

**Water Quality Indices and Net Returns for  
Crop Rotations in the Lower Blue Watershed**

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and

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June 2006

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## **Water Quality Indices and Net Returns for Crop Rotations in the Lower Blue Watershed**

### **Abstract**

This paper examines water quality indices and net returns for a corn-soybean rotation and a grain sorghum-soybean-wheat rotation in the Lower Blue Watershed. Reducing tillage had a marginal impact on production cost per acre, but was found to substantially improve soil erosion, N transport, and P transport for both the corn-soybean and grain sorghum-soybean-wheat rotations. The soil erosion, N transport, and P transport indices for the grain sorghum-soybean-wheat rotation were, in general, higher for the reduced tillage scenarios than the corresponding indices for the corn-soybean rotation indicating that water quality was relatively worse for the grain sorghum-soybean-wheat rotation. Levels of surface runoff were similar across rotations and practices.

## **Introduction**

Water quality issues associated with production agriculture have become increasingly important in recent years. Assuming that farmers are choosing crop rotations with the highest net return per acre, there may be a cost associated with improving water quality parameters. Therefore, policy makers, farmers, and extension personnel are interested in the practices that may improve water quality and the associated cost of these practices.

This white paper is part of a six part series that summarizes the results of a KDHE funded project that examined water quality indices and production cost per acre for typical crop rotations found in the Upper Delaware, Lower Blue, Lower Kansas, Lower Arkansas, Middle Arkansas, and Upper Arkansas watersheds. The overall objective of the project was to examine the tradeoff between net return per acre and water quality for representative non-irrigated crop rotations in each watershed. Results for the Lower Blue Watershed are summarized in this paper.

## **Methods**

The Erosion Productivity Impact Calculator (EPIC) model was used to simulate water quality parameters for each specific non-irrigated crop rotation. EPIC was designed to determine the effect of management strategies on agricultural production and soil and water resources. Input data for the EPIC model included historical weather data; soil type; tillage practices; and fertilizer, herbicide, and insecticide application amounts.

Several major soil types were used to compare water quality parameters across crop rotations and practices. Specifically, soils used to compute water quality parameter

indices included Clime in Pottawatomie county; Irwin in Riley county; Pawnee in Marshall county; Tully in Pottawatomie county; and Wymore in Marshall county.

To facilitate comparisons among non-irrigated crop rotations, a base crop rotation was selected for each watershed. This base crop rotation was assigned an index value of 1.000 for each water quality parameter. An index value for each water quality parameter was created for all of the other non-irrigated crop rotations by comparing the water quality parameter of a specific crop rotation to the water quality parameter for the base crop rotation. An index value greater than 1.000 indicates that the crop rotation has a less desirable level of the water quality parameter. Conversely, an index value less than 1.000 indicates that the crop rotation has a more desirable level of the water quality parameter. The four categories of water quality parameters used were as follows: soil erosion, surface runoff, N transport (organic nitrogen loss with sediment), and P transport (phosphorus loss with sediment).

Net return budgets were developed for a corn-soybean rotation and a grain sorghum-soybean-wheat rotation. Separate net return budgets were developed for conservation tillage and no-till practices. Gross returns were derived from KSU Farm Management Guides for northeast Kansas ([www.agmanager.info](http://www.agmanager.info)). Costs associated with seed, fertilizer, herbicide, field operations, non-machinery labor, interest, and miscellaneous items were included in the net return budgets. The costs associated with seed, drying, non-machinery labor, interest, and miscellaneous items were derived from KSU Farm Management Guides for northeast Kansas. Fertilizer costs were computed using the fertilizer amounts used in the EPIC model and prices reported in Kastens et al. (2005). Herbicide costs were computed using the herbicide amounts used in the EPIC

model and prices reported in Regehr et al. (2005). The field operations used for each rotation and tillage practice are reported in Tables 1-4. The field operations listed in these tables were used in both the EPIC model and net return budgets. Grain hauling charges were included as a field operation cost in the net return budgets. Specific dates are reported in Tables 1-4 because this information is required for the EPIC model.

Table 5 contains the crop rotation abbreviations used in the discussion below. Alternative #1 for the conservation tillage rotations eliminated the fall chisel following corn or grain sorghum, and the early spring field cultivation for soybeans. Alternative #2 for the conservation tillage rotations eliminated the cultivation in Alternative #1 and broadcasted nitrogen instead of knifing anhydrous ammonia in the first fertilizer application for corn or grain sorghum. Alternative #1 for the no-till rotations broadcasted nitrogen instead of knifing anhydrous ammonia in the first fertilizer application for corn or grain sorghum.

Alternative #2 for the corn-soybean conservation tillage rotation was used as the base for water quality parameter comparisons. The corn-soybean conservation tillage base rotation was used to compare cost changes across the corn-soybean rotations. Similarly, the grain sorghum-soybean-wheat conservation tillage base rotation was used to compare cost changes across the grain sorghum-soybean-wheat rotations.

### **Water Quality Indices**

Water quality indices for soil erosion are presented in Table 6. Eliminating the fall tillage following corn or grain sorghum, and the early spring field cultivation for soybeans reduced soil erosion substantially. For the corn-soybean rotation the reduction ranged from 14.3% Clime soil in Pottawatomie county to 25.7% for Wymore soil in

Marshall county. For the grain sorghum-soybean-wheat rotation the reduction in soil erosion ranged from 10.7% for Clime soil in Pottawatomie county to 16.1% for Wymore soil in Marshall county. Additional reductions in soil erosion were possible with no-till practices. For the corn-soybean rotation, the no-till base rotation exhibited soil erosion levels that were from 12.7% to 17.6% lower than the levels for the CSCT2 rotation. The reduction in soil erosion between the GSCT2 and no-till rotations ranged from 6.7% to 13.0% for the grain sorghum-soybean-wheat rotation.

Table 7 reports the surface runoff indices for the corn-soybean and grain sorghum-soybean-wheat rotations. Unlike the other water quality parameters, there was not much difference in surface runoff indices among rotations.

The N transport and P transport water quality indices are reported in Table 8 and Table 9. The results for these two measures are quite similar. A large improvement in N transport and P transport, particularly for the corn-soybean rotation, was obtained by reducing tillage. Also, it is worthy to note that the improvement in N transport and P transport obtained by broadcasting N instead of knifing anhydrous ammonia was relatively small.

### **Net Return Budgets**

Cost comparisons among crop rotations can be found in Table 10, Table 11, and Table 12. Table 10 reports the budget for the corn-soybean conservation tillage base rotation. Table 11 reports the budget for the grain sorghum-soybean-wheat conservation tillage base rotation. Table 12 reports the estimated cost differences between the rotations. In Table 12, the corn-soybean conservation tillage base rotation is used to compare cost differences among the corn-soybean rotations, and the grain sorghum-

soybean-wheat rotation is used to compare cost differences among the grain sorghum-soybean-wheat rotations. A positive number in Table 12 indicates that production cost per acre is relatively higher with the adoption of a specific practice. Conversely, a negative number indicates that production cost per acre is relatively lower with the adoption of a specific practice.

Using the results reported in Table 12, eliminating the fall chisel following corn or grain sorghum, and early spring field cultivation for soybeans reduced cost per acre by \$7.79. As noted in the previous section, eliminating these tillage operations also improved soil erosion, N transport, and P transport. The net return analysis in this paper does not consider changes in crop yields or risk that may occur when eliminating these tillage operations. These items would need to be taken into account before a decision to eliminate these tillage operations was implemented. However, given the potential reduction in cost and potential improvement in water quality, eliminating the fall chisel following corn or grain sorghum, and early field cultivation for soybeans certainly seems to be a practice that warrants additional consideration.

Adopting no-till practices involves a reduction in tillage, which reduces field operation cost, and an increase in herbicide cost. The net effect of adopting no-till practices on production cost per acre is relatively small in this study (Table 12). Previous research that has examined the impact of adopting a no-till practice or reducing tillage on production cost is inconclusive. The North Central Kansas Farm Management Association conducts an annual cost analysis of no-till farms and other crop farms. The results consistently show that production cost per harvested acre is similar for these two types of farms. It is important to note, however, that the cost mix does differ between no-

till and other crop farms. No-till farms have relatively lower per acre labor, machine hire, fuel, and depreciation costs, and relatively higher seed and herbicide costs per acre. In contrast to the North Central Kansas Farm Management Association no-till study, Langemeier (2005) found that farms that had reduced tillage were relatively more cost efficient or had lower per acre production costs. The improvement in cost efficiency was particularly pronounced in western Kansas.

In summary, reducing tillage had a marginal impact on production cost per acre, but was found to substantially improve soil erosion, N transport, and P transport. To the extent that water quality is an important public policy issue, an incentive system to encourage practices that reduce tillage operations seems to have merit.

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**Table 1. Field Operations for the Corn-Soybean Conservation Tillage Rotation.**

Corn: Base Case

|                        |        |
|------------------------|--------|
| Chisel                 | 5-Nov  |
| Fertilizer application | 5-Apr  |
| Field cultivate        | 15-Apr |
| Herbicide application  | 15-Apr |
| Fertilizer application | 16-Apr |
| Plant corn             | 16-Apr |
| Herbicide application  | 20-May |
| Harvest corn           | 1-Oct  |

Soybeans: Base Case

|                       |        |
|-----------------------|--------|
| Field cultivate       | 15-Apr |
| Field cultivate       | 14-May |
| Plant soybeans        | 16-May |
| Herbicide application | 14-Jun |
| Harvest soybeans      | 1-Oct  |

Alternative #1

Eliminate fall chisel following corn.  
Eliminate early spring field cultivation for soybeans.

Alternative #2

Eliminate fall chisel following corn.  
Eliminate early spring field cultivation for soybeans.  
Broadcast nitrogen instead of knifing anhydrous ammonia.

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**Table 2. Field Operations for the Corn-Soybean No-Till Rotation.**

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Corn: Base Case

|                        |        |
|------------------------|--------|
| Fertilizer application | 5-Apr  |
| Fertilizer application | 16-Apr |
| Herbicide application  | 16-Apr |
| Herbicide application  | 16-Apr |
| Plant corn             | 16-Apr |
| Herbicide application  | 20-May |
| Harvest corn           | 1-Oct  |

Soybeans: Base Case

|                       |        |
|-----------------------|--------|
| Herbicide application | 30-Apr |
| Plant soybeans        | 5-May  |
| Herbicide application | 1-Jun  |
| Harvest soybeans      | 1-Oct  |

Alternative #1

Broadcast nitrogen instead of knifing anhydrous ammonia.

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**Table 3. Field Operations for the Grain Sorghum-Soybean-Wheat Conservation Tillage Rotation.**

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Grain Sorghum: Base Case

|                        |        |
|------------------------|--------|
| Chisel                 | 15-Aug |
| Fertilizer application | 5-May  |
| Field cultivate        | 15-May |
| Fertilizer application | 25-May |
| Herbicide application  | 25-May |
| Plant sorghum          | 25-May |
| Harvest sorghum        | 25-Sep |

Soybeans: Base Case

|                       |        |
|-----------------------|--------|
| Chisel                | 5-Nov  |
| Field cultivate       | 15-Apr |
| Field cultivate       | 14-May |
| Plant soybeans        | 16-May |
| Herbicide application | 15-Jun |
| Herbicide application | 1-Jul  |
| Harvest soybeans      | 1-Oct  |

Wheat: Base Case

|                        |        |
|------------------------|--------|
| Fertilizer application | 16-Oct |
| Plant wheat            | 16-Oct |
| Harvest wheat          | 1-Jul  |

Alternative #1

Eliminate fall chisel for grain sorghum.  
 Eliminate early spring field cultivation for soybeans.

Alternative #2

Eliminate fall chisel for grain sorghum.  
 Eliminate early spring field cultivation for soybeans.  
 Broadcast nitrogen instead of knifing anhydrous ammonia.

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**Table 4. Field Operations for the Grain Sorghum-Soybean-Wheat No-Till Rotation.**

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Grain Sorghum: Base Case

|                        |        |
|------------------------|--------|
| Herbicide application  | 10-Aug |
| Herbicide application  | 15-Oct |
| Fertilizer application | 5-May  |
| Fertilizer application | 25-May |
| Herbicide application  | 25-May |
| Herbicide application  | 25-May |
| Plant sorghum          | 25-May |
| Harvest sorghum        | 25-Sep |

Soybeans: Base Case

|                       |        |
|-----------------------|--------|
| Herbicide application | 11-May |
| Plant soybeans        | 16-May |
| Herbicide application | 1-Jun  |
| Herbicide application | 1-Jul  |
| Harvest soybeans      | 1-Oct  |

Wheat: Base Case

|                        |        |
|------------------------|--------|
| Fertilizer application | 16-Oct |
| Plant wheat            | 16-Oct |
| Harvest wheat          | 1-Jul  |

Alternative #1

Broadcast nitrogen instead of knifing anhydrous ammonia.

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**Table 5. Crop Rotation Abbreviations.**

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|        |   |
|--------|---|
| CSCTB  | Corn-Soybean Conservation Tillage Base Rotation                 |
| CSCT1  | Corn-Soybean Conservation Tillage Alternative #1                |
| CSCT2  | Corn-Soybean Conservation Tillage Alternative #2                |
| CSNTB  | Corn-Soybean No-Till Base Rotation                              |
| CSNT1  | Corn-Soybean No-Till Alternative #1                             |
| GSWCTB | Grain Sorghum-Soybean-Wheat Conservation Tillage Base Rotation  |
| GSWCT1 | Grain Sorghum-Soybean-Wheat Conservation Tillage Alternative #1 |
| GSWCT2 | Grain Sorghum-Soybean-Wheat Conservation Tillage Alternative #2 |
| GSWNTB | Grain Sorghum-Soybean-Wheat No-Till Base Rotation               |
| GSWNT1 | Grain Sorghum-Soybean-Wheat No-Till Alternative #1              |

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**Table 6. Soil Erosion Indices for Corn-Soybean and Grain Sorghum-Soybean-Wheat Rotations.**

| County<br>Soil Type                         | MA<br>Pawnee | MA<br>Wymore | PO<br>Clime | PO<br>Tully | RI<br>Irwin |
|---|--------------|--------------|-------------|-------------|-------------|
| <u>Corn-Soybean Rotation</u>                |              |              |             |             |             |
| CSCTB                                       | 1.364        | 1.390        | 1.200       | 1.319       | 1.291       |
| CSCT1                                       | 1.022        | 1.033        | 1.028       | 1.038       | 1.038       |
| CSCT2                                       | 1.000        | 1.000        | 1.000       | 1.000       | 1.000       |
| CSNTB                                       | 0.824        | 0.830        | 0.873       | 0.842       | 0.836       |
| CSNT1                                       | 0.787        | 0.790        | 0.837       | 0.795       | 0.790       |
| <u>Grain Sorghum-Soybean-Wheat Rotation</u> |              |              |             |             |             |
| GSWCTB                                      | 1.302        | 1.351        | 1.220       | 1.281       | 1.257       |
| GSWCT1                                      | 1.101        | 1.134        | 1.090       | 1.098       | 1.101       |
| GSWCT2                                      | 1.094        | 1.130        | 1.093       | 1.089       | 1.091       |
| GSWNTB                                      | 0.952        | 0.987        | 1.020       | 1.000       | 0.973       |
| GSWNT1                                      | 0.936        | 0.971        | 1.017       | 0.983       | 0.957       |

County Abbreviations:

MA = Marshall  
 PO = Pottawatomie  
 RI = Riley

**Table 7. Surface Runoff Indices for Corn-Soybean and Grain Sorghum-Soybean-Wheat Rotations.**

| County<br>Soil Type                         | MA<br>Pawnee | MA<br>Wymore | PO<br>Clime | PO<br>Tully | RI<br>Irwin |
|---|--------------|--------------|-------------|-------------|-------------|
| <u>Corn-Soybean Rotation</u>                |              |              |             |             |             |
| CSCTB                                       | 1.016        | 1.015        | 1.004       | 1.000       | 0.996       |
| CSCT1                                       | 1.001        | 0.997        | 1.001       | 0.999       | 0.998       |
| CSCT2                                       | 1.000        | 1.000        | 1.000       | 1.000       | 1.000       |
| CSNTB                                       | 0.999        | 0.999        | 1.001       | 1.002       | 0.996       |
| CSNT1                                       | 0.998        | 0.996        | 1.001       | 1.006       | 0.996       |
| <u>Grain Sorghum-Soybean-Wheat Rotation</u> |              |              |             |             |             |
| GSWCTB                                      | 1.028        | 1.025        | 1.017       | 0.994       | 1.005       |
| GSWCT1                                      | 1.024        | 1.020        | 1.015       | 0.992       | 1.010       |
| GSWCT2                                      | 1.022        | 1.021        | 1.016       | 0.993       | 1.011       |
| GSWNTB                                      | 1.017        | 1.014        | 1.017       | 0.993       | 1.012       |
| GSWNT1                                      | 1.016        | 1.015        | 1.017       | 0.992       | 1.012       |

County Abbreviations:

MA = Marshall  
 PO = Pottawatomie  
 RI = Riley

**Table 8. N Transport Indices for Corn-Soybean and Grain Sorghum-Soybean-Wheat Rotations.**

| County<br>Soil Type                         | MA<br>Pawnee | MA<br>Wymore | PO<br>Clime | PO<br>Tully | RI<br>Irwin |
|---|--------------|--------------|-------------|-------------|-------------|
| <u>Corn-Soybean Rotation</u>                |              |              |             |             |             |
| CSCTB                                       | 1.338        | 1.499        | 1.317       | 1.422       | 1.365       |
| CSCT1                                       | 1.020        | 1.027        | 1.038       | 1.050       | 1.039       |
| CSCT2                                       | 1.000        | 1.000        | 1.000       | 1.000       | 1.000       |
| CSNTB                                       | 0.957        | 1.009        | 0.906       | 0.891       | 0.898       |
| CSNT1                                       | 0.946        | 0.989        | 0.864       | 0.839       | 0.856       |
| <u>Grain Sorghum-Soybean-Wheat Rotation</u> |              |              |             |             |             |
| GSWCTB                                      | 1.269        | 1.406        | 1.305       | 1.387       | 1.334       |
| GSWCT1                                      | 1.069        | 1.121        | 1.114       | 1.151       | 1.138       |
| GSWCT2                                      | 1.066        | 1.121        | 1.112       | 1.132       | 1.128       |
| GSWNTB                                      | 0.959        | 0.957        | 1.016       | 1.034       | 1.018       |
| GSWNT1                                      | 0.958        | 0.952        | 0.998       | 0.998       | 0.996       |

County Abbreviations:

MA = Marshall  
 PO = Pottawatomie  
 RI = Riley

**Table 9. P Transport Indices for Corn-Soybean and Grain Sorghum-Soybean-Wheat Rotations.**

| County<br>Soil Type                         | MA<br>Pawnee | MA<br>Wymore | PO<br>Clime | PO<br>Tully | RI<br>Irwin |
|---|--------------|--------------|-------------|-------------|-------------|
| <u>Corn-Soybean Rotation</u>                |              |              |             |             |             |
| CSCTB                                       | 1.300        | 1.437        | 1.269       | 1.377       | 1.331       |
| CSCT1                                       | 1.018        | 1.022        | 1.029       | 1.041       | 1.037       |
| CSCT2                                       | 1.000        | 1.000        | 1.000       | 1.000       | 1.000       |
| CSNTB                                       | 0.980        | 1.021        | 0.934       | 0.918       | 0.922       |
| CSNT1                                       | 0.985        | 1.031        | 0.916       | 0.888       | 0.897       |
| <u>Grain Sorghum-Soybean-Wheat Rotation</u> |              |              |             |             |             |
| GSWCTB                                      | 1.419        | 1.520        | 1.369       | 1.434       | 1.401       |
| GSWCT1                                      | 1.221        | 1.255        | 1.192       | 1.215       | 1.219       |
| GSWCT2                                      | 1.221        | 1.264        | 1.200       | 1.206       | 1.212       |
| GSWNTB                                      | 1.083        | 1.036        | 1.108       | 1.116       | 1.110       |
| GSWNT1                                      | 1.093        | 1.052        | 1.113       | 1.102       | 1.104       |

County Abbreviations:

MA = Marshall  
PO = Pottawatomie  
RI = Riley

**Table 10. Cost-Return Budget for the Corn-Soybean Conservation Tillage Base Rotation.**

|                                       | Corn           | Soybeans       | Rotation       |
|---------------------------------------|----------------|----------------|----------------|
| <b>INCOME PER ACRE</b>                |                |                |                |
| Yield per Acre                        | 110            | 33             |                |
| Price per Bushel                      | 2.31           | 5.83           |                |
| Net Government Payments               | 13.96          | 13.96          |                |
| Indemnity Payments                    | 0.00           | 0.00           |                |
| Miscellaneous Income                  | 0.00           | 0.00           |                |
| Returns/Acre                          | \$268.06       | \$206.35       | \$237.21       |
| <b>COSTS PER ACRE</b>                 |                |                |                |
| Seed                                  | 48.60          | 34.65          |                |
| Herbicide                             | 45.74          | 12.22          |                |
| Insecticide/Fungicide                 | 0.00           | 0.00           |                |
| Fertilizer and Lime                   | 39.50          | 0.00           |                |
| Crop Consulting                       | 0.00           | 0.00           |                |
| Crop Insurance                        | 0.00           | 0.00           |                |
| Drying                                | 14.30          | 0.00           |                |
| Field Operations                      | 78.81          | 63.77          |                |
| Non-Machinery Labor                   | 9.04           | 5.37           |                |
| Miscellaneous                         | 8.25           | 8.25           |                |
| Sub-Total                             | \$244.24       | \$124.26       | \$184.25       |
| Interest                              | 9.77           | 4.97           | 7.37           |
| Total Costs Excluding Land Charge     | \$254.01       | \$129.23       | \$191.62       |
| <b>RETURNS TO LAND AND MANAGEMENT</b> | <b>\$14.05</b> | <b>\$77.12</b> | <b>\$45.59</b> |

**Table 11. Cost-Return Budget for the Grain Sorghum-Soybean-Wheat Conservation Tillage Base Rotation.**

|                                       | Sorghum       | Soybeans       | Wheat           | Rotation       |
|---------------------------------------|---------------|----------------|-----------------|----------------|
| <b>INCOME PER ACRE</b>                |               |                |                 |                |
| Yield per Acre                        | 76            | 33             | 50              |                |
| Price per Bushel                      | 2.39          | 5.83           | 3.39            |                |
| Net Government Payments               | 13.96         | 13.96          | 13.96           |                |
| Indemnity Payments                    | 0.00          | 0.00           | 0.00            |                |
| Miscellaneous Income                  | 0.00          | 0.00           | 0.00            |                |
| Returns/Acre                          | \$195.60      | \$206.35       | \$183.46        | \$195.14       |
| <b>COSTS PER ACRE</b>                 |               |                |                 |                |
| Seed                                  | 13.78         | 34.65          | 10.80           |                |
| Herbicide                             | 34.41         | 11.11          | 0.00            |                |
| Insecticide/Fungicide                 | 0.00          | 0.00           | 0.00            |                |
| Fertilizer and Lime                   | 39.50         | 0.00           | 10.50           |                |
| Crop Consulting                       | 0.00          | 0.00           | 0.00            |                |
| Crop Insurance                        | 0.00          | 0.00           | 0.00            |                |
| Drying                                | 9.88          | 0.00           | 0.00            |                |
| Field Operations                      | 72.98         | 68.03          | 38.65           |                |
| Non-Machinery Labor                   | 6.81          | 5.37           | 5.31            |                |
| Miscellaneous                         | 8.25          | 8.25           | 8.25            |                |
| Sub-Total                             | \$185.61      | \$127.41       | \$73.51         | \$128.84       |
| Interest                              | 7.42          | 5.10           | 2.94            | 5.15           |
| Total Costs Excluding Land Charge     | \$193.03      | \$132.50       | \$76.45         | \$133.99       |
| <b>RETURNS TO LAND AND MANAGEMENT</b> | <b>\$2.57</b> | <b>\$73.85</b> | <b>\$107.01</b> | <b>\$61.14</b> |

**Table 12. Estimated Cost Differences Between Rotations.**

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|  | Change<br>in Cost |
|--|-------------------|
| <u>Corn-Soybean Rotations</u>                |                   |
| CSCTB  | \$0.00            |
| CSCT1  | -\$7.79           |
| CSCT2  | -\$0.73           |
| CSNTB  | -\$3.89           |
| CSNT1  | \$3.16            |
| <u>Grain Sorghum-Soybean-Wheat Rotations</u> |                   |
| GSWCTB                                       | \$0.00            |
| GSWCT1                                       | -\$5.19           |
| GSWCT2                                       | -\$0.49           |
| GSWNTB                                       | \$1.51            |
| GSWNT1                                       | \$6.21            |

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