Economic Impacts of Selected Water Conservation Policies in the Ogallala Aquifer

Report

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Executive Summary

Groundwater levels in the Southern Ogallala have been steadily declining over the last several decades. Continuation of current pumping rates could have serious implications for the viability of the Region's economy in the future. Policy makers and stakeholders are considering ways to extend the life of the aquifer to maintain the economic viability for future generations. This project funded by the Ogallala Initiative has the objective to assess the potential impacts on stakeholders in the Region from implementing alternative water conservation strategies. Hopefully, the results of this study will be useful in the consideration of water conservation policies in the future to insure that any strategies implemented minimize detrimental effects on producer income and the economy while conserving water for future purposes. A survey of stakeholders identified five strategies to be analyzed: permanent conversion to dryland production, technology adoption, biotechnology, water use restriction, and temporary conversion to dryland production.

Economic optimization models were developed to estimate changes in the aquifer, irrigated acreage and net farm income over a 60 year planning period. Socioeconomic models were utilized to evaluate impacts on the regional economy. Each conservation strategy was then evaluated with respect to the change in saturated thickness, producer income and impacts on the regional economy relative to the baseline.

The baseline scenario assumes no water conserving policy is implemented and producers operate in an unregulated profit maximizing manner. In select counties, the baseline simulation indicated decreases in saturated thickness over the 60 year period to 84.4 feet in the Northern Region, 43.7 feet in the Central Region, and 34.2 feet in the Southern Region.

The enhanced adoption of biotechnology that increased yields 0.5% annually coupled with one percent annual water use restriction was the most effective policy analyzed. Saturated thickness increased an average of 12.3% over the region while producer income increased 86.9% and the regional economy improved an average of 5%. A one percent annual water restriction produced similar results with respect to increasing saturated thickness (12.8%), however, producer income as well as industry output fell an average of 4.8% and 1.3%, respectively.

Permanently converting 10% of irrigated acreage to dryland (Plan A - idled 15 years before returning to dryland production) resulted in increasing saturated thickness an average of 3% relative to the baseline. Producer income overall improved slightly (1.1%); however, total industry output fell approximately 1.7%. A second permanent conversion to dryland scenario converting 10% of irrigated acreage to dryland (Plan B - acreage allowed to immediately convert to dryland production) resulted in the same impacts with respect to saturated thickness, however, improved in total industry output relative to Plan A (a decrease 1%). A temporary conversion of 10% of the irrigated acreage to dryland and the enhanced adoption of improved irrigation technology provided little impact. Temporary conversion increased ending saturated thickness an average of 1% while adoption of improved irrigation technology actually decreased ending saturated thickness

in two of the sub-regions. Impacts on producer income and the regional economy were negligible for either policy.

Several implications can be derived from the results of this study. First, some form of long term water use restriction (percentage per year or permanent conversion) is necessary in order to achieve any meaningful water savings. Second, accelerated adoption of improved biotechnology or irrigation technology without restrictions will not save water and, in fact, could increase water use lowering water availability in the future. However, using these strategies in combination with a water use restriction policy can help negate the negative impacts to producer income and the regional economy. Finally, temporary conversion to dryland has little impact on long term water savings and should not be pursued.

Shortcomings exist with every study and this one is no exception. Implementation levels were set at a level and given time and funding, no sensitivity analysis was performed on these variables. No attempt was made except for identifying the loss in producer income to assess the cost of implementing the conservation strategies analyzed. While individual policy alternatives have been compared to a baseline scenario, this research does not attempt to place a monetary value on the saved water or place monetary value on other benefits of water conservation. For reporting convenience, the modeling results for several counties have been aggregated together. This process may mask important differences between counties and underestimate the need for water conservation.

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Introduction

Crop production in the Great Plains is highly dependent on irrigation due to limited and highly variable rainfall. The Ogallala Aquifer is by far the largest single water source in the region. However, the groundwater stock in the Ogallala has been steadily declining because the minimal rate of natural recharge is far exceeded by the rate of withdrawals for irrigation. The decline of the aquifer has very serious implications for the High Plains economy as a whole. The Ogallala Project is funded by the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) and was formed to improve the sustainability of agricultural industries and rural communities through innovative scientific research.

The Southern Ogallala Region is the area overlying the Ogallala Aquifer from the northern border of Kansas to the southern reaches of the aquifer just north of the Midland-Odessa area of Texas. The study area is divided into three sub-regions. The northern sub-region consists of the area overlying the aquifer in Kansas and portions of Colorado. The central sub-region consists of the Oklahoma and Texas panhandle areas south to the line of counties including Parmer, Castro, Swisher, and Briscoe counties. The southern sub-region extends from that line of counties for Texas and New Mexico south to Andrews and Martin counties of Texas. The counties to be included in the analysis are those counties identified in the baseline scenario that will have a drawdown of greater that 40% of the initial saturated thickness over the 60 year planning period, Figure 1.

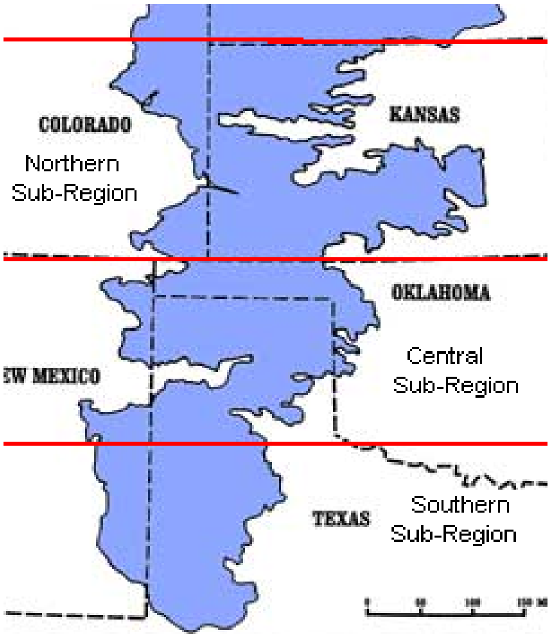

Figure 1. Study area overlying Ogallala.

The Economics Section of the Ogallala Aquifer Project conducted a water conservation policy survey to determine what alternative water conservation policies were analyzed for potential impacts with respect to water savings, implementation costs, producer income, and the regional economy (economic activity, employment, and income). Survey recipients were selected from the Southern Ogallala Region based on expertise and interest in agricultural water policy and included water districts, senators and representatives, commodity organizations, Ogallala Project leadership team, water planning groups and agencies, state authorities, and other authorities. A total of 150 surveys were evenly distributed across three sub-areas of the Southern Ogallala Region. The top five rated alternative water conservation policies were chosen to be analyzed and include permanent conversion to dryland production, technology adoption, biotechnology, water use restriction, and temporary conversion to dryland production (Table 1).

Table 1. Water Conservation Policy Survey Results (Top Five Choices).

Policy	Average Rating*
Convert to dryland permanent	4.18
Technology adoption	4.19
Biotechnology	4.28
Water use restriction	4.51
Convert to dryland temporary	4.53

* On a scale of 1-5 (A rating of 6 was applied to choices with no response.)

The overall objective of the study is to provide policy makers and other interested individuals an analysis with the estimated impacts of alternative water conservation policies. The results of this study are valuable information *if* water conservation policies are considered in the future to insure the strategies selected minimize change to incomes and the economy.

The purpose of this document is: 1) to provide documentation of if/how water conservation policies have been implemented in other areas of the United States, 2) outline the policy implementation parameters used in this study, and 3) to present the policy analysis results. An Industry Review Committee (IRC) was formed with carefully selected stakeholders from each sub-region to aid with development of the analysis and was very helpful in offering suggestions for needed changes.

Baseline and Policy Analysis

Methods Used for the Economic Models

This section will familiarize the reader with the economic models that were used to evaluate each of the alternative water conservation policies. There are two types of economic models that were used in the policy analyses. Economic optimization models consist of individual models for each of the counties in the study area that estimate changes in the aquifer and farm net income over a 60 year planning period. Socioeconomic models evaluate impacts on the regional economy. The socioeconomic models aggregate the results from the county optimization models to explain changes in the regional economy and regional employment.

The county optimization models begin with the initial county values for crop acreage, irrigated acreage, average saturated thickness, and depth to water. Given the initial conditions, the models estimate the level of crop production and water use that optimize farm net income over a 60 year planning period. The results of the model include changes in crop acres, irrigated acres, and farm net income over the planning horizon.

The underlying assumptions for the model include county, aquifer, and crop parameters. The parameters for each county include the number of acres planted in each crop, the number of irrigated acres, and the percentage of the county overlying the Ogallala Aquifer. The aquifer characteristics for each county include the average saturated thickness, depth to water, specific yield, and recharge.

The crop parameters for each crop include crop price, cost of production, and crop yield. Crop yield was determined by a production function which estimates yield as a response to applied water. Each crop in each county has a unique production function. As available water decreases, the crop yield decreases in response to reduced irrigation. Cost of pumping was calculated using the energy price and energy requirement due to the changing depth to water over the planning period. One of the unique aspects of this model is that water demand incorporates costs of pumping, changes in depth to water, and changing yields and crop mix as they respond to changing water availability over time.

The results of the county optimization models are aggregated into sub-regional results for the socioeconomic analyses to forecast the effects of the policies on overall economic activity. These models capture the often-cited "spillover effects" of changes in water availability on other economic sectors linked directly and indirectly to irrigated crop production. Models to evaluate the socioeconomic impacts on the overall study area and selected sub-regional impacts of the alternative scenarios analyzed use the input-output model, IMpact analysis for PLANning (IMPLAN). Input-output modeling is a method used to understand the linkages between elements of an economy and estimate the impacts of changes in the economy.

To measure impacts, the IMPLAN model produces multipliers which attempt to estimate the total economic impact of expenditures within an economy. These impacts are referred to as direct, indirect, and induced effects. The IMPLAN model contains comprehensive and detailed data coverage of the entire U.S. by county and the ability to incorporate user-supplied data at each stage of the model building process (Minnesota IMPLAN Group, Inc., 2000). Particular crop production costs for each sub-region are input into the model to get more detailed and region-specific results. These models generate the impact projections of employment, regional income, and industry output for each sub-region in the study area.

Policy Background and Implementation

Biotechnology

Description

The biotechnology water conservation policy would be a voluntary incentive-based policy that encourages landowners to adopt more water-efficient crop varieties. Qualset defines biotechnology as "an applied field of science whereby the scientific principles are used to discover new methodology and instrumentation to produce new forms of biological entities" (Qualset, 1991). The effects of biotechnology on water conservation are somewhat uncertain at this time. Researchers have begun to genetically engineer drought resistant seed that requires less water than their traditional counterparts; however, unlike other types of biotechnologies such as insect resistant and herbicide resistant crops, there are few, if any, drought resistant seed varieties marketed to producers. In this scenario, the adoption of biotechnology refers to only the adoption of drought tolerant varieties that increase production per unit of water.

Background

Since the late-1990s, there have been vast adoptions across the United States of biotechnology derived crops. In 1996, only 5 million acres were planted in biotechnology derived crops in the United States. Conversely, 123 million acres were planted in biotechnology derived crops in 2005 with the acres being concentrated in three major commercialized applications (virus resistant, herbicide resistant, and insect resistant) and eight crops (alfalfa, canola, corn, cotton, papaya, soybean, squash, and sweet corn) (Sankula, 2005).

The adoption of virus resistant, herbicide resistant, and insect resistant crops has allowed producers to increase yields and decrease pesticide use. Producers are finding that they can improve yields with the use of minimal inputs. Sankula states that "American growers' confidence in biotechnology-derived crops, as reflected in the increased adoption each year, is due to the positive impacts provided by these crops in the form of enhanced crops yields, improved insurance against pest problems, reduced pest management costs, lower pesticide use, and overall increase in grower returns" (Sankula, 2005).

Although there is no drought resistant biotechnology derived crops currently being marketed, Sankula points out that they are the next generation of development. Drought resistant corn is being field tested and preliminary results show increases in yield between 9% and 14%. Stress tolerance, including drought and insect tolerance, is a key objective for other crop genomic research. Drought tolerance in cotton is being investigated in Texas by scientists at Texas Tech University, Texas Agricultural Experiment Station, and USDA ARS laboratories.

Prior to the vast adoption of biotech varieties, Arabiyat (1998) used a dynamic optimization model to evaluate the effects of new irrigation technologies and biotechnology on groundwater use and net present value of agricultural returns for three counties in the Texas High Plains. Her study focused on how these improvements could help sustain irrigated agriculture and the Ogallala Aquifer. Arabiyat considered three scenarios: 1) improved irrigation technology, 2) improved biotechnology, and 3) improvements in irrigation technology and biotechnology while holding net returns constant. She concluded that technology advancement and the controlled use of groundwater could significantly contribute to the sustainability of agriculture in the Texas High Plains. She encouraged the adoption of these new technologies and concluded that they could help prolong the life of the aquifer and irrigation in the area through increased efficiency.

Biotechnology is affecting agricultural production overlying the Southern Ogallala Aquifer. Though current biotechnology derived crops have little if any effect on water use per acre, drought resistant varieties will likely be the next generation of biotech crops. Drought resistant crops could allow producers to achieve higher yield levels with decreasing water availability. For drought resistant crops to contribute to decreased water usage, they must be used in combination with policies that provide incentives for producers to decrease water use.

Recent bio-technological advances have affected crop production overlying the Ogallala Aquifer by increasing yields and decreasing pesticide usage, but have not specifically targeted water conservation. Producers using biotechnological advances can increase yield per acre while holding water use constant. Water use per acre is mostly unaffected, but the marginal value of water increases due to the increased crop yield per unit of water, thereby, speeding the approach to economic depletion of the aquifer.

Implementation

In order to implement a voluntary incentive-based policy to conserve water used from the Ogallala Aquifer, further advances in drought resistant varieties of crops must first be made.

If drought resistant varieties of crops are made available to producers, and a restriction is placed on the policy that requires producers to either decrease or maintain irrigated acres at current levels, an incentive-based policy to encourage adoption of more water efficient technologies could potentially provide substantial water conservation of the Ogallala Aquifer.

Growth in Agricultural productivity in the United States from 1948 to 2004 averaged 1.8% annually (Fuglie, MacDonald, and Ball, 2007). However, in this scenario the adoption of biotechnology refers to only the adoption of drought tolerant varieties that increase production per unit of water. Given this definition, the biotechnology adoption scenario assumes all crop yields increase at the rate of 0.5% per year. In addition, water use is assumed to be reduced at the rate of 1% per year.

The cost of implementing this strategy is two-fold. First, is the cost associated with the water use restriction including potential cost of metering and the resultant loss in producer's income? This is discussed under the water use restriction scenario. Second, some form of incentive will be required to encourage the adoption of drought tolerant varieties. The cost of these genes is unknown at this time; however, it could be approximated by analyzing the cost associated with other stacked gene technologies currently being sold.

Irrigation Technology Adoption

Description

Technology adoption has a significant impact on water use and is a long-term decision. Irrigators would benefit from high efficiency systems primarily through increased crop yields. For irrigators, high efficiency systems are potentially effective way of counteracting groundwater depletion. Many studies have provided evidence that modern irrigation technologies such as drip and sprinkler can yield higher expected profits than traditional technologies (University of California Committee of Consultants; McKenry, 1996). The goal of this policy is to achieve adoption and expansion of modern irrigation technologies by the producers on farms presently using conventional methods of irrigation.

Background

Irrigation is important for crop production in Texas and in the United States. The methods of applying irrigation may be classified as surface, subsurface, sprinkler and drip irrigation (Troeh et al., 1999, Schwab & Frevert, 1985). Irrigated agriculture in the U.S. critically depends on groundwater supplies. About two-thirds of all irrigated acreage in the U.S. utilizes groundwater supplies. Of fourteen million acres irrigated in areas where groundwater aquifers are declining, four million acres are located in Texas (National Research Council). The majority of this acreage is located in the Texas High Plains.

Irrigated crop production is a vital component of the economy in the Texas High Plains and is mainly dependent on the Ogallala Aquifer, which has declining water volume because withdrawals have greatly exceeded natural recharge. Despite its large size, the Ogallala recharges very slowly. The steady decline over the past two to three decades is a cause for concern throughout the region. Methods of irrigation that require more water to irrigate than necessary often play a significant role in depletion of an exhaustible groundwater aquifer. A common policy for conserving irrigation water is to encourage the adoption of more efficient, or water saving irrigation technologies that reduce evaporation and runoff losses. Adoption of modern irrigation technologies could contribute significantly to groundwater conservation efforts. It is often cited as a key to increasing water use efficiency in agriculture and reducing the use of scarce inputs (Cason and Uhlaner, 1991) while maintaining current levels of production.

Declining groundwater storage, high pumping energy costs, and low farm profits are causing major changes in irrigation in the Texas High Plains. The rate of decline of the Ogallala Aquifer has been reduced in recent years because of decreased irrigated land acreage (either converted to dryland or abandoned), lower application amounts per area irrigated, adoption of systems with lower application losses, and conversion from gravity to more efficient center pivot irrigation sprinkler systems (Musick et al., 1990). As water table levels continue to decline, but at a slower rate, increased emphasis is being placed on water conservation practices that increase application efficiencies and reduce system losses.

Surface irrigation is the most common method of applying irrigation water in arid areas. With traditional irrigation technologies, large quantities of water are applied in a short period of time. Gravity is used to spread the water which often results in non-uniform application of water, whereas, with modern irrigation technologies, small quantities of water are applied continuously over long periods of time and both equipment and pressure are used to distribute water uniformly throughout the field. Converting to systems with higher irrigation efficiency may affect water use, crop yield, and irrigation welfare. Efficient systems increase the share of gross irrigation (quantity of water diverted) that becomes net irrigation (quantity consumed by the crop) and lead to higher average yields as well as less variability in yields across years. They increase the amount of water that can reach the crop in periods of low rainfall. Efficient irrigation systems transmit a higher proportion of water applied to the root zone of the crop. This allows a higher level of water consumption for crops at a given level of water application and can allow the irrigator to reduce the application rates while still meeting the consumptive demands of the crops. These irrigation systems are expected to reduce water use by 10%-40% compared to conventional irrigation methods.

Casterline (1992) found that nationwide changes in acreage of modern irrigation technologies were not gradual, but occurred mostly during brief periods associated with extreme events like drought and high energy prices. Adoption of technically efficient irrigation systems can mitigate the effects of drought by allowing the irrigators to maintain water consumption with reduced applications. Irrigators can respond to drought in a variety of ways. In the short term, they can reduce water applications, fallow acreage or change crops. In the long run, they can adopt different efficient irrigation systems. One of the primary advantages of technically efficient irrigation systems is the cost reduction associated with reducing the volume of water that is delivered but is not translated into productive yield. Improvements in irrigation efficiency frequently correspond to moderate yield improvements (Zilberman, 1995) and can also reduce production costs. Efficient systems may reduce production costs because fewer pumping hours are needed for a given amount of net irrigation and operating expenses per hour may be smaller (Williams et al., 1997).

Two expanding technologies that will continue to improve irrigation application efficiencies are Low Energy Precision Application for center pivot and lateral move systems and surge flow application in the graded furrow systems. The earliest sprinkler configurations were high-pressure impact, but these have been replaced by low-pressure spray and LEPA (Lyle & Bordovsky, 1983) in the 1980s (Musick et al., 1988). Musick et al., (1988a) and Musick et al., (1988b) reported that center pivot sprinkler systems are the common mode of sprinkler irrigation in the Texas High Plains and graded furrow systems are the most common method of surface irrigation methods.

Center pivot sprinkler irrigation (Splinter, 1976) is well suited to the environment where land resources are not the major limitation, but water resources are restricted. Center pivot sprinkler systems are an economical, practical method for the Southern High Plains Region; particularly where growing season rainfall can reliably supply part of the crop water needs thereby reducing the gross irrigation capacity. Center pivot systems designed for low-pressure application are widely used and apply water mainly through low angle impact sprinklers, spray nozzles, or LEPA. Center pivot sprinklers are rapidly expanding on the Texas High Plains, and LEPA (low energy precision application) methods are widely used in this region to reduce water application losses, to use the relatively low well yields, and to reduce energy requirements for pressurization. Center pivot systems are used primarily to reduce irrigation labor requirements. An exception is the LEPA system, which increases application efficiency and reduces energy requirements.

Linear move sprinkler irrigation systems are an adaptation of center pivot sprinkler systems for use on fields which are not appropriate for center pivot systems. The low-pressure systems include: Low Energy Precision Application (LEPA), Low Pressure In Canopy (LPIC), Low Elevation Spray Application (LESA), and Medium Elevation Spray Application (MESA). LEPA is a Center Pivot or a Lateral move irrigator with low energy requirements using spray, bubbler or sock emitters. LEPA was introduced by Lyle and Bordovsky (1981) to further reduce sprinkler application losses due to droplet evaporation and drift in the high winds which commonly occur in this region thereby saving water and energy. Wind speed has the most effect on sprinkler application efficiency and wind speeds from low 2 to 4 mph to relatively high 10 mph double the application losses. LEPA with spray nozzle on center pivot drops operating 8-16 inches above the furrow elevation is the most efficient water application system in the Texas High Plains. LEPA requires surface storage or high intake soils to avoid surface redistributions from the applied water and to avoid field runoff from both rainfall and irrigation. The LEPA irrigation method permits precise control of the irrigation application and provides uniform irrigations. LEPA can avoid some application losses and with proper management, LEPA should nearly maximize portioning of the applied water to meet the crop water use needs. Lyle and Bordovsky (1983) reported advantages for alternate furrow LEPA compared to every furrow LEPA besides the reduction in hardware costs.

Hills et al. (1988) reported that application efficiency, however, was not related to system speed for a lateral move sprinkler. Application efficiencies for LEPA irrigations have been reported in the range 96% to 98% (Lyle & Bordovsky, 1983; Schneider & Howell, 1990). Howell and Phene (1983) reported static uniformities of 98% similar to those found by Lyle and Bordovsky (1981) and suggested that below canopy spray LEPA application losses were about 10%. Irrigation management to reduce water application has resulted in substantial decline in groundwater pumped in the Texas High Plains.

Considering the average application efficiency of 83% with the center pivot systems and the 98% reported for LEPA, conversion to LEPA could provide a 15% increase in water available for plant use which is less than the reported 20% to 25% by New (1986).

Implementation

There are three broad classes of factors affecting irrigation technology adoption: economic variables, environmental characteristics and institutional variables. The methodology for modeling this policy involves different aspects. First, collection of data was necessary to determine the number of irrigated acres under sprinkler irrigation systems and subsurface drip irrigation in the study area. The efficiencies of alternative irrigation methods have also been estimated as well as the fixed and variable costs associated with the systems. The overall implementation level has been determined in addition to conversion levels to efficient irrigation systems for each sub-region.

Data on the number of irrigated acres utilizing conventional versus advanced irrigation systems were collected for each sub-region. Irrigated acres utilizing conventional methods are 214,000, 671,000, and 300,000 for the Northern, Central, and Southern sub-regions, respectively. Advanced irrigation systems account for 1,971,763, 1,701,000, and 1,820,000 acres for LEPA and 6,599, unknown, and 83,000 for drip for the Northern, Central, and Southern sub-regions, respectively. These estimates will serve as the starting point to be used in converting acres under conventional methods to more efficient methods.

Application efficiencies to be used in the analysis are 60% for furrow, 75% for surge flow, 78% for MESA, 88% for LESA, 95% for LEPA, and 99% for drip. Conversion levels for acres under conventional irrigation methods to sprinkler systems are 75%, 90%, and 95% for Southern, Central, and Northern sub-regions of the study area, respectively. In relation, the remaining acres under conventional irrigation methods will be converted to sub-surface drip irrigation, until sub-surface drip irrigation accounts for 25%, 10%, and 5% of total irrigation technology for the Southern, Central, and Northern sub-regions, respectively. The implementation level of an increase in acreage under the advanced irrigation technology is 10% of the target rate every year. Assuming this rate, it would take approximately 10 years to completely convert the area under conventional irrigation systems to both sprinkler systems and sub-surface drip irrigation.

The irrigation technology adoption policy could be implemented with incentives for producers that switch to more efficient irrigation systems. The results from this analysis could serve as a baseline in determining the level of incentive that would need to be provided. Analysis of the costs and performance of the irrigation adoption portion of EQIP program may also provide insight into the potential implementation cost.

Water Use Restriction

Description

The “Water Use Restriction” policy is a mandatory annual or multi-year limit that reduces the amount of water pumped. The goal of this policy is to reduce the amount of water pumped from the Ogallala Aquifer for agricultural irrigation in order to sustain water supply for future generations.

Background

The decline of the Ogallala Aquifer has caused a growing concern for groundwater conservation in the region. In response, state lawmakers are seeking the development of different policies in order to conserve this precious resource. One policy option that can be implemented is a “Water Use Restriction” policy. The idea of restricting water use is a fairly new idea, and thus, only a few states have applied such a policy in their groundwater management plan.

State Groundwater Laws

There are four basic types of state groundwater allocation rules: 1) capture, 2) reasonable use, 3) correlative rights, and 4) prior appropriation. The rule of capture is the right of a landowner to withdraw unlimited amounts of water found beneath his land. Currently, Texas is the only major state that still adheres to this English common-law rule. Under the reasonable use rule, overlying landowners can pump water from beneath their land and use it for a beneficial purpose so long as it is determined to be reasonable use. However, this rule does not apportion water rights to the groundwater supply among landowners. The states that follow the reasonable use rule include Alabama, Arizona, Florida, Illinois, Iowa, Kentucky, Maryland, Michigan, Nebraska, New Hampshire, New York, North Carolina, Ohio, Pennsylvania, Tennessee, West Virginia, and Wisconsin. The correlative rights rule was initially developed by California. Under this rule, each landowner is entitled to a fair proportion of the common pool determined by the ratio of land owned overlying the basin. Other states following this rule include Arkansas, Delaware, Minnesota, Missouri, Nebraska, and New Jersey. Finally, the prior appropriation rule is a permit system for groundwater that allocates groundwater based on historical use. Colorado, Idaho, Kansas, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming follow prior appropriation.

Some states have found that these basic groundwater allocation rules are simply not enough to control over-drafting and mining of aquifers. In response, critical areas have been established and local groundwater districts have been formed to deal with these problems. Generally, the states that follow the prior appropriation rule leave the responsibility of governing groundwater with the state and have some local input, whereas, local districts have greater authority in states that do not follow this rule (Kaiser and Skillern, 2001).

Selected Examples of Groundwater Restrictions

The Arizona Groundwater Management Act (GMA) was passed in 1980 which created first time restrictions on the amount of groundwater that could be used in areas called active management areas (AMA). These areas were identified to have severe overdraft and include 80% of the state's population and 70% of the state's groundwater overdraft. One key provision in the GMA was the establishment of groundwater rights. Any well within the AMA that has a pump capacity greater than 35 gallons per minute must have a right to withdraw water. In addition, these water users must measure and record annual water use and report to the state.

There are three types of "grandfathered rights" that are based on past water use. First, the irrigation grandfathered right applies to any land that was irrigated between 1975 and 1980. This allows the irrigator to pump the minimum amount of water necessary to irrigate the land. The second, Type 1 right, pertains to land that has been retired from farming and converted to a non-irrigation use. The maximum amount of water that can be pumped under this right is three acre-feet per acre. The third grandfathered right, Type 2 right, is for a non-irrigation purpose only. The maximum amount that can be pumped equals the maximum pumped in any one year between 1975 and 1980. No new irrigation is allowed in the active management areas. The overall goal of the GMA is to reduce per capita or per acre water use through a series of 10-year plans from 1980 to 2025 until a safe yield is achieved. Safe yield is defined as the hydrologic concept of achieving and maintaining a long-term balance between the annual amount of groundwater withdrawn and the amount of natural and artificial recharge (Arizona Department of Water Resources, 2007).

Although California operates under the correlative rights rule, these rights are not defined until a basin is adjudicated. When a case is brought to adjudicate the basin, the court decides who the well owners are, how much they can pump, and who will be the water master in charge of monitoring the basin to ensure proper management. Sixteen basins in southern California have been adjudicated. In addition, California has allowed management of groundwater in areas with overdrafting by special legislation districts, city and county ordinances, local agencies, and groundwater management districts (California Department of Water Resources, 1999).

Colorado passed the Ground Water Management Act in 1965 which created the Colorado Groundwater Commission with the authority to regulate groundwater in designated groundwater basins. The commission has implemented groundwater depletion rules in the eastern and northern basins of the state. The eastern basins are allowed 40% mining of groundwater over 25 years, whereas, the northern basins are more limited with a rule of 40% mining over 100 years. Thirteen local groundwater districts have also been created within these basins. However, these districts remain under the control of the Groundwater Commission (Kaiser and Skillern, 2001).

Since 1945, Kansas has appropriated water through permits. The sole issuance of these permits, however, was not enough to control groundwater mining. Five Groundwater Management Districts were formed after 1972. In addition, intensive groundwater use control areas (IGUCAs) were established with the power of reducing permissible withdrawal of groundwater. In 1992, Kansas established an IGUCA on the Wet Walnut Creek in central Kansas. The Walnut Creek IGUCA Order cut existing water rights and stopped the authorization of new water rights in the area. Senior rights, obtained prior to 1965, were cut from 22% to 33%, while Junior rights, obtained after 1965, were cut 64% to 71% (Peck, 2003).

It can be concluded that Arizona has the most sophisticated water policy in place and is ahead of other states in the development of a system to conserve water. It was found that most states are implementing incentive-type programs such as a Conservation Reserve Program (CRP) (Sullivan et al, 2004) or a Conservation Reserve Enhancement Program (CREP) in order to reduce groundwater use rather than imposing restrictions. However, with the continued depletion of groundwater, more and more restrictions are being placed on areas with high aquifer overdraft.

Implementation

The method of modeling the Water Use Restriction policy consists of a plan of implementation along with the costs associated with implementing the policy. The plan for implementing the policy includes the following parameters. A Water Use Restriction will be enacted in counties identified by each sub-region of the Southern Ogallala Aquifer that are projected to use more than 40% of saturated thickness over 60 years. The restriction will be applied to wells used primarily for irrigated agriculture in these counties. Each irrigator will be responsible for measuring and reporting water usage to local water districts or the state authority using an approved water metering device. Total water pumped for agricultural irrigation will be reduced by 10% per decade (1% per year).

The cost for implementing the policy could involve several different levels. The cost for each irrigator to obtain an approved water metering device is estimated to be $1,000 per meter. These costs would not apply in the Kansas sub-region where water meters are already in place. The impacts of the decrease in production on producer income can be measured from the baseline economic optimization models. Finally, the impacts resulting from the decrease in producer income on the Southern Ogallala Regional economy can be measured from the baseline socioeconomic (IMPLAN) models.

A Voluntary Temporary Conversion to Dryland Production

Description

The “Voluntary Temporary Conversion to Dryland Production” (Water CRP) policy instrument is a voluntary incentive-based program that compensates landowners to temporarily convert irrigated cropland to dryland. The goal of this policy is to achieve a short-run reduction in agricultural consumptive use by leasing and temporarily retiring irrigation water rights obtained from willing landowners.

The “Voluntary Temporary Conversion to Dryland Production” policy instrument is used to address priority areas that require immediate curtailment of groundwater consumption in order to achieve an environmental or social objective.

Background

The concept of leasing water rights to achieve short run objectives is relatively new and as such the literature in this area is very limited. The Environmental Quality Incentives Program (EQIP) provides a voluntary conservation program for farmers and ranchers that promote agricultural production and environmental quality as compatible national goals. EQIP is administered by the National Resource Conservation Service (NRCS) in cooperation with various state agencies and provides funding to promote ground and water conservation in the Ogallala Aquifer Region. Within Kansas, EQIP funds from the EQIP-Ground and Surface Water Conservation (GSWC) program are allocated to Quick Response Areas.[1] Under this program, NRCS pays to temporarily conserve ground and surface water used to irrigate farmland. A producer enrolling in the program agrees to not irrigate enrolled acres for four years and in turn receives annual payments for three years of the contract period. The producer retains the right to dryland crop the acreage during the contract period. To encourage participation, typically, the state and local groundwater management supplements funds to make a lease payment for the fourth year.

A second mechanism for leasing water rights is the Conservation Reserve Enhancement Program (CREP). The CREP is similar in structure to the Conservation Reserve Program (CRP). CREP is a voluntary program for agricultural landowners that implements conservation practices and requires state and federal partnerships. States are allowed considerable flexibility in defining the environmental goals of their program. Some states have elected to develop a CREP that requires the temporary retirement of water rights. Nebraska and Idaho have CREP programs that temporarily suspend irrigated crop production. In addition to the temporary loss of water rights, these programs suspend nonirrigated production for 14 to 15 years.

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[1] Quick Response Areas are defined by the Kansas Department of Agriculture’s Department of Water Resources based on aquifer conditions, withdrawal patterns, and socioeconomic considerations. Quick Response Areas have the highest priority for dryland incentive grants.

The implementation of an efficient and effective water conservation strategy for the Ogallala Aquifer is a complex problem. Policy makers and stakeholders must weigh the potential water savings that may be generated from a particular water conservation scheme against the implementation costs and potential impacts on the regional economy. Leatherman et al. (2006) compiled the regional economic impact study associated with the proposed Kansas CREP. Supalla, Buell, and McMullen, (2006) compiled the regional economic impact study associated with the proposed Nebraska CREP and Pritchett et al. (2005) compiled the regional economic impact study associated with the proposed Colorado CREP.

Implementation

Due to increasing popularity, the CREP style program, with temporary water rights retirement, will serve as a framework for this analysis. Modeling this policy option will consist of two components. The first is an economic/hydrological model that estimates the water use and aquifer impacts associated with the scheme. The second is an economic impact model that estimates the regional economic impact associated with the policy option. The results of both components are measured against a status quo scenario. Both components will require a variety of assumptions.

The magnitude of acreage enrolled in the CREP as well as the timing of enrollment, and program duration impact the economic and hydrological results. Past studies have assumed that the maximum allowed program acreage is enrolled in the first year, and to an extent, have been criticized for this assumption. This may be an unrealistic assumption as landowners could rarely be expected to alter existing business arrangements in such a short time frame. Several assumptions will be required. This study will assume a 15 year program duration, that the maximum allowed program enrolled acreage is 10% of the irrigated acres in the study region, and 20% of this acreage are enrolled in each of the first five years.

Revenues from irrigated crop production are totally lost during the program. The lost crop revenue, due to the retired irrigated crop land, can be viewed as a direct negative economic impact to the region. The hydrological/economic model will be used to provide the estimate of crop mix and revenue under the policy scenario. Supalla et al. (2006) and the Pritchett study used average county crop and average drawdown data. Leatherman et al. (2006) developed a model to predict which landowners would enroll and used individual crop mix and water use (in aggregate) to make predictions. This study will be based on model predicted irrigated crop mix and crop yields and could assume that irrigated acreage reductions are proportionally distributed across crops based on the predicted irrigated crop mix during the appropriate time period.

During the program period, enrolled acreage may be subject to conventional CRP requirements. Some income may be generated from haying and grazing and recreation which, if appropriate, will be included in the analysis. Since nonirrigated crop production may be allowed on the enrolled acreage in future CREP programs the policy will be modeled both with and without nonirrigated production. The magnitudes of haying and grazing and recreation revenues are difficult to measure and will exhibit high variability over the study regions. Each study area will require a different methodology to quantify this impact and may require different assumptions relative to the revenues generated from enrolled acreage.

At the termination of the CREP program, participants are allowed to resume irrigated crop production since program participation requires only temporary suspension of the water right. This study assumes that all enrolled acreage resumes irrigated production after initial enrollment, with appropriate start-up costs included for renewed irrigation. Crop mix and crop yields will be endogenous to the model and returning acres could be assumed to be proportionally distributed across crops based on the predicted irrigated crop mix during the appropriate time period.

The cost (to the state) of retiring water rights generally is provided as direct payments to the landowner and can be viewed as a direct positive economic impact to the region for the term of payments. The short term and long term discounted differences in producer income can serve as a proxy for what the potential producer compensation may have to be.

A Voluntary Permanent Conversion to Dryland Production

Description

The "Voluntary Permanent Conversion to Dryland Production" policy instrument is a voluntary incentive-based program that compensates landowners to permanently convert irrigated cropland to dryland. The goal of this policy is to achieve an absolute long-run reduction in agricultural consumptive use by purchasing and permanently retiring irrigation water rights from willing landowners.

The "Voluntary Permanent Conversion to Dryland Production" policy instrument is used to address two concerns in the area of water conservation. First, the rapid development of irrigation in areas overlying the Ogallala Aquifer led to over appropriation of available water, which in turn led to significant decline rates of the aquifer. As state water managers seek to reduce consumptive use, approach sustainable yields, and extend the economic life of the aquifer one policy instrument often considered is a voluntary water rights buy-out program. Secondly, for the majority of the 20th century, state and federal water policies were designed to encourage settlement and to develop the agricultural industry in western states. As a result, agriculture consumes between 70% and 95% of the available water resources in most arid western states. As society moves into the 21st century, public concerns over decreasing wildlife populations, the desire for more water-oriented recreational facilities, the water needs of an expanding industrial sector, and increased population concentration call into question the current allocation of water resources. With increasing frequency, policy makers are asked to decide how to equitably transfer water rights from agricultural to competing sectors. One method often considered is the voluntary retirement of agricultural water rights where rights are procured by willing buyers, generally the state, from willing sellers.

Background

The concept of purchasing and retiring water rights to achieve either objective is relatively new and as such the literature in this area is limited. Ise and Sunding (1998) evaluated the state sponsored purchase of agricultural water rights in the Lahontan Valley of Nevada. This program was a result of rapidly declining wetlands and migratory bird populations in the area. Golden (2005) evaluated the per acre cost of the value of water rights in the Rattlesnake Sub-basin of Kansas for their buyout program, also the result of rapidly declining wetlands. Golden and Peterson (2006) compared the state's cost of purchasing water rights to the cost of subsidizing more efficient irrigation equipment and Supalla et al. (2006) compared the state's cost of purchasing water rights to the state's cost of leasing water rights; both studies suggested that purchasing water rights was a more cost effective way to achieve reductions in groundwater consumption.

Voluntary water rights buy out programs fall generally into two classes. The first is a strict water right buyout program where the transaction impacts only the status of the water right and the landowner maintains the right to nonirrigated production. The programs in the Lahontan Valley of Nevada and the Rattlesnake Sub-basin of Kansas are examples of this program structure. A second mechanism for purchasing water rights is the Conservation Reserve Enhancement Program (CREP). The CREP is similar in structure to the Conservation Reserve Program (CRP). CREP is a voluntary program for agricultural landowners that implement conservation practices and require state and federal partnerships. States are allowed considerable flexibility in defining the environmental goals of their program. Some states have elected to develop a CREP that requires the permanent retirement of water rights. Colorado and Kansas have CREP programs that permanently retire water rights. In addition to the permanent loss of water rights these programs suspend nonirrigated production for 14 to 15 years.

The implementation of an efficient and effective water conservation strategy for the Ogallala Aquifer is a complex problem. Policy makers and stakeholders must weigh the potential water savings that may be generated from a particular water conservation scheme against the implementation costs and potential impacts on the regional economy. Leatherman et al. (2006) compiled the regional economic impact study associated with the proposed Kansas CREP. Supalla, Buell, and McMullen, (2006) compiled the regional economic impact study associated with the proposed Nebraska CREP and Pritchett et al. (2005) compiled the regional economic impact study associated with the proposed Colorado CREP.

Implementation

Due to increasing popularity, the CREP style program, with permanent water rights retirement, will serve as a framework for this analysis. Modeling this policy option will consist of two components. The first is an economic/hydrological model that estimates the water use and aquifer impacts associated with the scheme. The second is an economic impact model that estimates the regional economic impact associated with the policy option. The results of both components are measured against a status quo scenario. Both components will require a variety of assumptions.

The magnitude of acreage enrolled in the CREP as well as the timing of enrollment, and program duration impact the economic and hydrological results. Past studies have assumed that the maximum allowed program acreage is enrolled in the first year, and to an extent, have been criticized for this assumption. This may be an unrealistic assumption as landowners could rarely be expected to alter existing business arrangements in such a short time frame. This study will assume a 15 year program duration, that the maximum allowed program enrolled acreage is 10% of the irrigated acres in the study region, and 20% of this acreage is enrolled in each of the first five years.

Revenues from irrigated crop production are totally lost during the program. The lost crop revenue, due to the retired irrigated crop land, can be viewed as a direct negative economic impact to the region. The hydrological/economic model will be used to provide the estimate of crop mix and revenue under the policy scenario. Supalla et al. (2006) and the Pritchett study used average county crop and average drawdown data. Leatherman et al. (2006) developed a model to predict which landowners would enroll and used individual crop mix and water use (in aggregate) to make predictions. This study will be based on model predicted irrigated crop mix and crop yields and assume that irrigated acreage reductions are proportionally distributed across crops based on the predicted irrigated crop mix during the appropriate time period.

During the program period, enrolled acreage may or may not be subject to conventional CRP requirements. Some income may be generated from haying and grazing and recreation which, if appropriate, will be included in the analysis. Since nonirrigated crop production may be allowed on the enrolled acreage in future CREP programs, the policy will be modeled both with and without nonirrigated production (the different scenarios will be identified as Plan A and Plan B respectively). The magnitudes of haying and grazing and recreation revenues are difficult to measure and will exhibit high variability over the study regions. Each study area will require a different methodology to quantify this impact and may require different assumptions relative to the revenues generated from enrolled acreage.

At the termination of the CREP program, participants are allowed to resume crop production. Since program participation requires permanent abandonment of the water rights, only non-irrigated production is allowed. This study assumes that, depending on land characteristics, enrolled acreage either resumes non-irrigated production or remains in pasture after the 15 year enrollment. Crop mix and crop yields will be endogenous to the model and returning acres could be assumed to be proportionally distributed across crops based on the predicted non-irrigated crop mix during the appropriate time period.

The cost (to the state) of retiring water rights generally is provided as direct payments to the landowner and can be viewed as a direct positive economic impact to the region for the term of payments. The short term and long term discounted differences in producer income can serve as a proxy for what the potential producer compensation may have to be.

Results by Region

The results of the policy analysis are presented by sub-region on the following pages. The economic models were used to evaluate a baseline level and each alternative water conservation policy in the Northern, Central, and Southern sub-regions. The baseline scenario assumes no changes from current water policies over the planning period. The alternative water conservation policies analyzed in this study include biotechnology, irrigation technology, water use restriction, temporary conversion to dryland, and permanent conversion to dryland production.

A target area was identified in each sub-region of the Southern Ogallala Aquifer that included counties that are projected to use more than 40% of saturated thickness over 60 years. Alternative policies were only evaluated for counties in the target area. The following results from the economic optimization models only include the target area, whereas, the socioeconomic results and regional economics include the entire sub-region.

Results of the alternative water conservation policy scenarios were compared to the baseline scenario to identify the relative effect of the policy. Hopefully, the results of this analysis will provide the primary information that policy makers and state agencies need to assess the potential economic implications of these policy alternatives.

Northern Sub-Region Policy Comparison

Regional Economy

The Northern Region has a population of 257,241, average income per household of $55,138 and covers 45,887 square miles. The economy of the Northern Region is comprised of total industry output of $16 billion, value added of $6.4 billion, and employment of 150,040.

Target Area

The target area used in this summary is comprised of Finney, Ford, Grant, Gray, Haskell, Meade, Morton, and Stanton Counties located in southwest Kansas. These counties are located within Kansas Crop Reporting District #30 and fall under the jurisdiction of Ground Water Management District #3. There are a total of 2,312,955 cropland acres in the target area, of which 1,192,243 or 51.5% are irrigated. The combined counties currently consume 1,439,345 acre-feet of groundwater annually. The saturated thickness of the aquifer currently ranges from approximately 87 feet in Ford County to approximately 315 feet in Meade County with depth of water ranging from approximately 104 feet in Ford County to approximately 292 feet in Haskell County. Current decline rates vary from approximately 1 foot per year in Ford County to approximately 3 feet per year in portions of Grant and Gray Counties. On average 20.5% of the irrigated acreage is devoted to alfalfa production, 59.7% to irrigated corn production, and 9.5% to irrigated wheat production. Approximately 77% of these acres are currently irrigated with LEPA style irrigation technology.

Baseline Scenario

The baseline scenario assumes that no water conserving policy is implemented and producers operate in an unregulated profit maximizing manner. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 84.4 feet (Table 1). As saturated thickness declines, well capacity diminishes and pumping costs increase which results in total annual water use being reduced from 1,419,417 acre-feet to 523,319 acre-feet (Table 2). When water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 43.7% (Table 3). The net effect of this scenario is that the target area average net income per acre is reduced by approximately 35.7% to $126.12 per acre (Table 4). Over the 60 year planning horizon, each cropland acre generates a net present value[2] of $6,021.90.

The socioeconomic impacts of agricultural crop production in the sub-region are presented in 2007 dollars (Table 5). Gross receipts of $105,703 million from crop production result in a total economic impact of $198,824 million in industry output, $103,857 million in value added and an average of 39,384 jobs over 60 years.

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[2] Net present value was calculated assuming a 3% discount rate.

Biotechnology Adoption Scenario

The biotechnology adoption scenario assumes that water use is reduced at the rate of 1% per year, and crop yields increase at the rate of 0.5% per year. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 91.3 feet or approximately 8.2% more than the baseline scenario (Table 1). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 1,419,417 acre-feet to 478,356 acre-feet or approximately 8.6% less than the baseline scenario (Table 2). When water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 38.9% or 11.0% less than the baseline scenario (Table 3). The net effect of this scenario is that the target area average net income per acre increases over time to $235.39 per acre or 86.6% more than the baseline scenario (Table 4). Over the 60 year planning horizon, each cropland acre generates a net present value of $7,441.75 or 23.6% more than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the biotechnology scenario are 3% higher than the baseline scenario over 60 years (Table 5). Gross receipts of $108,632 million from crop production result in a total economic impact of $204,347 million in industry output, $106,833 million in value added and an average of 40,397 jobs.

Irrigation Technology Adoption Scenario

The irrigation technology adoption scenario assumes that irrigation efficiency improves as LEPA style center pivots (95% efficient) are replaced by sub-surface drip systems (99% efficient) until 5% of the irrigated acreage is irrigated with sub-surface drip technology. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 84.1 feet or approximately 0.4% less than the baseline scenario (Table 1). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level. However, since technology improvements reduce the marginal cost of water, total annual water use decreases to 562,574 acre-feet or approximately 7.5% more than the baseline scenario (Table 2). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 44.3% or 1.4% more than the baseline scenario (Table 3). The net effect of this scenario is that the target area average net income per acre decreases over time to $127.28 per acre or 0.9% more than the baseline scenario (Table 4). Over the 60 year planning horizon, each cropland acre generates a net present value of $6,003.94 or 0.3% less than the baseline scenario.

There is very little change in socioeconomic impacts of agricultural crop production in the region under the technology adoption scenario compared to the baseline scenario over 60 years (Table 5). Gross receipts of $105,852 million from crop production result in a total economic impact of $199,154 million in industry output, $104,039 million in value added and an average of 39,482 jobs.

Water Use Restriction Scenario

The water use restriction scenario assumes that water use is reduced at the rate of 1% per year. Under this assumption, on average, over the 60 year planning horizon the saturated thickness declines to 92.4 feet or approximately 9.4% more than the baseline scenario (Table 1). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 449,360 acre-feet or approximately 14.1% less than the baseline scenario (Table 2). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 35.7% or 18.3% less than the baseline scenario (Table 3). The net effect of this scenario is that the target area average net income per acre decreases over time to $126.50 per acre or 0.3% more than the baseline scenario (Table 4). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,921.30 or 1.7% less than the baseline scenario.

There is very little change in socioeconomic impacts of agricultural crop production in the region under the water use restriction scenario compared to the baseline scenario over 60 years (Table 5). Gross receipts of $105,240 million from crop production result in a total economic impact of $197,856 million in industry output, $103,488 million in value added and an average of 39,141 jobs.

Temporary Conversion to Dryland Scenario

The temporary conversion to dryland scenario assumes that 2% of the initial irrigated acreage is converted to dryland use each year for 5 years for a total of 10%. This acreage is then allowed to re-enter irrigated production after year 15. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 85.2 feet or approximately 0.9% more than the baseline scenario (Table 1). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 539,451 acre-feet or approximately 3.1% more than the baseline scenario (Table 2). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 44.3% or 1.3% more than the baseline scenario (Table 3). The net effect of this scenario is that the target area average net income per acre decreases over time to $127.43 per acre or 1.0% more than the baseline scenario (Table 4). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,885.00 or 2.3% less than the baseline scenario.

There is very little change in socioeconomic impacts of agricultural crop production in the region under the temporary conversion to dryland scenario compared to the baseline scenario over 60 years (Table 5). Gross receipts of $105,177 million from crop production result in a total economic impact of $197,850 million in industry output, $103,397 million in value added and an average of 39,234 jobs.

Permanent Conversion to Dryland Scenario Plan A

This permanent conversion to dryland scenario assumes that 2% of irrigated acreage is idled each year for the first 5 years for a total of 10%. This acreage then remains idled for 15 years and is then allowed to resume the production of dryland crops. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 88.0 feet or approximately 4.2% more than the baseline scenario (Table 1). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 550,535 acre-feet or approximately 5.2% more than the baseline scenario (Table 2). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 42.2% or 3.4% less than the baseline scenario (Table 3). The net effect of this scenario is that the target area average net income per acre decreases over time to $129.41 per acre or 2.6% more than the baseline scenario (Table 4). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,824.46 or 3.3% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the permanent conversion to dryland scenario are approximately one percent lower than the baseline scenario over 60 years (Table 5). Gross receipts of $104,804 million from crop production result in a total economic impact of $197,079 million in industry output, $103,027 million in value added and an average of 39,096 jobs.

Permanent Conversion to Dryland Scenario Plan B

This permanent conversion to dryland scenario assumes that 2% of irrigated acreage is converted to dryland production each year for the first 5 years for a total of 10%. This acreage is allowed to immediately convert to the production of dryland crops. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 88 feet or approximately 4.2% more than the baseline scenario (Table 1). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 550,535 acre-feet or approximately 5.2% more than the baseline scenario (Table 2). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 42.2% or 3.4% less than the baseline scenario (Table 3). The net effect of this scenario is that the target area average net income per acre decreases over time to $129.41 per acre or 2.6% more than the baseline scenario (Table 4). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,880.75 or 2.3% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the permanent conversion to dryland scenario are approximately one percent lower than the baseline scenario over 60 years (Table 5). Gross receipts of $105,099 million from crop production result in a total economic impact of $197,621 million in industry output, $103,329 million in value added and an average of 39,209 jobs.

Table 1. Northern Sub-Region Target Area Weighted Average Saturated Thickness (feet)*

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60
Baseline	173.0	152.7	131.8	114.1	100.3	90.0	84.4
Biotechnology	173.0	154.2	135.9	120.6	108.0	97.5	91.3
Change	*0.0%*	*1.0%*	*3.1%*	*5.7%*	*7.7%*	*8.3%*	*8.2%*
Irrigation Tech.	173.0	152.8	132.0	114.4	100.7	90.1	84.1
Change	*0.0%*	*0.1%*	*0.1%*	*0.3%*	*0.4%*	*0.2%*	*-0.4%*
Water Use Rest.	173.0	153.3	134.3	118.8	106.6	97.2	92.4
Change	*0.0%*	*0.4%*	*1.9%*	*4.2%*	*6.2%*	*8.1%*	*9.4%*
Temporary Conv.	173.0	153.6	134.1	116.1	102.0	91.1	85.2
Change	*0.0%*	*0.6%*	*1.7%*	*1.8%*	*1.6%*	*1.2%*	*0.9%*
Permanent Conv. (A)	173.0	153.4	133.9	117.7	104.8	94.1	88.0
Change	*0.0%*	*0.5%*	*1.6%*	*3.1%*	*4.4%*	*4.6%*	*4.2%*
Permanent Conv. (B)	173.0	153.4	133.9	117.7	104.8	94.1	88.0
Change	*0.0%*	*0.5%*	*1.6%*	*3.1%*	*4.4%*	*4.6%*	*4.2%*

*Averages are weighted by the area overlying the aquifer in each county.

Table 2. Northern Sub-Region Target Area Total Water Use (1,000 acre-feet)

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60	Total
Baseline	1,419	1,363	1,242	1,051	850	613	523	60,588
Biotechnology	1,419	1,272	1,113	947	799	609	478	56,597
Change	*0.0%*	*-6.7%*	*-10.4%*	*-9.8%*	*-6.0%*	*-0.7%*	*-8.6%*	*-6.6%*
Irrigation Tech.	1,419	1,363	1,237	1,044	851	635	563	60,863
Change	*0.0%*	*0.0%*	*-0.5%*	*-0.6%*	*0.1%*	*3.6%*	*7.5%*	*0.5%*
Water Use Rest.	1,419	1,286	1,115	951	776	579	449	56,080
Change	*0.0%*	*-5.6%*	*-10.3%*	*-9.5%*	*-8.7%*	*-5.5%*	*-14.1%*	*-7.4%*
Temporary Conv.	1,419	1,281	1,242	1,068	868	633	539	60,222
Change	*0.0%*	*-6.0%*	*0.0%*	*1.6%*	*2.1%*	*3.2%*	*3.1%*	*-0.6%*
Permanent Conv. (A)	1,419	1,296	1,162	990	821	641	551	58,737
Change	*0.0%*	*-4.9%*	*-6.5%*	*-5.7%*	*-3.4%*	*4.6%*	*5.2%*	*-3.1%*
Permanent Conv. (B)	1,419	1,296	1,162	990	821	641	551	58,737
Change	*0.0%*	*-4.9%*	*-6.5%*	*-5.7%*	*-3.4%*	*4.6%*	*5.2%*	*-3.1%*

Table 3. Northern Sub-Region Target Area Irrigated Acres as a Percentage of Total Acres*

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60
Baseline	51.5%	51.5%	51.5%	51.5%	51.3%	45.3%	43.7%
Biotechnology	51.5%	51.5%	51.5%	51.5%	51.3%	45.2%	38.9%
Change	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*-0.4%*	*-11.0%*
Irrigation Tech.	51.5%	51.5%	51.5%	51.5%	50.7%	45.3%	44.3%
Change	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*-1.1%*	*0.0%*	*1.4%*
Water Use Rest.	51.5%	51.5%	51.5%	51.5%	50.3%	43.4%	35.7%
Change	*0.0%*	*0.0%*	*0.0%*	*-0.1%*	*-1.8%*	*-4.2%*	*-18.3%*
Temporary Conv.	51.5%	46.4%	50.5%	51.5%	51.5%	45.9%	44.3%
Change	*0.0%*	*-10.0%*	*-2.0%*	*0.0%*	*0.6%*	*1.2%*	*1.3%*
Permanent Conv. (A)	51.5%	46.4%	46.4%	46.4%	46.4%	43.3%	42.2%
Change	*0.0%*	*-10.0%*	*-10.0%*	*-10.0%*	*-9.5%*	*-4.4%*	*-3.4%*
Permanent Conv. (B)	51.5%	46.4%	46.4%	46.4%	46.4%	43.3%	42.2%
Change	*0.0%*	*-10.0%*	*-10.0%*	*-10.0%*	*-9.5%*	*-4.4%*	*-3.4%*

*The percentage is based on the total irrigated acres in the target area (at time = t) divided by total irrigated and nonirrigated cropland acres in the target area.

Table 4. Northern Sub-Region Target Area Average Net Income per Acre*

Policy Scenario	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60	Net Present Value
Baseline	$196.27	$190.29	$175.79	$156.38	$134.38	$126.12	$6,021.90
Biotechnology	$214.04	$226.96	$233.93	$237.58	$235.34	$235.39	$7,441.75
Change	*9.1%*	*19.3%*	*33.1%*	*51.9%*	*75.1%*	*86.6%*	*23.6%*
Irrigation Tech.	$195.21	$188.36	$173.93	$155.48	$134.96	$127.28	$6,003.94
Change	*-0.5%*	*-1.0%*	*-1.1%*	*-0.6%*	*0.4%*	*0.9%*	*-0.3%*
Water Use Rest.	$192.69	$183.59	$170.92	$154.84	$137.12	$126.50	$5,921.30
Change	*-1.8%*	*-3.5%*	*-2.8%*	*-1.0%*	*2.0%*	*0.3%*	*-1.7%*
Temporary Conv.	$183.34	$188.93	$177.58	$158.85	$136.38	$127.43	$5,885.00
Change	*-6.6%*	*-0.7%*	*1.0%*	*1.6%*	*1.5%*	*1.0%*	*-2.3%*
Permanent Conv. (A)	$183.91	$181.72	$171.27	$156.21	$138.81	$129.41	$5,824.46
Change	*-6.3%*	*-4.5%*	*-2.6%*	*-0.1%*	*3.3%*	*2.6%*	*-3.3%*
Permanent Conv. (B)	$188.16	$182.63	$171.27	$156.21	$138.81	$129.41	$5,880.75
Change	*-4.1%*	*-4.0%*	*-2.6%*	*-0.1%*	*3.3%*	*2.6%*	*-2.3%*

*The average is based on the total irrigated and nonirrigated net revenue (at time = t) divided by total irrigated and nonirrigated cropland acres.

Table 5. Northern Sub-Region 60 Year Regional Economic Impacts

	Direct	Indirect	Induced	Total	Change from Baseline	% Change from Baseline
Baseline						
Output*	105,703	54,581	38,540	198,824		
Value Added*	50,044	30,305	23,508	103,857		
Employment	19,438	12,210	7,736	39,384		
Biotech						
Output*	108,632	56,065	39,650	204,347	5,523	3%
Value Added*	51,523	31,124	24,186	106,833	2,975	3%
Employment	19,912	12,525	7,959	40,397	1,013	3%
Technology Adoption						
Output*	105,852	54,698	38,604	199,154	330	0%
Value Added*	50,120	30,372	23,548	104,039	182	0%
Employment	19,499	12,234	7,749	39,482	98	0%
Water Use Restriction						
Output*	105,240	54,193	38,423	197,856	-968	0%
Value Added*	49,958	30,092	23,437	103,488	-369	0%
Employment	19,304	12,124	7,713	39,141	-243	-1%
Temporary Conversion						
Output*	105,177	54,300	38,373	197,850	-974	0%
Value Added*	49,836	30,154	23,407	103,397	-460	0%
Employment	19,378	12,154	7,702	39,234	-150	0%
Permanent Conversion (A)						
Output*	104,804	54,029	38,247	197,079	-1,744	-1%
Value Added*	49,693	30,004	23,330	103,027	-831	-1%
Employment	19,314	12,106	7,677	39,096	-287	-1%
Permanent Conversion (B)						
Output*	105,099	54,160	38,362	197,621	-1,203	-1%
Value Added*	49,851	30,078	23,400	103,329	-529	-1%
Employment	19,371	12,138	7,700	39,209	-175	0%

*Millions of dollars

Central Sub-Region Policy Comparison

Regional Economy

The Central Region has a population of 388,971, average income per household of $60,682 and covers 23,292 square miles. The economy of the Central Region is comprised of total industry output of $23 billion, value added of $10 billion, and employment of 203,689.

Target Area

The Central Sub-Region target area includes Castro, Dallam, Deaf Smith, Hartley, Moore, Parmer, Sherman, and Swisher counties in the Texas Panhandle. Dallam, Hartley, Moore and Sherman counties are located in the Texas Water Development Board's (TWDB) Groundwater Management Area 1 (GMA1), and are all part of the North Plains Groundwater Conservation District. Castro, Deaf Smith, Parmer, and Swisher counties are in the TWDB Groundwater Management Area 2 (GMA2), with Deaf Smith, Parmer, and Castro counties being located in the High Plains Underground Water Conservation District No. 1. The target area consists of 2,398,567 cropland acres, of which approximately 63% are irrigated. These eight counties consume approximately 2.3 million acre-feet of groundwater annually. The saturated thickness of the aquifer in this area averages 110 feet, and ranges from approximately 43 feet in Swisher County to approximately 182 feet in Sherman County. Approximately 95% of all irrigated acres in the area are under center pivot sprinkler irrigation systems. Of the total irrigated acres under all practices, approximately 38% is planted in sprinkler-irrigated corn, 30% in sprinkler-irrigated wheat, and 16% in sprinkler-irrigated cotton.

Baseline Scenario

The baseline scenario assumes that no water conserving policy is implemented and producers operate in an unregulated profit maximizing manner. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 43.7 feet (Table 6). As saturated thickness declines, well capacity diminishes and pumping costs increase which results in total annual water use being reduced from 2,303,317 acre-feet to 754,794 acre-feet (Table 7). When water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 17.4% (Table 8). The net effect of this scenario is that the target area average net income per acre is reduced approximately 40.8% to $106.85 per acre (Table 9). Over the 60 year planning horizon, each cropland acre generates a net present value of $4,307.36.

The socioeconomic impacts of agricultural crop production in the region are presented in 2007 dollars (Table 10). Gross receipts of $47,622 million from crop production result in a total economic impact of $105,970 million in industry output, $48,634 million in value added and an average of 29,183 jobs over 60 years.

Biotechnology Adoption Scenario

The biotechnology adoption scenario assumes that water use is reduced at the rate of 1% per year, and crop yields increase at the rate of 0.5% per year. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 49.2 feet or approximately 12.4% more than the baseline scenario (Table 6). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 2,303,317 acre-feet to 588,155 acre-feet or approximately 22.1% less than the baseline scenario (Table 7). When water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 14.9% or 14.4% less than the baseline scenario (Table 8). The net effect of this scenario is that the target area average net income per acre increases over time to $225.77 per acre or 111.3% more than the baseline scenario (Table 9). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,505.16 or 27.8% more than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the biotechnology scenario are approximately 6% higher than the baseline scenario over 60 years (Table 10). Gross receipts of $50,243 million from crop production result in a total economic impact of $111,993 million in industry output, $51,337 million in value added and an average of 30,434 jobs.

Irrigation Technology Adoption Scenario

The irrigation technology adoption scenario assumes that irrigation efficiency improves as LEPA style center pivots (95% efficient) are replaced by sub-surface drip systems (99% efficient) until 10% of the irrigated acreage is irrigated with sub-surface drip technology. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 43.7 feet or approximately no change from the baseline scenario (Table 6). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 2,303,317 acre-feet to 754,609 acre-feet or approximately no change from the baseline scenario (Table 7). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 17.3% or 0.3% less than the baseline scenario (Table 8). The net effect of this scenario is that the target area average net income per acre decreases over time to $105.73 per acre or 1.1% less than the baseline scenario (Table 9). Over the 60 year planning horizon, each cropland acre generates a net present value of $4,216.14 or 2.1% less than the baseline scenario.

There is very little change in socioeconomic impacts of agricultural crop production in the region under the technology adoption scenario compared to the baseline scenario over 60 years (Table 10). Gross receipts of $47,410 million from crop production result in a total economic impact of $105,509 million in industry output, $48,430 million in value added and an average of 29,026 jobs.

Water Use Restriction Scenario

The water use restriction scenario assumes that water use is reduced at the rate of 1% per year. Under this assumption, on average, over the 60 year planning horizon the saturated thickness declines to 49.2 feet or approximately 12.4% more than the baseline scenario (Table 6). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 596,510 acre-feet or approximately 21.0% less than the baseline scenario (Table 7). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 14.0% or 19.6% less than the baseline scenario (Table 8). The net effect of this scenario is that the target area average net income per acre decreases over time to $99.43 per acre or 6.9% less than the baseline scenario (Table 9). Over the 60 year planning horizon, each cropland acre generates a net present value of $4,074.99 or 5.4% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the water use restriction scenario are approximately three percent lower than the baseline scenario over 60 years (Table 10). Gross receipts of $46,249 million from crop production result in a total economic impact of $103,014 million in industry output, $47,273 million in value added and an average of 28,133 jobs.

Temporary Conversion to Dryland Scenario

The temporary conversion to dryland scenario assumes that 2% of the initial irrigated acreage is converted to dryland use each year for 5 years for a total of 10%. This acreage is then allowed to re-enter irrigated production after year 15. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 44.1 feet or approximately 0.8% more than the baseline scenario (Table 6). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 764,236 acre-feet or approximately 1.3% more than the baseline scenario (Table 7). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 17.6% or 1.4% more than the baseline scenario (Table 8). The net effect of this scenario is that the target area average net income per acre decreases over time to $107.21 per acre or 0.3% more than the baseline scenario (Table 9). Over the 60 year planning horizon, each cropland acre generates a net present value of $4,197.53 or 2.5% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the temporary conversion to dryland scenario are two percent lower than the baseline scenario over 60 years (Table 10). Gross receipts of $46,764 million from crop production result in a total economic impact of $104,069 million in industry output, $47,765 million in value added and an average of 28,637 jobs.

Permanent Conversion to Dryland Scenario Plan A

This permanent conversion to dryland scenario assumes that 2% of irrigated acreage is idled each year for the first 5 years for a total of 10%. This acreage then remains idled for 15 years and is then allowed to resume the production of dryland crops. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 44.2 feet or approximately 1.1% more than the baseline scenario (Table 6). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 768,282 acre-feet or approximately 1.8% more than the baseline scenario (Table 7). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 17.7% or 1.9% more than the baseline scenario (Table 8). The net effect of this scenario is that the target area average net income per acre decreases over time to $107.36 per acre or 0.5% more than the baseline scenario (Table 9). Over the 60 year planning horizon, each cropland acre generates a net present value of $4,187.06 or 2.8% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the permanent conversion to dryland scenario are two percent lower than the baseline scenario over 60 years (Table 10). Gross receipts of $46,650 million from crop production result in a total economic impact of $103,813 million in industry output, $47,658 million in value added and an average of 28,564 jobs.

Permanent Conversion to Dryland Scenario Plan B

This permanent conversion to dryland scenario assumes that 2% of irrigated acreage is converted to dryland production each year for the first 5 years for a total of 10%. This acreage is allowed to immediately convert to the production of dryland crops. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 44.2 feet or approximately 1.1% more than the baseline scenario (Table 6). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced to 768,282 acre-feet or approximately 1.8% more than the baseline scenario (Table 7). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 17.7% or 1.9% more than the baseline scenario (Table 8). The net effect of this scenario is that the target area average net income per acre decreases over time to $107.36 per acre or 0.5% more than the baseline scenario (Table 9). Over the 60 year planning horizon, each cropland acre generates a net present value of $4,244.23 or 1.5% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the permanent conversion to dryland scenario are one percent lower than the baseline scenario over 60 years (Table 10). Gross receipts of $47,013 million from crop production result in a total economic impact of $104,619 million in industry output, $48,052 million in value added and an average of 28,773 jobs.

Table 6. Central Sub-Region Target Area Weighted Average Saturated Thickness (feet)*

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60
Baseline	111.3	95.5	78.1	65.0	55.7	49.0	43.7
Biotechnology	111.3	96.1	81.7	70.1	60.8	54.0	49.2
Change	*0.0%*	*0.7%*	*4.7%*	*7.9%*	*9.2%*	*10.2%*	*12.4%*
Irrigation Tech.	111.3	95.1	77.3	64.6	55.7	49.0	43.7
Change	*0.0%*	*-0.4%*	*-1.0%*	*-0.5%*	*-0.0%*	*-0.0%*	*-0.0%*
Water Use Rest.	111.3	95.1	79.5	68.8	60.3	53.9	49.2
Change	*0.0%*	*-0.4%*	*1.9%*	*6.0%*	*8.3%*	*10.0%*	*12.4%*
Temporary Conv.	111.3	95.5	78.3	65.4	56.3	49.5	44.1
Change	*0.0%*	*0.1%*	*0.3%*	*0.7%*	*1.1%*	*0.9%*	*0.8%*
Permanent Conv. (A)	111.3	95.5	78.3	65.6	56.5	49.7	44.2
Change	*0.0%*	*0.0%*	*0.3%*	*1.1%*	*1.4%*	*1.2%*	*1.1%*
Permanent Conv. (B)	111.3	95.5	78.3	65.6	56.5	49.7	44.2
Change	*0.0%*	*0.0%*	*0.3%*	*1.1%*	*1.4%*	*1.2%*	*1.1%*

*Averages are weighted by the area overlying the aquifer in each county.

Table 7. Central Sub-Region Target Area Total Water Use (1,000 acre-feet)

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60	Total
Baseline	2,303	2,489	2,182	1,659	1,121	899	755	98,446
Biotechnology	2,303	2,151	1,744	1,201	1,104	840	588	87,882
Change	*0.0%*	*-13.6%*	*-20.1%*	*-27.6%*	*-1.5%*	*-6.6%*	*-22.1%*	*-10.7%*
Irrigation Tech.	2,303	2,490	2,098	1,538	1,120	899	755	96,935
Change	*0.0%*	*0.1%*	*-3.8%*	*-7.3%*	*0.0%*	*0.0%*	*0.0%*	*-1.5%*
Water Use Rest.	2,303	2,318	1,671	1,391	1,046	815	597	87,881
Change	*0.0%*	*-6.9%*	*-23.4%*	*-16.2%*	*-6.6%*	*-9.4%*	*-21.0%*	*-10.7%*
Temporary Conv.	2,303	2,405	2,105	1,564	1,141	913	764	96,507
Change	*0.0%*	*-3.4%*	*-3.5%*	*-5.8%*	*1.8%*	*1.5%*	*1.3%*	*-2.0%*
Permanent Conv. (A)	2,303	2,412	2,040	1,550	1,150	919	768	96,340
Change	*0.0%*	*-3.1%*	*-6.5%*	*-6.6%*	*2.6%*	*2.2%*	*1.8%*	*-2.1%*
Permanent Conv. (B)	2,303	2,412	2,040	1,550	1,150	919	768	96,340
Change	*0.0%*	*-3.1%*	*-6.5%*	*-6.6%*	*2.6%*	*2.2%*	*1.8%*	*-2.1%*

Table 8. Central Sub-Region Target Area Irrigated Acres as a Percentage of Total Acres*

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60
Baseline	63.0%	56.8%	49.7%	38.1%	25.8%	20.7%	17.4%
Biotechnology	63.0%	50.7%	42.5%	36.5%	27.3%	20.9%	14.9%
Change	*0.0%*	*-10.6%*	*-14.5%*	*-4.2%*	*5.9%*	*1.1%*	*-14.4%*
Irrigation Tech.	63.0%	56.6%	47.6%	35.0%	25.7%	20.7%	17.3%
Change	*0.0%*	*-0.2%*	*-4.1%*	*-8.1%*	*-0.4%*	*-0.4%*	*-0.3%*
Water Use Rest.	63.0%	53.5%	39.6%	33.0%	24.6%	19.1%	14.0%
Change	*0.0%*	*-5.7%*	*-20.2%*	*-13.3%*	*-4.7%*	*-7.8%*	*-19.6%*
Temporary Conv.	63.0%	54.1%	47.3%	35.9%	26.3%	21.1%	17.6%
Change	*0.0%*	*-4.6%*	*-4.8%*	*-5.6%*	*2.0%*	*1.6%*	*1.4%*
Permanent Conv. (A)	63.0%	54.1%	45.2%	35.2%	26.5%	21.2%	17.7%
Change	*0.0%*	*-4.6%*	*-9.0%*	*-7.4%*	*2.8%*	*2.3%*	*1.9%*
Permanent Conv. (B)	63.0%	54.1%	45.2%	35.2%	26.5%	21.2%	17.7%
Change	*0.0%*	*-4.6%*	*-9.0%*	*-7.4%*	*2.8%*	*2.3%*	*1.9%*

*The percentage is based on the total irrigated acres in the target area (at time = t) divided by total irrigated and nonirrigated cropland acres in the target area.

Table 9. Central Sub-Region Target Area Average Net Income per Acre*

Policy Scenario	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60	Net Present Value
Baseline	$180.48	$165.10	$142.80	$119.52	$111.78	$106.85	$4,307.36
Biotechnology	$191.13	$197.58	$207.30	$208.67	$217.25	$225.77	$5,505.16
Change	*5.9%*	*19.7%*	*45.2%*	*74.6%*	*94.4%*	*111.3%*	*27.8%*
Irrigation Tech.	$177.00	$158.91	$136.44	$117.73	$110.39	$105.73	$4,216.14
Change	*-1.9%*	*-3.8%*	*-4.5%*	*-1.5%*	*-1.2%*	*-1.1%*	*-2.1%*
Water Use Rest.	$172.13	$145.52	$132.87	$116.79	$107.69	$99.43	$4,074.99
Change	*-4.6%*	*-11.9%*	*-7.0%*	*-2.3%*	*-3.7%*	*-6.9%*	*-5.4%*
Temporary Conv.	$171.54	$161.43	$140.13	$120.32	$112.30	$107.21	$4,197.53
Change	*-5.0%*	*-2.2%*	*-1.9%*	*0.7%*	*0.5%*	*0.3%*	*-2.5%*
Permanent Conv. (A)	$171.62	$158.47	$139.38	$120.69	$112.52	$107.36	$4,187.06
Change	*-4.9%*	*-4.0%*	*-2.4%*	*1.0%*	*0.7%*	*0.5%*	*-2.8%*
Permanent Conv. (B)	$176.76	$159.50	$139.38	$120.69	$112.52	$107.36	$4,244.23
Change	*-2.1%*	*-3.4%*	*-2.4%*	*1.0%*	*0.7%*	*0.5%*	*-1.5%*

*The average is based on the total irrigated and nonirrigated net revenue (at time = t) divided by total irrigated and nonirrigated cropland acres.

Table 10. Central Sub-Region 60 Year Regional Economic Impacts

	Direct	Indirect	Induced	Total	Change from Baseline	% Change from Baseline
Baseline						
Output*	47,622	37,319	21,029	105,970		
Value Added*	15,478	20,274	12,882	48,634		
Employment	17,922	7,561	3,701	29,183		
Biotech						
Output*	50,243	39,437	22,313	111,993	6,023	6%
Value Added*	16,097	21,572	13,668	51,337	2,704	6%
Employment	18,327	8,180	3,927	30,434	1,251	4%
Technology Adoption						
Output*	47,410	37,144	20,955	105,509	-462	0%
Value Added*	15,398	20,195	12,837	48,430	-204	0%
Employment	17,792	7,547	3,688	29,026	-157	-1%
Water Use Restriction						
Output*	46,249	36,243	20,523	103,014	-2,956	-3%
Value Added*	14,909	19,793	12,572	47,273	-1,360	-3%
Employment	17,044	7,476	3,612	28,133	-1,050	-4%
Temporary Conversion						
Output*	46,764	36,641	20,664	104,069	-1,902	-2%
Value Added*	15,188	19,919	12,658	47,765	-869	-2%
Employment	17,560	7,440	3,636	28,637	-546	-2%
Permanent Conversion (A)						
Output*	46,650	36,541	20,623	103,813	-2,157	-2%
Value Added*	15,156	19,869	12,633	47,658	-976	-2%
Employment	17,508	7,427	3,629	28,564	-619	-2%
Permanent Conversion (B)						
Output*	47,013	36,799	20,806	104,619	-1,352	-1%
Value Added*	15,282	20,025	12,745	48,052	-582	-1%
Employment	17,611	7,500	3,662	28,773	-411	-1%

*Millions of dollars

Southern Sub-Region Policy Comparison

Regional Economy

The Southern Region has a population of 652,472, average income per household of $60,523 and covers 27,959 square miles. The economy of the Southern Region is comprised of total industry output of $32 billion, value added of $18.5 billion, and employment of 358,146.

Target Area

The target area used in this summary is comprised of Crosby, Floyd, Gaines, Hale, Lamb, Lubbock, Terry, and Yoakum Counties located in the Texas High Plains. These counties are each located in one of four underground water conservation districts (UWCDs) in the region including High Plains UWCD #1, Llano Estacado UWCD, Sandy Land UWCD, or South Plains UWCD. There are a total of 2,174,422 cropland acres in the target area of which 1,421,650 or 65.4% are irrigated. The saturated thickness of the aquifer currently ranges from an average of 54 feet in Yoakum County to an average of 84 feet in Terry County with average depth of water ranging from approximately 94 feet in Yoakum County to approximately 231 feet in Crosby County. On average 76.5% of the irrigated acreage is devoted to cotton production, 4.8% to irrigated corn production, 6.0% to irrigated grain sorghum production, 4.9% to irrigated wheat production, and 7.3% to irrigated peanut production. Approximately 96.2% of these acres are currently irrigated with center pivot irrigation technology.

Baseline Scenario

The baseline scenario assumes that no water conserving policy is implemented and producers operate in an unregulated profit maximizing manner. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 34.2 feet (Table 11). As saturated thickness declines, well capacity diminishes and pumping costs increase which results in total annual water use being reduced from 1,905,124 acre-feet to 948,054 acre-feet (Table 12). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 40.9% (Table 13). The net effect of this scenario is that the target area average net income per acre is reduced by approximately 16% to $171.08 per acre (Table 14). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,477.81.

The socioeconomic impacts of agricultural crop production in the region are presented in 2007 dollars (Table 15). Gross receipts of $59,447 million from crop production result in a total economic impact of $132,673 million in industry output, $62,584 million in value added and an average of 40,413 jobs over 60 years.

Biotechnology Adoption Scenario

The biotechnology adoption scenario assumes that water use is reduced at the rate of 1% per year, and crop yields increase at the rate of 0.5% per year. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 39.9 feet or approximately 16.3% more than the baseline scenario (Table 11). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 1,905,124 acre-feet to 658,923 acre-feet or approximately 30.5% less than the baseline scenario (Table 12). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 34.1% or 16.6% less than the baseline scenario (Table 13). The net effect of this scenario is that the target area average net income per acre increases over time to $278.42 per acre or 62.8% more than the baseline scenario (Table 14). Over the 60 year planning horizon, each cropland acre generates a net present value of $6,766.44 or 23.5% more than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the biotechnology scenario are 6% higher than the baseline scenario over 60 years (Table 15). Gross receipts of $62,897 million from crop production result in a total economic impact of $140,406 million in industry output, $66,197 million in value added and an average of 42,822 jobs.

Irrigation Technology Adoption Scenario

The irrigation technology adoption scenario assumes that irrigation efficiency improves as LEPA style center pivots (95% efficient) are replaced by sub-surface drip systems (99% efficient) until 25% of the irrigated acreage is irrigated with sub-surface drip technology. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 34.1 feet or approximately 0.4% less than the baseline scenario (Table 11). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level. However, since technology improvements reduce the marginal cost of water, total annual water use decreases to 945,860 acre-feet or approximately 0.2% less than the baseline scenario (Table 12). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 39.3% or 3.9% less than the baseline scenario (Table 13). The net effect of this scenario is that the target area average net income per acre decreases over time to $164.32 per acre or 4.0% less than the baseline scenario (Table 14). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,284.29 or 3.5% less than the baseline scenario.

There is very little change in socioeconomic impacts of agricultural crop production in the region under the technology adoption scenario compared to the baseline scenario over 60 years (Table 15). Gross receipts of $59,204 million from crop production result in a total economic impact of $131,941 million in industry output, $62,367 million in value added and an average of 40,567 jobs.

Water Use Restriction Scenario

The water use restriction scenario assumes that water use is reduced at the rate of 1% per year. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 39.9 feet or approximately 16.6% more than the baseline scenario (Table 11). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 1,905,124 acre-feet to 648,031 acre-feet or approximately 31.7% less than the baseline scenario (Table 12). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 31.7% or 22.5% less than the baseline scenario (Table 13). The net effect of this scenario is that the target area average net income per acre decreases over time to $157.54 per acre or 7.9% less than the baseline scenario (Table 14). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,373.19 or 1.9% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the water use restriction scenario are one percent lower than the baseline scenario over 60 years (Table 15). Gross receipts of $58,670 million from crop production result in a total economic impact of $130,916 million in industry output, $61,834 million in value added and an average of 40,020 jobs.

Temporary Conversion to Dryland Scenario

The temporary conversion to dryland scenario assumes that 2% of the initial irrigated acreage is converted to dryland use each year for 5 years for a total of 10%. Then this acreage is allowed to re-enter irrigated production after year 15. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 34.7 feet or approximately 1.3% more than the baseline scenario (Table 11). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 1,905,124 acre-feet to 961,803 acre-feet or approximately 1.5% more than the baseline scenario (Table 12). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 40.9% or 0.1% more than the baseline scenario (Table 13). The net effect of this scenario is that the target area average net income per acre decreases over time to $171.66 per acre or 0.3% more than the baseline scenario (Table 14). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,309.45 or 3.1% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the temporary conversion to dryland scenario are two percent lower than the baseline scenario over 60 years (Table 15). Gross receipts of $58,397 million from crop production result in a total economic impact of $130,302 million in industry output, $61,534 million in value added and an average of 39,748 jobs.

Permanent Conversion to Dryland Scenario Plan A

This permanent conversion to dryland scenario assumes that 2% of irrigated acreage is idled each year for the first 5 years for a total of 10%. This acreage then remains idled for 15 years and is then allowed to resume the production of dryland crops. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 35.5 feet or approximately 3.6% more than the baseline scenario (Table 11). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 1,905,124 acre-feet to 957,086 acre-feet or approximately 1.1% more than the baseline scenario (Table 12). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 40.6% or 0.6% less than the baseline scenario (Table 13). The net effect of this scenario is that the target area average net income per acre decreases over time to $171.29 per acre or 0.1% more than the baseline scenario (Table 14). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,285.13 or 3.5% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the permanent conversion to dryland scenario are two percent lower than the baseline scenario over 60 years (Table 15). Gross receipts of $58,158 million from crop production result in a total economic impact of $129,780 million in industry output, $61,324 million in value added and an average of 39,607 jobs.

Permanent Conversion to Dryland Scenario Plan B

This permanent conversion to dryland scenario assumes that 2% of irrigated acreage is converted to dryland production each year for the first 5 years for a total of 10%. This acreage is then allowed to immediately convert to the production of dryland crops. Under these assumptions, on average, over the 60 year planning horizon the saturated thickness declines to 35.5 feet or approximately 3.6% more than the baseline scenario (Table 11). As saturated thickness declines, well capacity diminishes, pumping costs increase, and it takes less water to reach the profit maximizing level which results in total annual water use being reduced from 1,905,124 acre-feet to 957,086 acre-feet or approximately 1.0% more than the baseline scenario (Table 12). When per acre water use is restricted, producers of irrigated crops respond by reducing total irrigated acres, shifting to a less water intensive crop, or converting to dryland production. As this occurs, the percent of irrigated acreage within the target area declines to 40.6% or 0.6% less than the baseline scenario (Table 13). The net effect of this scenario is that the target area average net income per acre decreases over time to $171.29 per acre or 0.1% more than the baseline scenario (Table 14). Over the 60 year planning horizon, each cropland acre generates a net present value of $5,378.25 or 1.8% less than the baseline scenario.

The socioeconomic impacts of agricultural crop production in the region under the permanent conversion to dryland scenario are one percent lower than the baseline scenario over 60 years (Table 15). Gross receipts of $58,709 million from crop production result in a total economic impact of $131,043 million in industry output, $61,946 million in value added and an average of 39,982 jobs.

Table 11. Southern Sub-Region Target Area Weighted Average Saturated Thickness (feet)*

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60
Baseline	70.4	61.7	53.3	46.2	40.9	37.0	34.2
Biotechnology	70.4	61.9	54.0	47.9	43.5	40.8	39.9
Change	*0.0%*	*0.2%*	*1.2%*	*3.5%*	*6.0%*	*10.3%*	*16.3%*
Irrigation Tech.	70.4	61.8	53.0	45.6	40.6	36.8	34.1
Change	*0.0%*	*0.1%*	*-0.7%*	*-1.3%*	*-0.9%*	*-0.5%*	*-0.4%*
Water Use Rest.	70.4	61.8	53.8	47.7	43.2	40.8	39.9
Change	*0.0%*	*0.2%*	*0.8%*	*3.1%*	*5.8%*	*10.3%*	*16.6%*
Temporary Conv.	70.4	62.3	54.6	47.3	41.8	37.6	34.7
Change	*0.0%*	*0.9%*	*2.4%*	*2.1%*	*2.1%*	*1.6%*	*1.3%*
Permanent Conv. (A)	70.4	62.2	54.5	47.6	42.4	38.4	35.5
Change	*0.0%*	*0.9%*	*2.3%*	*3.0%*	*3.6%*	*3.8%*	*3.6%*
Permanent Conv. (B)	70.4	62.2	54.5	47.6	42.4	38.4	35.5
Change	*0.0%*	*0.9%*	*2.3%*	*3.0%*	*3.6%*	*3.8%*	*3.6%*

*Averages are weighted by the area overlying the aquifer in each county.

Table 12. Southern Sub-Region Target Area Total Water Use (1,000 acre-feet)

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60	Total
Baseline	1,905	1,676	1,557	1,370	1,213	1,045	948	82,213
Biotechnology	1,905	1,654	1,456	1,255	1,055	857	659	74,820
Change	*0.0%*	*-1.3%*	*-6.5%*	*-8.4%*	*-12.4%*	*-18.0%*	*-30.5%*	*-9.0%*
Irrigation Tech.	1,905	1,672	1,610	1,357	1,175	1,040	946	82,326
Change	*0.0%*	*-0.3%*	*3.4%*	*-0.9%*	*-3.3%*	*-0.4%*	*-0.2%*	*0.1%*
Water Use Rest.	1,905	1,654	1,456	1,244	1,044	846	648	74,686
Change	*0.0%*	*-1.4%*	*-6.5%*	*-9.2%*	*-13.2%*	*-19.0%*	*-31.7%*	*-9.2%*
Temporary Conv.	1,905	1,569	1,573	1,391	1,228	1,068	962	81,650
Change	*0.0%*	*-6.4%*	*1.0%*	*1.6%*	*1.1%*	*2.3%*	*1.5%*	*-0.7%*
Permanent Conv. (A)	1,905	1,577	1,509	1,352	1,188	1,064	957	80,513
Change	*0.0%*	*-5.9%*	*-3.1%*	*-1.3%*	*-2.1%*	*1.8%*	*1.1%*	*-2.1%*
Permanent Conv. (B)	1,905	1,577	1,509	1,352	1,188	1,064	957	80,513
Change	*0.0%*	*-5.9%*	*-3.1%*	*-1.3%*	*-2.1%*	*1.8%*	*1.0%*	*-2.1%*

Table 13. Southern Sub-Region Target Area Irrigated Acres as a Percentage of Total Acres*

Policy Scenario	Year 0	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60
Baseline	65.4%	60.6%	58.6%	51.9%	47.8%	44.9%	40.9%
Biotechnology	65.4%	61.3%	57.7%	53.0%	48.0%	42.1%	34.1%
Change	*0.0%*	*1.1%*	*-1.6%*	*2.0%*	*1.0%*	*-6.1%*	*-16.6%*
Irrigation Tech.	65.4%	60.3%	60.3%	52.5%	46.0%	43.0%	39.3%
Change	*0.0%*	*-0.6%*	*3.3%*	*1.2%*	*-3.6%*	*-4.2%*	*-3.9%*
Water Use Rest.	65.4%	60.5%	56.3%	50.9%	45.7%	39.0%	31.7%
Change	*0.0%*	*-0.2%*	*-3.8%*	*-2.0%*	*-3.8%*	*-13.1%*	*-22.5%*
Temporary Conv.	65.4%	55.6%	57.7%	52.7%	47.9%	44.9%	40.9%
Change	*0.0%*	*-8.3%*	*-1.6%*	*1.4%*	*0.2%*	*0.0%*	*0.1%*
Permanent Conv. (A)	65.4%	56.0%	54.4%	51.0%	46.1%	44.2%	40.6%
Change	*0.0%*	*-8.3%*	*-7.1%*	*-1.8%*	*-3.6%*	*-1.6%*	*-0.6%*
Permanent Conv. (B)	65.4%	56.0%	54.4%	51.0%	46.1%	44.2%	40.6%
Change	*0.0%*	*-8.3%*	*-7.1%*	*-1.8%*	*-3.6%*	*-1.6%*	*-0.6%*

*The percentage is based on the total irrigated acres in the target area (at time = t) divided by total irrigated and nonirrigated cropland acres in the target area.

Table 14. Southern Sub-Region Target Area Average Net Income per Acre*

Policy Scenario	Year 10	Year 20	Year 30	Year 40	Year 50	Year 60	Net Present Value
Baseline	$203.67	$197.59	$188.42	$182.34	$175.65	$171.08	$5,477.81
Biotechnology	$224.12	$240.66	$254.35	$265.29	$273.32	$278.42	$6,766.44
Change	*10.0%*	*21.8%*	*35.0%*	*44.5%*	*55.6%*	*62.8%*	*23.5%*
Irrigation Tech.	$198.18	$188.98	$179.20	$173.53	$168.57	$164.32	$5,284.29
Change	*-2.7%*	*-4.4%*	*-4.9%*	*-4.9%*	*-4.0%*	*-4.0%*	*-3.5%*
Water Use Rest.	$200.56	$194.31	$186.04	$177.06	$167.52	$157.54	$5,373.19
Change	*-1.5%*	*-1.7%*	*-1.3%*	*-2.7%*	*-4.6%*	*-7.9%*	*-1.9%*
Temporary Conv.	$186.99	$196.21	$189.66	$183.16	$176.59	$171.66	$5,309.45
Change	*-8.2%*	*-0.7%*	*0.7%*	*0.4%*	*0.5%*	*0.3%*	*-3.1%*
Permanent Conv. (A)	$187.14	$193.07	$187.84	$181.41	$176.24	$171.29	$5,285.13
Change	*-8.1%*	*-2.3%*	*-0.3%*	*-0.5%*	*0.3%*	*0.1%*	*-3.5%*
Permanent Conv. (B)	$195.50	$194.76	$187.84	$181.41	$176.24	$171.29	$5,378.25
Change	*-4.0%*	*-1.4%*	*-0.3%*	*-0.5%*	*0.3%*	*0.1%*	*-1.8%*

*The average is based on the total irrigated and nonirrigated net revenue (at time = t) divided by total irrigated and nonirrigated cropland acres.

Table 15. Southern Sub-Region 60 Year Regional Economic Impacts

	Direct	Indirect	Induced	Total	Change from Baseline	% Change from Baseline
Baseline						
Output*	59,447	43,892	29,334	132,673		
Value Added*	19,324	25,346	17,914	62,584		
Employment	23,229	11,818	5,366	40,413		
Biotech						
Output*	62,897	46,479	31,030	140,406	7,733	6%
Value Added*	20,410	26,837	18,950	66,197	3,613	6%
Employment	24,623	12,522	5,676	42,822	2,409	6%
Technology Adoption						
Output*	59,204	43,519	29,219	131,941	-732	-1%
Value Added*	19,403	25,121	17,844	62,367	-217	0%
Employment	23,551	11,671	5,345	40,567	154	0%
Water Use Restriction						
Output*	58,670	43,253	28,992	130,916	-1,757	-1%
Value Added*	19,152	24,977	17,705	61,834	-750	-1%
Employment	23,064	11,653	5,303	40,020	-393	-1%
Temporary Conversion						
Output*	58,397	43,057	28,847	130,302	-2,372	-2%
Value Added*	19,050	24,867	17,617	61,534	-1,050	-2%
Employment	22,877	11,595	5,277	39,748	-664	-2%
Permanent Conversion (A)						
Output*	58,158	42,864	28,757	129,780	-2,894	-2%
Value Added*	19,004	24,759	17,562	61,324	-1,260	-2%
Employment	22,791	11,555	5,260	39,607	-806	-2%
Permanent Conversion (B)						
Output*	58,709	43,274	29,060	131,043	-1,630	-1%
Value Added*	19,200	24,999	17,747	61,946	-638	-1%
Employment	22,982	11,684	5,316	39,982	-431	-1%

*Millions of dollars

Summary

The Ogallala Aquifer is a critical lifeline for agriculture for much of the Great Plains. However, the groundwater levels in the Ogallala have been steadily declining which could have serious implications for the Region's economy as a whole in the future. The Ogallala Initiative funded through the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) has the objective to improve the sustainability of agricultural industries and rural communities through innovative scientific research.

The objective of this research project was to assess the potential impacts on stakeholders in the Region from implementing alternative water conservation strategies. Hopefully, the results of this study will be useful in the consideration of water conservation policies in the future to insure that any strategies implemented minimize detrimental effects on producer income and the economy while conserving water for future purposes. A survey of stakeholders was utilized to identify the five strategies to be evaluated. The five water conservation policies identified to be analyzed included: permanent conversion to dryland production, technology adoption, biotechnology, water use restriction, and temporary conversion to dryland production.

An Industry Review Committee (IRC) was formed with the purpose of providing input into how the policies should be developed and what level of implementation should be used in the policy analysis process. Implementation levels that were initially obtained from the IRC are outlined in this report and were the basis of the economic modeling process.

The study area overlies the Ogallala Aquifer from the northern border of Kansas to the southern reaches of the aquifer just north of the Midland-Odessa area of Texas. The study area was divided into three sub-regions for analyses because of differences in saturated thickness, cropping patterns, and climate. The northern sub-region consists of the area overlying the aquifer in Kansas and portions of Colorado. The central sub-region consists of the Oklahoma and Texas panhandle areas south to the line of counties including Parmer, Castro, Swisher, and Briscoe counties. The southern sub-region extends from that line of counties for Texas and New Mexico south to Andrews and Martin counties of Texas.

Two types of economic models were used to conduct the policy analyses. Economic optimization models consist of individual models for each of the 98 counties in the study area that estimate changes in the aquifer, irrigated acreage and net farm income over a 60 year planning period. Socioeconomic models were developed to evaluate impacts on the regional economy. The socioeconomic models aggregate the results from the county optimization models to explain changes in the regional economy and regional employment.

The procedure utilized to evaluate alternative conservation strategies was the same in all sub-regions. A baseline was estimated for every county within the sub-regions assuming initially, current water use and cropping patterns. Alternative conservation strategies were implemented in only those counties identified in the baseline scenario that had a drawdown of greater that 40% of the initial saturated thickness over the 60 year planning period. Each alternative conservation strategy was then evaluated with respect to the change in saturated thickness, producer income and impacts on the regional economy relative to the baseline.

Results including the levels of saturated thickness, producer income and the regional impacts to the economy are important in comparing water conservation policy alternatives. The change in saturated thickness provides information on whether water savings goals are being met, changes in producer income provide an idea for the amount of compensation that may be required for producer participation in the water conservation strategy and the socioeconomic analysis provides insight on the impacts to the regional economy.

The baseline scenario assumes no water conserving policy is implemented and producers operate in an unregulated profit maximizing manner. The baseline simulation indicated decreases in saturated thickness over the 60 year period to 84.4 feet in the Northern Region, 43.7 feet in the Central Region, and 34.2 feet in the Southern Region. Average producer net income per acre decreases to $126.12, $106.85, and $171.08 for the Northern, Central, and Southern regions, respectively over 60 years. Agricultural crop production has a total economic impact on industry output of $198,824, $105,970, and $132,673 million in the Northern, Central, and Southern regions, respectively. The regional impact on value added is $103,857, $48,634, and $62,584 million over 60 years, while average employment is 39,384, 29,183, and 40,413 jobs for the Northern, Central, and Southern regions, respectively.

The biotechnology adoption scenario assumes that water use is reduced at the rate of 1% per year, while crop yields increase at the rate of 0.5% per year. Under these assumptions, on average, the saturated thickness improves by 8.2%, 12.4%, and 16.3% over the baseline scenario in year 60 in the Northern, Central, and Southern regions, respectively. Average producer net income per acre increases greatly over the baseline scenario and is 86.6% higher in the Northern Region, 111.3% higher in the Central Region, and 62.8% higher in the Southern Region at year 60. The impact on total industry output from agricultural crop production is 3%, 6%, and 6% greater than the baseline scenario over the 60 year period for the Northern, Central, and Southern regions, respectively. The value added and employment impacts experience approximately the same percentage increases over the baseline scenario.

The irrigation technology adoption scenario assumes that irrigation efficiency improves as LEPA style center pivots (95% efficient) are replaced by sub-surface drip systems (99% efficient) until 5%, 10%, and 25% of the irrigated acreage is irrigated with sub-surface drip technology in the Northern, Central, and Southern regions, respectively. In the Central Region furrow irrigation was included in the move to sub-surface drip. The implementation level of an increase in acreage under the advanced irrigation technology is 10% every year. Under these assumptions, on average, the saturated thickness decreases by 0.4% in the Northern Region, has approximately no change in the Central Region, and decreases by 0.4% in the Southern Region over the baseline scenario by year 60. Average producer net income per acre is 0.9% higher in the Northern Region, 1.1% lower in the Central Region, and 4% lower in the Southern Region compared to the baseline scenario at year 60. The impact on total industry output from agricultural crop production is approximately the same as the baseline scenario in the Northern and Central regions and 1% less in the Southern Region over the 60 year period. The value added and employment impacts experience approximately the same percentage changes from the baseline scenario.

The water use restriction scenario assumes that water use is reduced at the rate of 1% per year. Under this assumption, on average, the saturated thickness improves by 9.4%, 12.4%, and 16.6% over the baseline scenario by year 60 in the Northern, Central, and Southern regions, respectively. Average producer net income per acre is 0.3% higher in the Northern Region, 6.9% lower in the Central Region, and 7.9% lower in the Southern Region compared to the baseline scenario at year 60. The impact on total industry output from agricultural crop production is approximately the same as the baseline scenario in the Northern Region, 3% less in the Central Region and 1% less in the Southern Region over the 60 year period. The value added and employment impacts experience approximately the same percentage changes from the baseline scenario.

The temporary conversion to dryland scenario assumes that 2% of the initial irrigated acreage is converted to dryland use each year for five years for a total of 10%. This acreage is then allowed to re-enter irrigated production after year 15. Under these assumptions, on average, the saturated thickness increases by 0.9%, 0.8%, and 1.3% in the Northern, Central, and Southern regions, respectively. Average producer net income per acre is 1% higher in the Northern Region, 0.3% higher in the Central Region, and 0.3% higher in the Southern Region compared to the baseline scenario at year 60. The impact on total industry output from agricultural crop production is approximately the same as the baseline scenario in the Northern Region and 2% less in the Central and Southern regions over the 60 year period. The value added and employment impacts experience approximately the same percentage changes from the baseline scenario.

The permanent conversion to dryland (Plan A) scenario assumes that 2% of irrigated acreage is idled each year for the first 5 years for a total of 10%. This acreage remains idled for 15 years and is then allowed to resume the production of dryland crops.
Under these assumptions, on average, the saturated thickness increases by 4.2%, 1.1%, and 3.6% in the Northern, Central, and Southern regions, respectively. Average producer net income per acre is 2.6% higher in the Northern Region, 0.5% higher in the Central Region, and 0.1% higher in the Southern Region compared to the baseline scenario at year 60. The impact on total industry output from agricultural crop production is 1% less than the baseline scenario in the Northern Region and 2% less in the Central and Southern regions over the 60 year period. The value added and employment impacts experience approximately the same percentage decreases from the baseline scenario.

The permanent conversion to dryland (Plan B) scenario assumes that 2% of irrigated acreage is converted to dryland production each year for the first 5 years for a total of 10%. This acreage is allowed to immediately convert to the production of dryland crops. Under these assumptions, on average, the saturated thickness increases by 4.2%, 1.1%, and 3.6% in the Northern, Central, and Southern regions, respectively. Average producer net income per acre is 2.6% higher in the Northern Region, 0.5% higher in the Central Region, and 0.1% higher in the Southern Region compared to the baseline scenario at year 60. The impact on total industry output from agricultural crop production is 1% less than the baseline scenario in all regions over the 60 year period. The value added and employment impacts experience approximately the same percentage decreases from the baseline scenario.

Conclusions

The biotechnology and water use restriction policies result in the greatest increase in saturated thickness over the baseline. This is due both of these policies assuming a one percent reduction in water use per year. The temporary conversion to dryland alternative initially saves around the same amount of saturated thickness as the permanent conversion to dryland. However, the temporary begins to use more water after approximately year 25 due to acreage gradually being allowed back into irrigated production after year 15. The irrigation technology policy does not result in much water savings and, in fact, may result in more water use. To make the irrigation technology policy work, a water use restriction should be implemented as well to insure water use is constrained. From a socioeconomic standpoint, any water conservation policy that is implemented will make the regional economy worse off with the exception of biotechnology and irrigation technology (in certain regions).

The selection of a water conservation policy by policymakers greatly depends on their goals for particular counties and/or regions. If the goal of the policymakers is to implement a policy that will result in the greatest amount of water savings, the water use restriction policy, biotechnology policy (if the technological advances are available), or permanent conversion to dryland policies would be the choice. If the goal of the policymakers is to conserve water with the least amount of impacts to the regional economy, the biotechnology adoption policy would be the choice. The biotechnology policy would satisfy both of these goals. However, there are few (if any) drought resistant seed varieties marketed to producers and the annual increase in yields (0.5%) used in this study may need to be refined.

The adoption of a water conservation policy, similar to the technology adoption process, may reduce groundwater consumption in the short-run but will not reduce groundwater consumption over an infinite horizon. The water saved today will eventually be used and the water resource exhausted. The reported water savings are potential water savings. The study area was chosen because of current concerns over aquifer decline rates and diminishing well capacities. Average well capacity and average water use were the basis for this analysis. Undoubtedly, there are producers in the area that are currently incapable of fully irrigated production. If the aquifer is stabilized their water use could increase. From an equitability and administrative standpoint, water appropriation regulations may need to be modified to ensure that water use is constrained.

While individual policy alternatives have been compared to a baseline scenario, this research does not attempt to place a monetary value on the saved water or place monetary value on other benefits of water conservation. For reporting convenience, the modeling results for several counties have been aggregated together. This process may mask important differences between counties and underestimate the need for water conservation. While some counties may not benefit financially from a water conservation strategy other counties might. Johnson et al (2005) suggests that the evaluation and implementation of water conservation policy be based on county or sub-county level modeling as compared to multiple county aggregations.

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