Monitoring the Impacts of Sheridan County 6 Local Enhanced Management Area

Interim Report for 2013 – 2015

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I. Introduction

Study Objectives

Current levels of groundwater consumption in northwest Kansas raise concerns relative to the long-term feasibility of irrigated agriculture in the area. In order to extend the economic life of the aquifer and maintain the economic base of the region, groundwater water use reductions may need to be considered. Past economic studies differ in the calculated economic impact associated with groundwater use reductions. One high priority subarea in northwest Kansas has recently mandated a reduction in groundwater use. Monitoring the Sheridan #6 Local Enhanced Management Area (LEMA) in real time will allow us to observe producer innovation aimed at maintaining revenues and disseminate these data to producers and stakeholders in other areas. The knowledge of how irrigated crop producers react to conservation policies will provide guidance on what is expected to happen in the future as groundwater supplies are diminished and/or conservation policies are implemented.

The purpose of this report is to provide the methods, assumptions, and estimates of the likely economic impacts associated with a groundwater use reduction in the Sheridan #6 LEMA. The reader should note that this is an 'Interim Report' which provides information on the first three years (2013 – 2015) of a five-year study. This research will compare water usage, cropping practices, and economic outcomes for the Sheridan #6 LEMA and surrounding irrigated acreage not located within the LEMA boundaries. This will be accomplished by:

1. Developing annual 'partial budgets' from data obtained from irrigated crop producers (current and historic) (Table 1). The partial budgets will generate measures of 'Cash Flow'.
    a. Each year, aggregated cash flow will be compared for land parcels within the LEMA boundaries and outside LEMA boundaries.
    b. After 5 years, historic cash flow and partial budgets will be compared and across boundaries (comparing LEMA and non-LEMA producers).
2. Developing measures of land-use changes for land parcels within the LEMA boundaries and outside LEMA boundaries from data obtained from irrigated producers and/or the Kansas Water Right Information System (WRIS).
    a. Each year, aggregated land-use will be compared for land parcels within the LEMA boundaries and outside LEMA boundaries.
    b. After 5 years, historic land-use will be compared both across time (comparing LEMA producers before and after) and across boundaries (comparing LEMA and non-LEMA producers).
3. Developing measures of water-use changes for land parcels within the LEMA boundaries and outside LEMA boundaries from data obtained from irrigated producers and/or WRIS.
    a. Each year, aggregated water-use will be compared for land parcels within the LEMA boundaries and outside LEMA boundaries.
    b. After 5 years, historic water-use will be compared both across time (comparing LEMA producers before and after) and across boundaries (comparing LEMA and non-LEMA producers).

Background on Sheridan County 6 LEMA

The Ogallala Aquifer is significantly over-appropriated. The aquifer has declined in some areas more than 60% since predevelopment. Past efforts to slow the decline and insure the future economic viability of the region have been largely unsuccessful. The 2012 Legislature passed SB 310 making LEMAs a part of Kansas water law. This law gives groundwater management districts (GMDs) the authority to initiate a voluntary public hearing process to consider a specific conservation plan to meet local goals. LEMAs are proactive, locally designed, and initiated water management strategies for a specific geographic area that are promoted through a GMD and then reviewed and approved by the Chief Engineer. Once approved by the Chief Engineer the LEMA plan becomes law, effectively modifying prior appropriation regulations. The stated purpose of the LEMA legislation was to reduce groundwater consumption in order to conserve the state's water supply and extend the life of the Ogallala Aquifer.

On December 31, 2012, the chief engineer issued his Order of Decision accepting the LEMA proposed by GMD#4 producers for the Sheridan #6 high priority area. This voluntary LEMA imposed a fixed-quantity-per-right groundwater use restriction on local irrigators, which on average is approximately 20% less than historic use. Producers within the boundaries of the LEMA were assigned a 5-year allocation of 55 inches per acre. The LEMA blueprint may well be the future of groundwater management in Kansas. The LEMA process overcomes the problems associated with the 'top-down' Intensive Groundwater Use Control Area (IGUCA) process. To an extent, the new process also minimizes the common property externality associated with groundwater extraction.

Golden, Peterson, and O'Brien (2008) provided the initial economic analysis associated with the LEMA water use restriction. This static analysis yielded net economic losses associated with reduced groundwater use. Applying dynamic case study techniques, Golden and Leatherman (2010) suggested that, in the Wet Walnut Creek IGUCA, producers were able to mitigate the initial economic losses through innovation. This was accomplished by maintaining/expanding the production of higher valued crops and by adopting efficient irrigation technologies and practices. With these alternate research results in mind it is important that we monitor the economic outcomes associated with the water use restriction and disseminate the information to stakeholders. At present there are additional LEMAs planned for GMD 1, GMD 2, and GMD 4, however there is some hesitancy as local producers want to 'wait and see what happens in Sheridan #6 LEMA'.

When water-use is restricted irrigated producers develop and implement strategies to mitigate potential revenue losses. Buller (1988) and Wu, Bernardo, and Mapp (1996) suggest that producers will change crop mix by shifting from high water-use crops, such as corn, into crops with lower consumptive use, possibly even converting to nonirrigated production. Burness and Brill (2001) and Williams et al. (1996) suggest that in such cases producers will adopt more efficient irrigation technology. Harris and Mapp (1986) and Klocke et al. (2004) suggest that computer-aided technologies and improved irrigation scheduling might provide a solution. Schlegel, Stone, and Dumler (2005) report significant water savings with the adoption of limited irrigation management strategy. This research will provide insights into the management strategies adopted by irrigated producers in the Sheridan #6 LEMA.

II. Agronomic Model Overview

The agronomic portion of this research relies heavily on the quasi-experimental control group analysis method. This method defines an agronomic parameter of interest, a target area, a control area, and a treatment. Preferably, the only difference between the target area and the control area is that the target area received the treatment and the control area did not receive the treatment. For our case, the treatment is the implementation of the LEMA, as depicted in Figure 1, the target area is the Sheridan #6 high priority area, the control area is comprised of irrigated cropland within a three mile boundary around the Sheridan #6 high priority area, and the agronomic parameters of interest are crop mix and groundwater use. If the agronomic parameters in the target and control areas are comparable before the treatment occurs, then any statistically significance difference in the agronomic parameters of interest after the treatment occurs represents the effect of the treatment. As an example, if the target area and control area had comparable irrigated acreage before the LEMA was implemented, and the target area had statistically fewer acres than the control area after the LEMA was implemented then it is assumed that the LEMA caused a reduction in the number of irrigated acres in the target area.

A strong association between the target and control counties will simplify the statistical modeling by comparing parameters in a similar framework. By minimizing the effects of other factors such as commodity prices, rainfall, and soil types, the effects of the LEMA should be easier to identify. The benefits of this approach are its intuitive appeal, transparency, and the fact that it is less dependent on assumptions regarding functional forms of structural models and reduced-form relationships. Since the target and control areas are similar, the use of a linear model to control for potentially convoluting factors should give a good approximation (ERS, 2004). The quasi-experimental control group analysis has been used extensively in impact analysis (ERS, 2004; Bohm and Lind, 1993; Reed and Rogers, 2003; Eklund, Jawa, and Rajala, 1999; Huff et al., 1985; Golden and Leatherman, 2010).

Broder, Taylor, and McNamara (1992) define a time-series linear regression discontinuity model that is suitable for this analysis. The model is estimated using binary variables (dummy variables) to test impacts associated with a treatment for significant intercept shifts or discontinuities. Golden and Leatherman, (2010) applied a similar model to their analysis of the Wet Walnut IGUCA, and a more detailed description of the model can be found there.

In the following sections models for each agronomic variable of interest will be developed and the results reported and discussed. In most cases, data from the target and control areas will be graphed to provide a visual depiction of the data being discussed. Making direct comparisons of agronomic variable across the target and control area is problematic. While the data are statistically similar the magnitude will not be identical. Indexed values will be used to make relative comparisons. When applied to a time series, indexed values are obtained by dividing each annual value by the starting value. When multiplied by 100, an indexed value represents the percent of staring values that occurs in each year.

The regression model used to analyze the indexed values can be defined as

$$\Delta AV = \quad AV_T - AV_C = \beta_0 + \beta_1 * D$$

where ΔAV is the difference in the indexed value of the agronomic variable of interest, T indexes the target area, C indexes the control area, and D is a binary variable that takes the value of zero for the years 2003 through 2012, and a value of one for the years 2013 and 2014. β_0 is the estimated intercept and β_1 is the estimated intercept shift which defines the impact of the LEMA.

III. Agronomic Results

The following results are based on data obtained from the Kansas Water Right Information System (WRIS) for the years 2003 through 2015. The WRIS dataset provides time series data on each point of diversion (PDIV), typically a single water well, in the target area and control area. Producer generated annual water use reports provide the basis for the WRIS dataset. For each PDIV the dataset includes total annual acre-foot groundwater usage, total acres irrigated, and crop type. The crop type is listed as a code number, as example the crop code for a field that is 100% corn is '2' and the crop code for a field that that has both corn and grain sorghum (a mixed crop field) is '23'. When crop specific acres are discussed below a 'Mixed Crop Allocation Table' was used to allocate acres to individual crops, as an example, if the crop code was '23' it was assumed that the reported irrigated acres was comprised of 50% corn and 50% grain sorghum. As a result, when crop specific acreage is discussed below, all fields that were comprised of a either a single crop or mixed crop were included in the calculation.[1] Unfortunately, for a mixed crop field, producer's only report total acre-foot groundwater usage, and no reasonable method has been developed to allocate the total acre-foot groundwater usage to individual crops. As a result, when crop specific groundwater usage is discussed below, only fields that were comprised of a single crop were included in the calculation.[2]

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[1] This method is consistent with methods used by the Kansas Department of Agriculture.

[2] The average groundwater use for alfalfa, grain sorghum, and wheat are not reported as there were insufficient numbers of single crop fields to generate valid results.

Total Irrigated Acres
Figure 2, illustrates the indexed values for total irrigated acreage within the target and control areas and Table 2 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 1.7% fewer irrigated acres than the control area and after the LEMA the target area averaged an additional statistically significant 8.5% fewer irrigated acres than the control area. This implies that the LEMA generated an average 8.5% reduction in irrigated acreage relative to the control area.

Total Groundwater Use
Figure 3, illustrates the indexed values for total groundwater use within the target and control areas and Table 3 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 1.3% greater groundwater use than the control area and after the LEMA the target area averaged an additional statistically significant 25.3% less groundwater use than the control area. This implies that the LEMA generated an average 25.3% reduction in total groundwater use relative to the control area.

Average Groundwater Use per Acre
Figure 4, illustrates the indexed values for the average groundwater use per acre within the target and control areas and Table 4 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 2.6% greater average groundwater use per acre than the control area and after the LEMA the target area averaged an additional statistically significant 19.0% less average groundwater use per acre than the control area. This implies that the LEMA generated an average 19.0% reduction in average groundwater use per acre relative to the control area.

Total Irrigated Corn Acres
Figure 5, illustrates the indexed values for the total irrigated corn acres within the target and control areas and Table 5 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 9.2% less total irrigated corn acres than the control area and after the LEMA the target area averaged an additional statistically significant 22.8% less total irrigated corn acres than the control area. This implies that the LEMA generated an average 22.8% reduction in total irrigated corn acres relative to the control area. The percentage change amounts to an average of approximately 2,990 acres of decreased corn acreage within the target area.

Total Irrigated Alfalfa Acres
Figure 6, illustrates the indexed values for the total irrigated alfalfa acres within the target and control areas and Table 6 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 28.3% less total irrigated alfalfa acres than the control area and after the LEMA the target area averaged an additional statistically insignificant 4.9% less total irrigated alfalfa acres than the control area. This implies that the LEMA had no statistically significant impact on total irrigated alfalfa acres relative to the control area.

Total Irrigated Grain Sorghum Acres
Figure 7, illustrates the indexed values for the total irrigated grain sorghum acres within the target and control areas and Table 7 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 33.8% more total irrigated grain sorghum acres than the control area and after the LEMA the target area averaged an additional statistically significant 406.2% more total irrigated grain sorghum acres than the control area. This implies that the LEMA generated an average 406.2% increase in total irrigated grain sorghum acres relative to the control area. The percentage change amounts to an average of approximately 900 acres of increased grain sorghum acreage within the target area.

Total Irrigated Soybean Acres
Figure 8, illustrates the indexed values for the total irrigated soybean acres within the target and control areas and Table 8 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 1.0% more total irrigated soybean acres than the control area and after the LEMA the target area averaged an additional statistically insignificant 13.5% less total irrigated soybean acres than the control area. This implies that the LEMA had no statistically significant impact on total irrigated soybean acres relative to the control area.

Total Irrigated Wheat Acres
Figure 9, illustrates the indexed values for the total irrigated wheat acres within the target and control areas and Table 9 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 20.1% more total irrigated wheat acres than the control area and after the LEMA the target area averaged a statistically significant 95.0% more total irrigated wheat acres than the control area. This implies that the LEMA generated an average 95.0% increase in total irrigated wheat acres relative to the control area. The percentage change amounts to an average of approximately 700 acres of increased wheat acreage within the target area.

Total Irrigated Mixed Crop Acres
Figure 10, illustrates the indexed values for the total irrigated mixed crop acres within the target and control areas and Table 10 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 17.1% less total irrigated mixed crop acres than the control area and after the LEMA the target area averaged a statistically significant 18.3% less total irrigated mixed crop acres than the control area. This implies that the LEMA generated an average 18.3% decrease in total irrigated mixed crop acres relative to the control area. The percentage change amounts to an average of approximately 1,300 acres of decreased mixed crop acreage within the target area.

Average Groundwater Use per Irrigated Corn Acre
Figure 11, illustrates the indexed values for the average groundwater use per irrigated corn acre within the target and control areas and Table 11 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically insignificant 0.9% less average groundwater use per acres than the control area and after the LEMA the target area averaged a statistically significant 20.2% less average groundwater use per acres than the control area. This implies that the LEMA generated a statistically significant 20.2% reduction in the average groundwater use per irrigated corn acre relative to the control area.

Average Groundwater Use per Irrigated Soybean Acre
Figure 12, illustrates the indexed values for the average groundwater use per irrigated corn acre within the target and control areas and Table 12 reports the regression results. The results suggest that prior to the LEMA the target area averaged a statistically significant 9.9% more average groundwater use per acres than the control area and after the LEMA the target area averaged a statistically significant 19.4% less average groundwater use per acres than the control area. This implies that the LEMA generated a statistically significant 19.4% reduction in the average groundwater use per irrigated soybean acre relative to the control area.

IV. Economic Results

As we move into the 21st century, goals for our water resources are gradually changing. Concerns over aquifer decline rates call into question the current allocation of water resources. With increasing frequency, producers and policy makers are asked to decide how to reduce groundwater consumption. Policy makers, producers, and other stakeholders are concerned about the likely negative economic impacts that the agricultural producers might incur as crop water use is reduced. Unfortunately, there is little economic literature and less empirical data that is capable of providing guidance on the likely impacts.

This section of the report reviews economic data collected from irrigated crop producers. These producers generally have irrigated cropland within the boundaries of the LEMA as well as irrigated cropland outside the boundaries of the LEMA. Producer involvement is strictly voluntary; they report data directly to GMD #4 who passes the data to the author for analysis. Due to the limited number of participants reporting economic data, the results cannot be considered statistically valid, never the less they are informative. Additional, rainfall and soil type were not reported by the producers and these variables are important determinants of crop yield. In the following tables 'Cash Flow' is the economic metric reported. Cash Flow is defined as gross revenue (crop price x crop yield) less variable costs of production (fertilizer, seed, herbicide, hired labor etc.). While each producer reported their own crop price, for this analysis, the average crop price reported by all producers was used in the cash flow calculation. Land rent and fixed equipment costs were not included in the analysis.

Table 13 summarizes the producer reported data for the 2013 crop year. Irrigated corn producers within the LEMA boundary reported using 19.8% less groundwater and yielding 6.5% less corn as compared to irrigated corn producers outside the LEMA boundary. These data are relatively consistent with irrigated crop production functions developed by Kansas State University Research and Extension which exhibit diminish marginal returns. Somewhat surprisingly, irrigated corn producers within the LEMA boundary reported 1.5% more cash flow than their higher yielding counterparts outside the LEMA. Irrigated soybean producers within the LEMA boundary reported using 9.3% less groundwater and yielding 6.2% less soybeans as compared to irrigated soybean producers outside the LEMA boundary. These data are relatively consistent with irrigated crop production functions developed by Kansas State University Research and Extension. Somewhat surprisingly, irrigated soybean producers within the LEMA boundary reported 1.5% more cash flow than their higher yielding counterparts outside the LEMA. There was no irrigated grain sorghum reported from outside the LEMA boundary. The producers that grew irrigated grain sorghum inside the LEMA boundary applied an average of 4.1 inches per acre (63.3% less than irrigated corn producers inside the LEMA boundary) and generated the largest reported cash flow of any irrigated crop.

Table 14 summarizes the producer reported data for the 2014 crop year. Irrigated corn producers within the LEMA boundary reported using 49.0% less groundwater and yielding 15.6% less corn as compared to irrigated corn producers outside the LEMA boundary. Irrigated corn producers within the LEMA boundary reported 11.5% less cash flow than their higher yielding counterparts outside the LEMA. It should be noted that there was only one observation of irrigated corn produced outside the LEMA boundary. Irrigated soybean producers within the LEMA boundary reported using 34.3% more groundwater and yielding 13.3% less soybeans as compared to irrigated soybean producers outside the LEMA boundary. Irrigated soybean producers within the LEMA boundary reported 32.6% less cash flow than their counterparts outside the LEMA. In this case producers within the LEMA boundary used more groundwater but this evidence suggests that higher levels of groundwater use do not necessarily imply higher returns. It should be noted that there was only one observation of irrigated soybeans produced outside the LEMA boundary. There was no irrigated grain sorghum reported from outside the LEMA boundary. The producers that grew irrigated grain sorghum inside the LEMA boundary applied an average of 6.0 inches per acre (40.0% less than irrigated corn producers inside the LEMA boundary) and generated comparable cash.

As of this interim report, there is insufficient data necessary to publish economic information for the 2015 crop year.

V. Rainfall Data

As previously mentioned, rainfall is a major determinant of groundwater use and crop yield. Figure 13 illustrates the historic annual rainfall for Sheridan County for the years 2000 through 2015. The average for this period was 19.81 inches per year. The 2013 through 2015 annual rainfall amounts were 17.55, 14.83, and 24.23 inches, respectively. Both 1023 and 2014 were dryer than normal years, while 2015 was a wetter than normal year.

VI. Conclusions

The purpose of this report was to provide the methods, assumptions, and estimates of the agronomic and economic impacts associated with groundwater use reductions in the Sheridan #6 LEMA. The reader should note that this is an 'Interim Report' and only provides information on the first three years of a five-year study and should be considered a preliminary analysis. As additional data is collected in the future the results will be more robust.

Relative to their neighbors outside the LEMA boundary, irrigated crop producers within the boundary of the LEMA: reduced total groundwater use by a statistically significant 25.3%, reduced average groundwater use per acre by a statistically significant 19.0%, reduced irrigated crop acreage by a statistically significant 8.5%, reduced irrigated corn acreage by a statistically significant 22.8%, increased irrigated grain sorghum acreage by a statistically significant 406.2%, and increased irrigated wheat acreage by a statistically significant 95.0%.

The economic result, to date, are consistent with Golden and Leatherman (2010) and suggests that, given the certainty of groundwater use reductions, producers are able to implement strategies to maintain returns and apply less groundwater. Additional research on the risk associated with reduced groundwater use is needed. The producer supplied data suggests that producers within the LEMA boundary have been able to reduce groundwater use with minimal impacts on cash flow. While we can observe the changes in crop mix and water use we cannot discern, at this point, exact strategies producers are using to reduce variable expenses and/or adjust cultural practices. Moving forward, we need to increase the number of producers reporting their economic data.

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VIII. Tables

Table 1. Example of Partial Budgets

Name of Operator			**Due October 1, 2014**			
Phone #			Return to: Manager, GMD4			
Email:			(Electronic copy preferred)			
Crop Year 2013						
	Parcels *(land handled as a single parcel; can be 1/2 circle, can be multiple circles); add parcel columns as needed*					
Operator Designated Farm Identifier (name or number)	**1**	**2**	**3**	**4**	**5**	**6**
Is This Farm in the LEMA (yes or no)						
Total Groundwater Pumped per crop*						
Well Capacity (GPM/Acre)						
Total Irrigated Acres						
Crops						
INCOME PER ACRE						
A. Yield per acre						
B. Price per bushel**						
C. Miscellaneous income *(if due to LEMA)*						
D. Returns/acre ((A x B) + C) *(auto filled)*						
E. COSTS PER ACRE						
1. Seed						
2. Herbicide						
3. Insecticide / Fungicide						
4. Fertilizer and Lime						
5. Crop Consulting						
6. Drying						
7. Miscellaneous						
8. Custom Hire						
9. Labor						
a. Planting						
b. Tilling						
c. Spraying						
d. Disking						
e. Harvesting						
f. Harvest Hauling						
g.						
10. Irrigation						
a. Labor (own time or hired)						
b. Fuel and Oil						
c. Repairs and Maintenance						
11. Land Charge / Rent* * *						
F. TOTAL COSTS						
G. RETURNS OVER COSTS (D - F) *(auto filled)*						

*** If growing wheat, total spring & fall water; if following wheat with another crop, separate out water per crop type**

** If not yet sold, give best estimate of price

***Any leases re-negotiated due to LEMA? If a % arrangement, give totals; write in crop shares

Table 2. Regression Results for the Difference in Total Irrigated Acreage

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.017*
D	Impact of LEMA	-0.085*
R^2	Degree of Fit	0.557

* Statistically significant at the 10% level

Table 3. Regression Results for the Difference in Total Groundwater Use

Variable	Description	Parameter Estimate
Intercept	Intercept	0.013
D	Impact of LEMA	-0.253*
R^2	Degree of Fit	0.892

* Statistically significant at the 10% level

Table 4. Regression Results for the Difference in Average Groundwater Use per Acre

Variable	Description	Parameter Estimate
Intercept	Intercept	0.026*
D	Impact of LEMA	-0.190*
R^2	Degree of Fit	0.865

* Statistically significant at the 10% level

Table 5. Regression Results for the Difference in Total Irrigated Corn Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.092*
D	Impact of LEMA	-0.228*
R^2	Degree of Fit	0.715

* Statistically significant at the 10% level

Table 6. Regression Results for the Difference in Total Irrigated Alfalfa Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.283*
D	Impact of LEMA	-0.049
R^2	Degree of Fit	0.004

* Statistically significant at the 10% level

Table 7. Regression Results for the Difference in Total Irrigated Grain Sorghum Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	0.338
D	Impact of LEMA	4.062*
R^2	Degree of Fit	0.839

* Statistically significant at the 10% level

Table 8. Regression Results for the Difference in Total Irrigated Soybean Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	0.010
D	Impact of LEMA	-0.135
R^2	Degree of Fit	0.096

* Statistically significant at the 10% level

Table 9. Regression Results for the Difference in Total Irrigated Wheat Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	0.112
D	Impact of LEMA	0.950*
R^2	Degree of Fit	0.600

* Statistically significant at the 10% level

Table 10. Regression Results for the Difference in Total Irrigated Mixed Crop Acres

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.171*
D	Impact of LEMA	-0.183*
R^2	Degree of Fit	0.237

* Statistically significant at the 10% level

Table 11. Regression Results for the Difference in Total Average Groundwater Use per Irrigated Corn Acre

Variable	Description	Parameter Estimate
Intercept	Intercept	-0.009
D	Impact of LEMA	-0.202*
R^2	Degree of Fit	0.841

* Statistically significant at the 10% level

Table 12. Regression Results for the Difference in Total Average Groundwater Use per Irrigated Soybean Acre

Variable	Description	Parameter Estimate
Intercept	Intercept	0.099*
D	Impact of LEMA	-0.194*
R^2	Degree of Fit	0.412

* Statistically significant at the 10% level

Table 13. 2013 Producer Reported Economic Data

Item	Observations	Water Use (in/ac)	Yield (bu/ac)	Cash Flow ($/ac)	Cash Flow ($/in)
Corn Weighted Average - Inside LEMA	6	11.1	198.0	$403	$36
Corn Weighted Average - Outside LEMA	4	13.8	211.6	$397	$29
Sorghum Weighted Average - Inside LEMA	2	4.1	152	$434	$107
Sorghum Weighted Average - Outside LEMA	0	NA	NA	NA	NA
Soybeans Weighted Average - Inside LEMA	2	10.3	63.8	$418	$41
Soybeans Weighted Average - Outside LEMA	2	11.3	68	$412	$36

Table 14. 2014 Producer Reported Economic Data

Item	Observations	Water Use (in/ac)	Yield (bu/ac)	Cash Flow ($/ac)	Cash Flow ($/in)
Corn Weighted Average - Inside LEMA	5	10.0	229.5	$449	$45
Corn Weighted Average - Outside LEMA	1	19.7	272.0	$507	$26
Sorghum Weighted Average - Inside LEMA	1	6.0	152	$438	$73
Sorghum Weighted Average - Outside LEMA	0	NA	NA	NA	NA
Soybeans Weighted Average - Inside LEMA	2	9.0	60.7	$262	$29
Soybeans Weighted Average - Outside LEMA	1	6.7	70	$388	$58
Sunflowers Weighted Average - Outside LEMA	1	6.0	88.1	$788	$131

IX. Figures

Figure 1. Target and Control Area

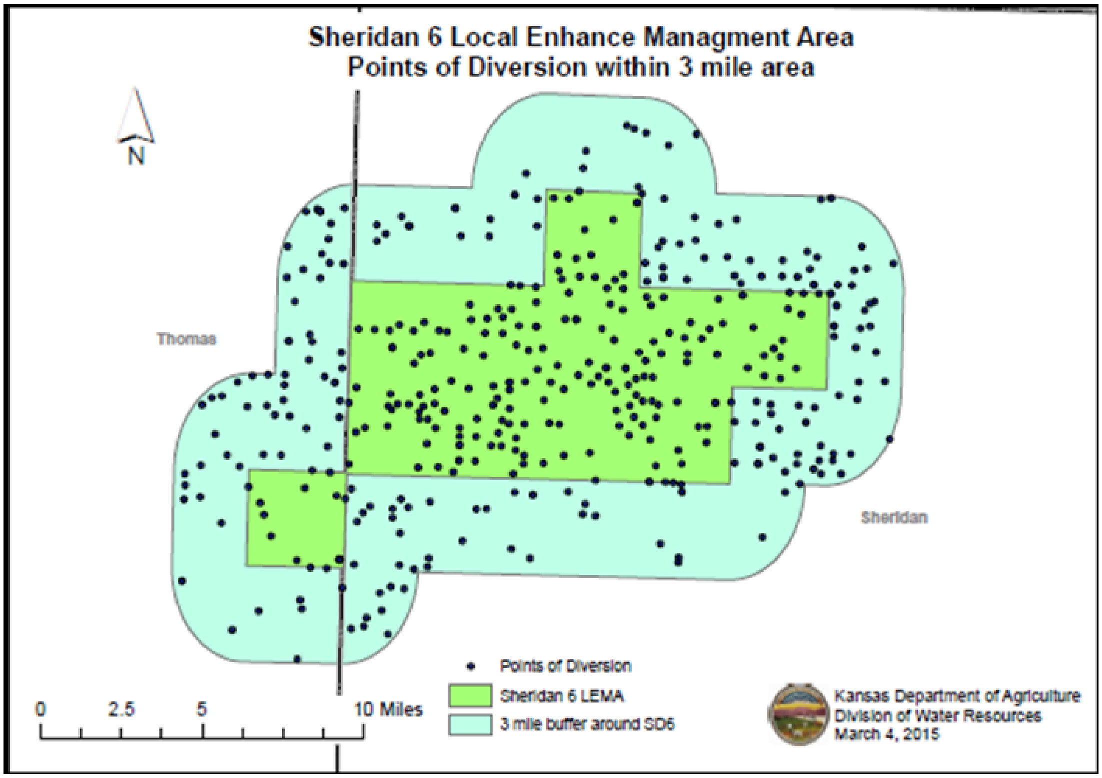


Figure 2. Total Irrigated Acres

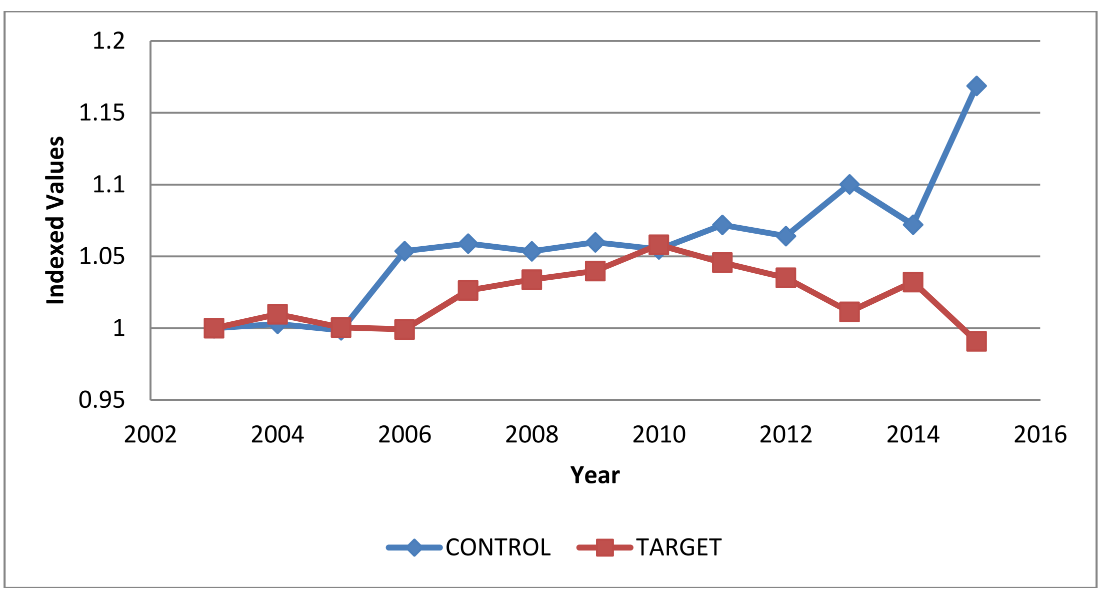


Figure 3. Total Groundwater Use

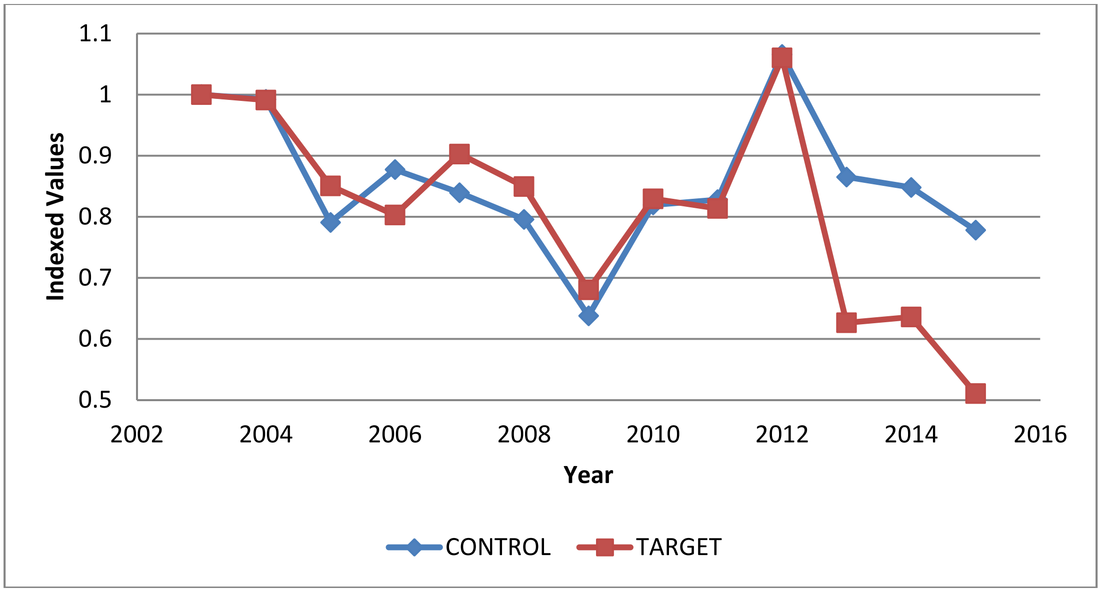


Figure 4. Average Groundwater Use per Acre

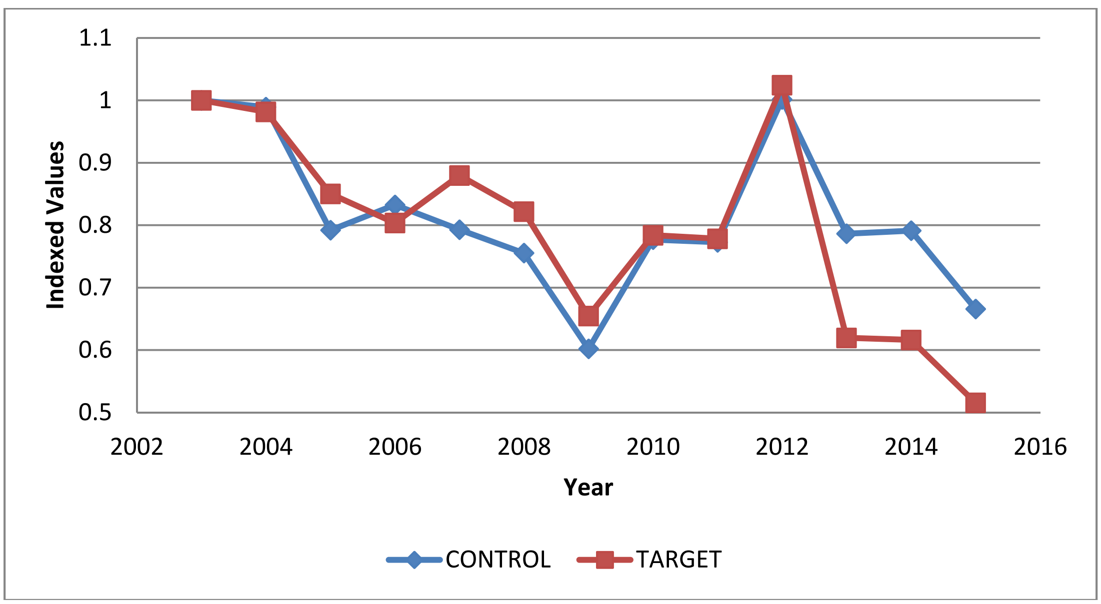


Figure 5. Total Irrigated Corn Acres

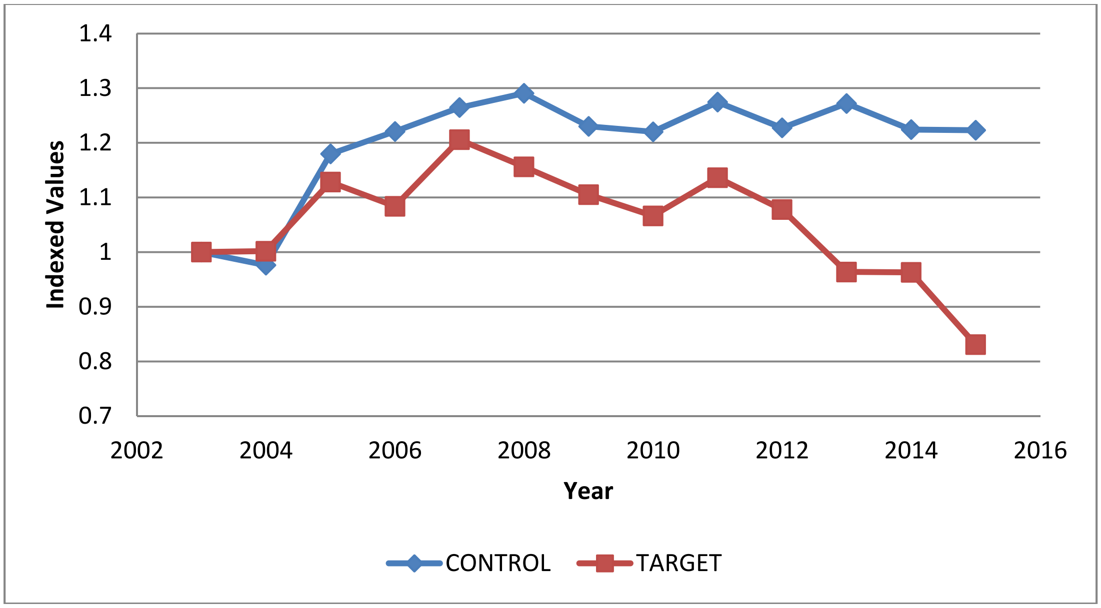


Figure 6. Total Irrigated Alfalfa Acres

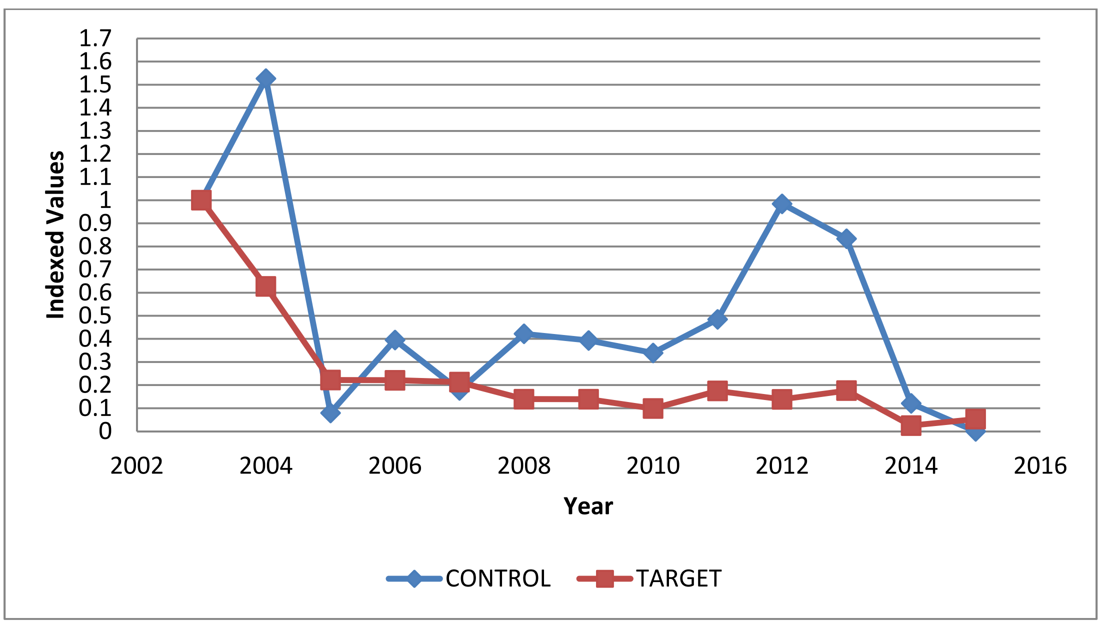


Figure 7. Total Irrigated Grain Sorghum Acres

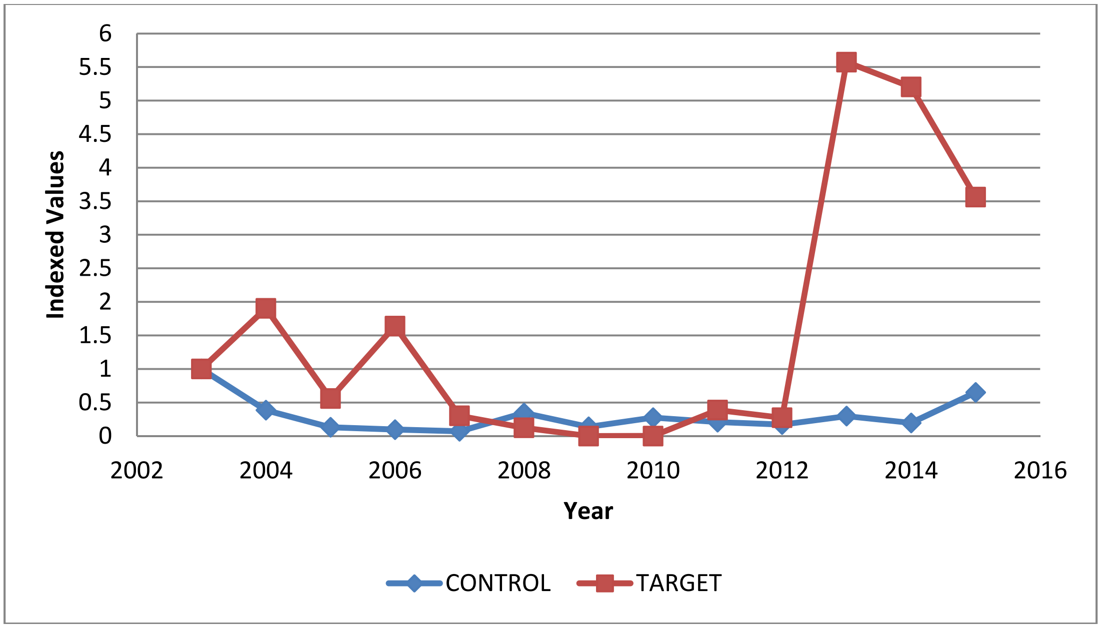


Figure 8. Total Irrigated Soybean Acres

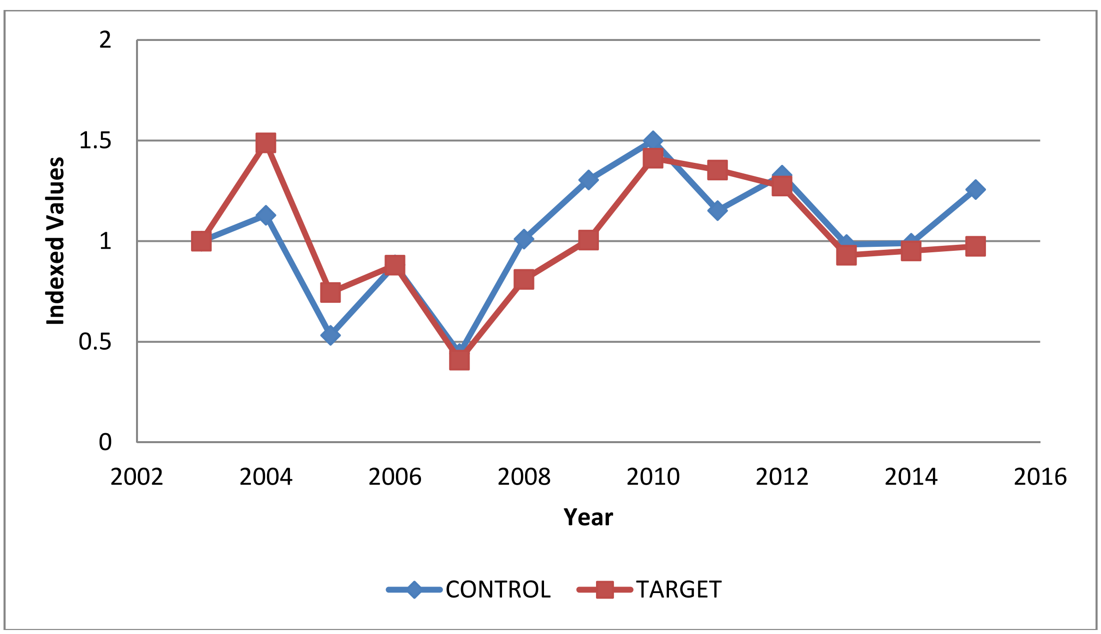


Figure 9. Total Irrigated Wheat Acres

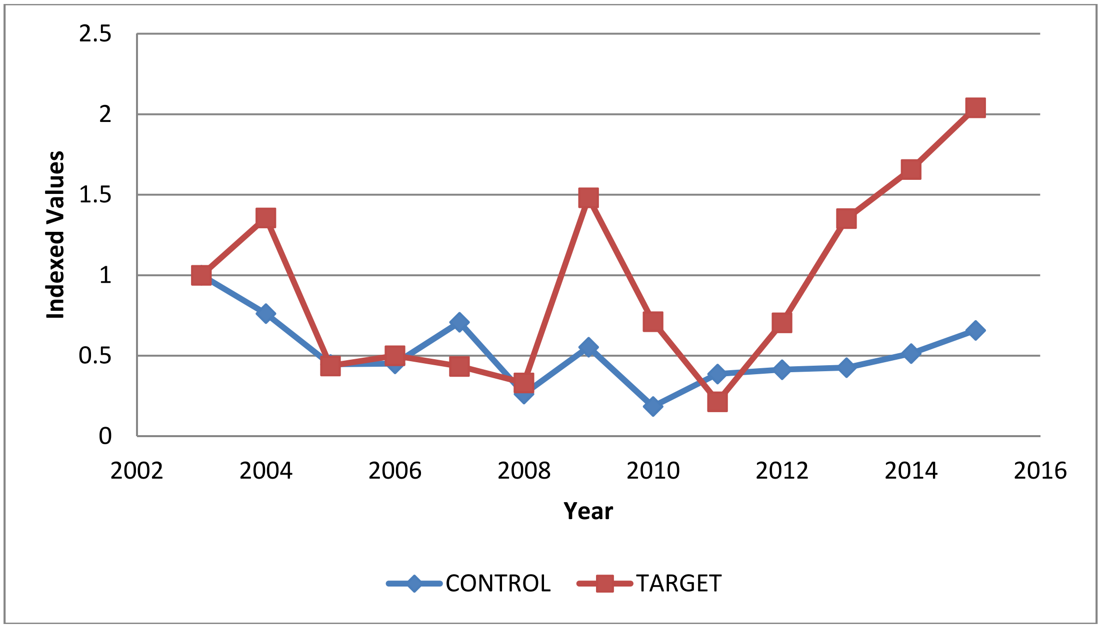


Figure 10. Total Irrigated Mixed Crop Acres

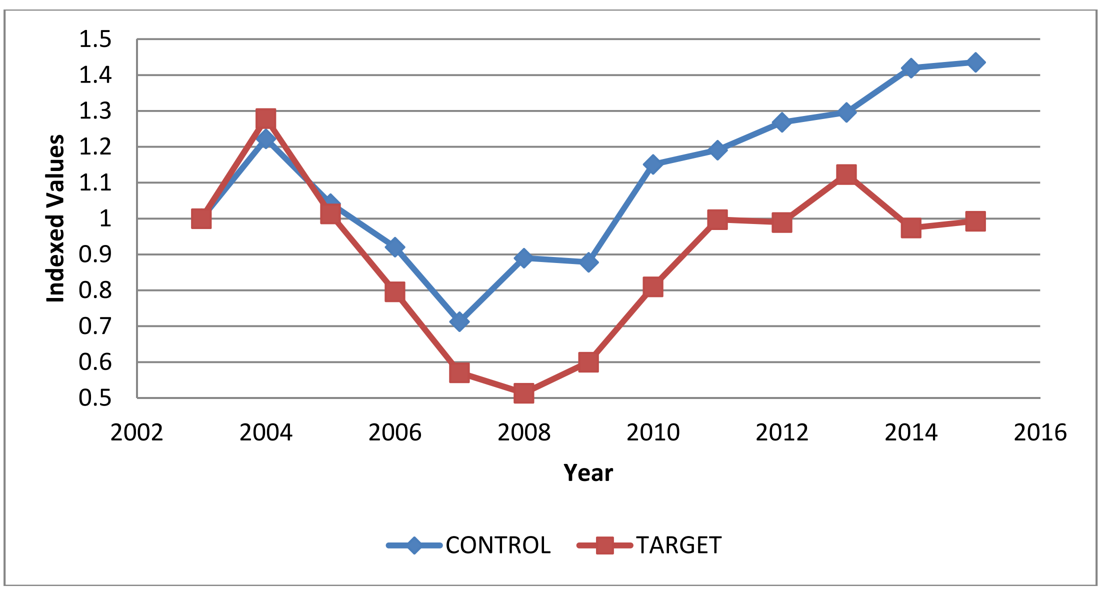


Figure 11. Average Groundwater Use per Irrigated Corn Acre

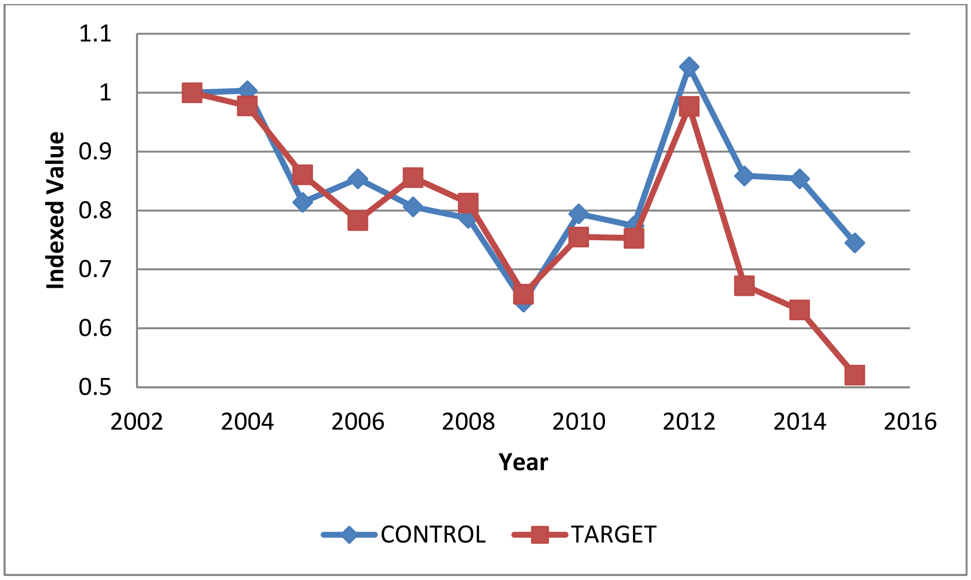


Figure 12. Average Groundwater Use per Irrigated Soybean Acre

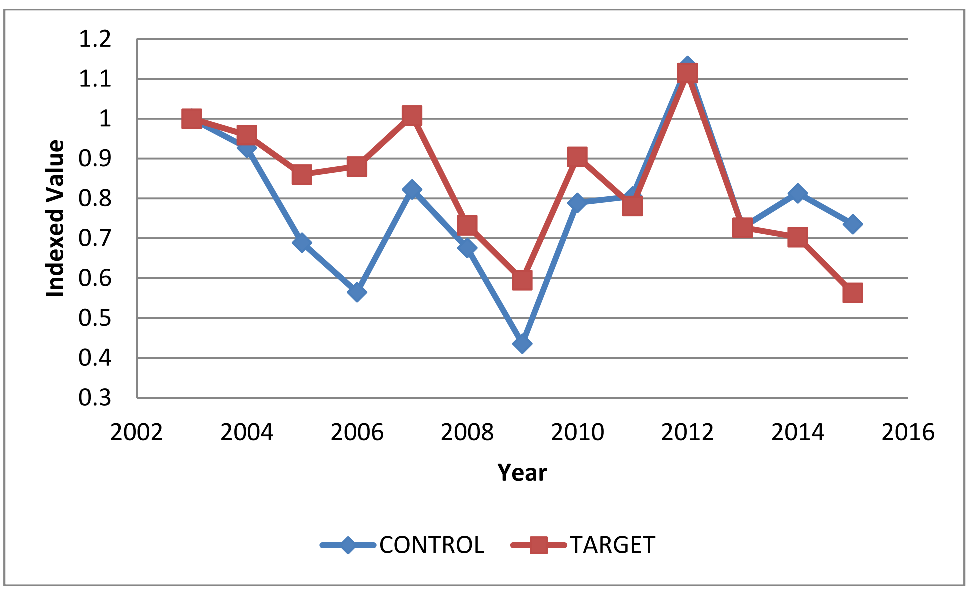
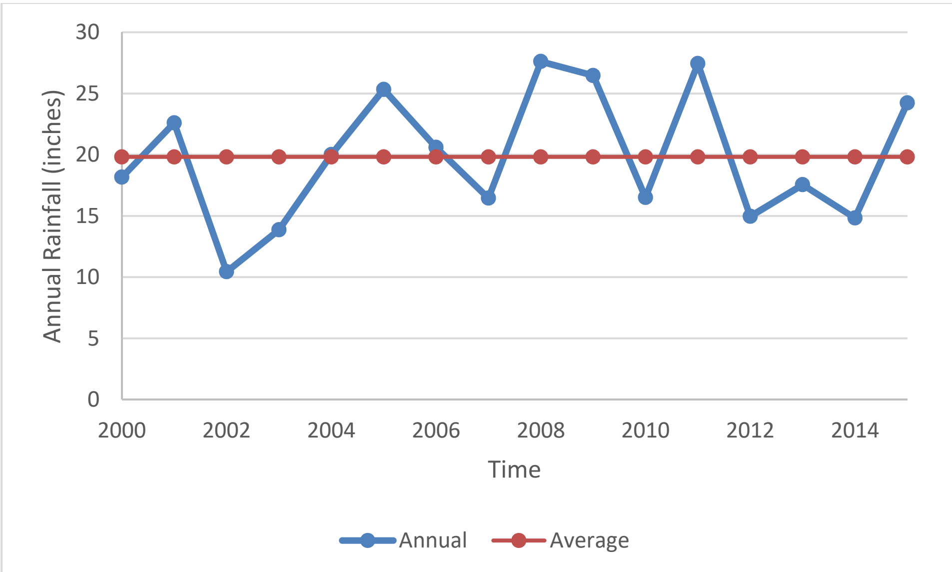


Figure 13. Historic Annual Rainfall for Sheridan County



Source: http://mesonet.k-state.edu/data/20002016+Monthly+Precipitation+by+County.txt