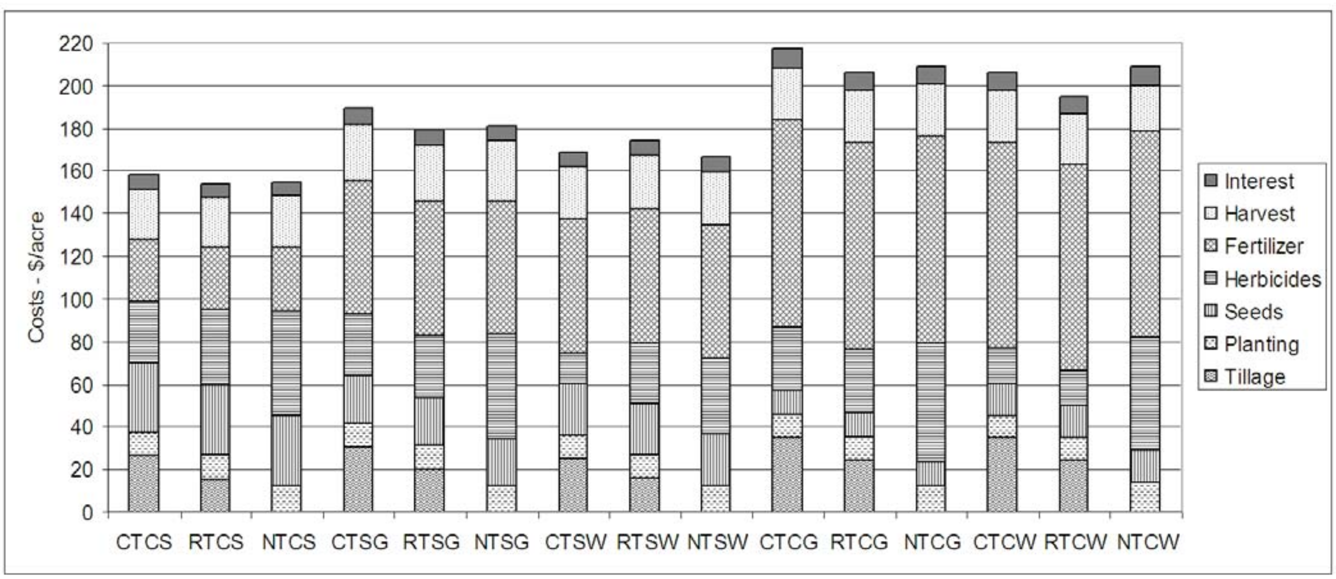
[a] The cropping systems are explained in Table 1 and described in the text.

Figure 3. Costs (2007) by cropping system ($/acre) [a]



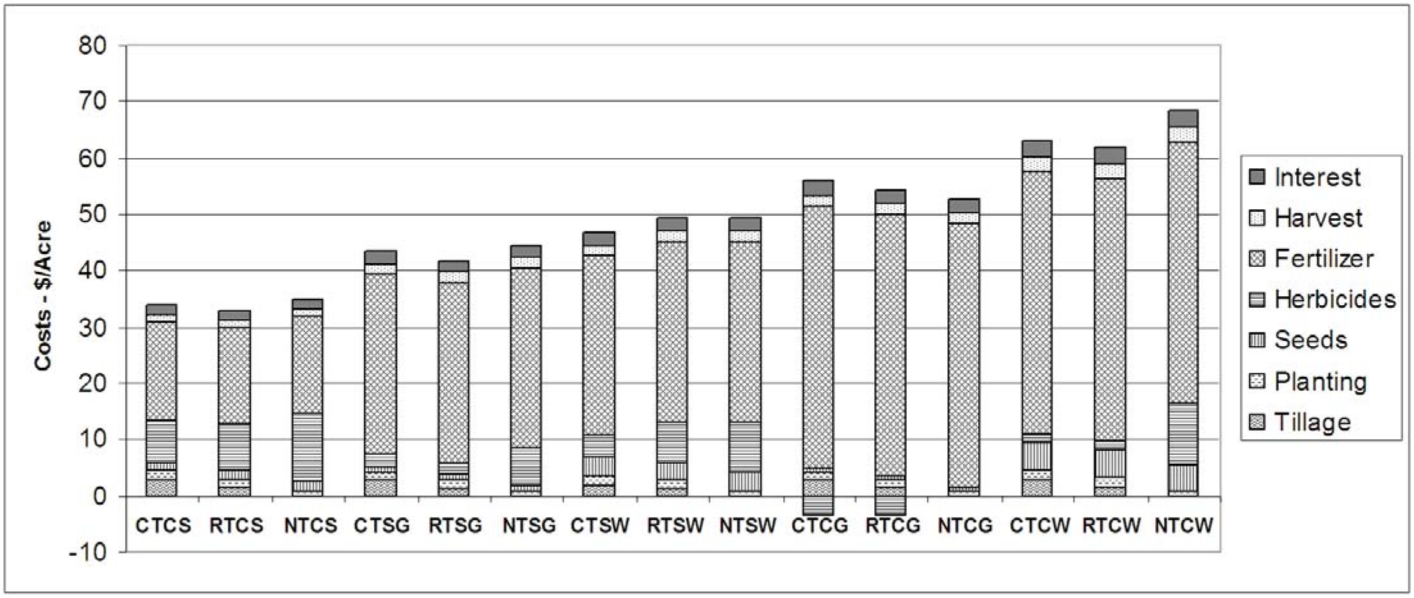
[a] The cropping systems are explained in Table 1 and described in the text.

Figure 4. Costs (2008) by cropping system ($/acre) [a]



[a] The cropping systems are explained in Table 1 and described in the text.

Figure 5. Change in costs from 2006 to 2008 by cropping system ($/acre) [a]



[a] The cropping systems are explained in Table 1 and described in the text.