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Seymour Aquifer
Water Quality Improvement Project
Final Report

J. Sij, C. Morgan, M. Belew, D. Jones, and K. Wagner
Texas A&M AgriLife
Texas AgriLife Research
Texas AgriLife Extension Service

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Texas Water Resources Institute
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Partners
Texas AgriLife Research
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LIST OF ABBREVIATIONS

BMP	Best Management Practice
CWA	Clean Water Act
EPA	U.S. Environmental Protection Agency
FSA	Farm Service Agency
GPS	Global Positioning System
lb/ac	pounds per acre
mg/L	milligrams per liter
ppm	parts per million
NRCS	Natural Resources Conservation Service
SDI	Subsurface Drip Irrigation
SWCD	Soil and Water Conservation District
RTK	Real time kinematic
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
2,4-D	2,4-dichlorophenoxyacetic acid

EXECUTIVE SUMMARY

The Seymour Aquifer is a shallow aquifer underlying over 300,000 acres in 20 counties in northwest central Texas. High nitrate concentrations are widespread in the Seymour Aquifer. Median nitrate levels in Knox, Haskell, Baylor, Hall, Wichita, Wilbarger, and Fisher counties exceeded the federal safe drinking water standard (10 mg/L NO_3-N). This high concentration is a concern because although 90% of the water pumped from the aquifer is used for irrigation, it is also used as a municipal water source for the communities of Vernon, Burkburnett, and Electra and rural families in the region.

To address this threat, the Texas State Soil and Water Conservation Board (TSSWCB), with 319(h) grant funding provided by the Environmental Protection Agency (EPA), worked cooperatively with the Haskell, Wichita-Brazos, and California Creek Soil and Water Conservation Districts (SWCDs); U.S. Department of Agriculture - Natural Resources Conservation Service (NRCS); Texas AgriLife Extension Service (AgriLife Extension); Texas A&M AgriLife – Texas Water Resources Institute (TWRI); Rolling Plains Groundwater Conservation District; and Texas AgriLife Research (AgriLife Research) to encourage the installation of subsurface drip irrigation (SDI) systems and other best management practices (BMPs) to improve water quality (i.e. reduce nitrate) and increase water quantity in the Seymour Aquifer. The project provided technical and financial assistance to producers to implement SDI and other BMPs, education programs and demonstrations of methods for reducing nitrate infiltration and improving irrigation efficiency and an evaluation of the effectiveness of SDI implementation.

Considerable interest has been generated in SDI and other more efficient irrigation methods through the efforts of project partners. Through technical and financial assistance provided by the project through the TSSWCB and Haskell, Wichita-Brazos and California Creek SWCDs, 17 producers installed SDI systems on over 1,000 acres. In addition, irrigation management was implemented through the Water Quality Management Plans (WQMPs) developed on over 1,800 acres and nutrient management was implemented on over 2,500 acres. NRCS also began funding irrigation improvements in Haskell, Knox, Baylor, Wilbarger, Hardeman and Foard counties through the Seymour Aquifer Special Emphasis Area. Since this Special Emphasis Area was established in 2004, over $16 million dollars have been provided.

In addition to implementing BMPs, a very important component of this project was conducting educational programs and demonstrations. Through seven programs conducted between 2005 and 2008, AgriLife Research and AgriLife Extension provided educational programs and demonstrations on nutrient management and irrigation management to 671 participants. The establishment of the permanent SDI demonstration site at the Chillicothe Station will ensure that these programs are sustained for many years to come and offer producers in the Texas Rolling Plains additional crop production options to enhance economic returns and water quality, and improve their quality of life.

Although not confirmed by field sampling, which showed no significant difference between the nitrogen budgets of SDI and pivot irrigation, model results suggest that leaching is approximately twice as likely under pivot irrigation as under SDI. However, based on results of this project, conversion from pivot to drip irrigation without better nutrient management will not significantly affect nitrate in the aquifer. In order to reduce inorganic N in the Seymour Aquifer hydrologic system, the inorganic N being delivered to the field through irrigation needs to be accounted for in nutrient management plans. Even though groundwater high in nitrates is considered to be a negative with respect to drinking water quality standards, it can be considered to be a significant N resource for agricultural production. Irrigation water pumped from the Seymour Aquifer is frequently high in nitrates. Therefore, by taking credit for the “free” N in irrigation water, producers, over time, may be able to reduce N in groundwater while realizing significant financial benefits.

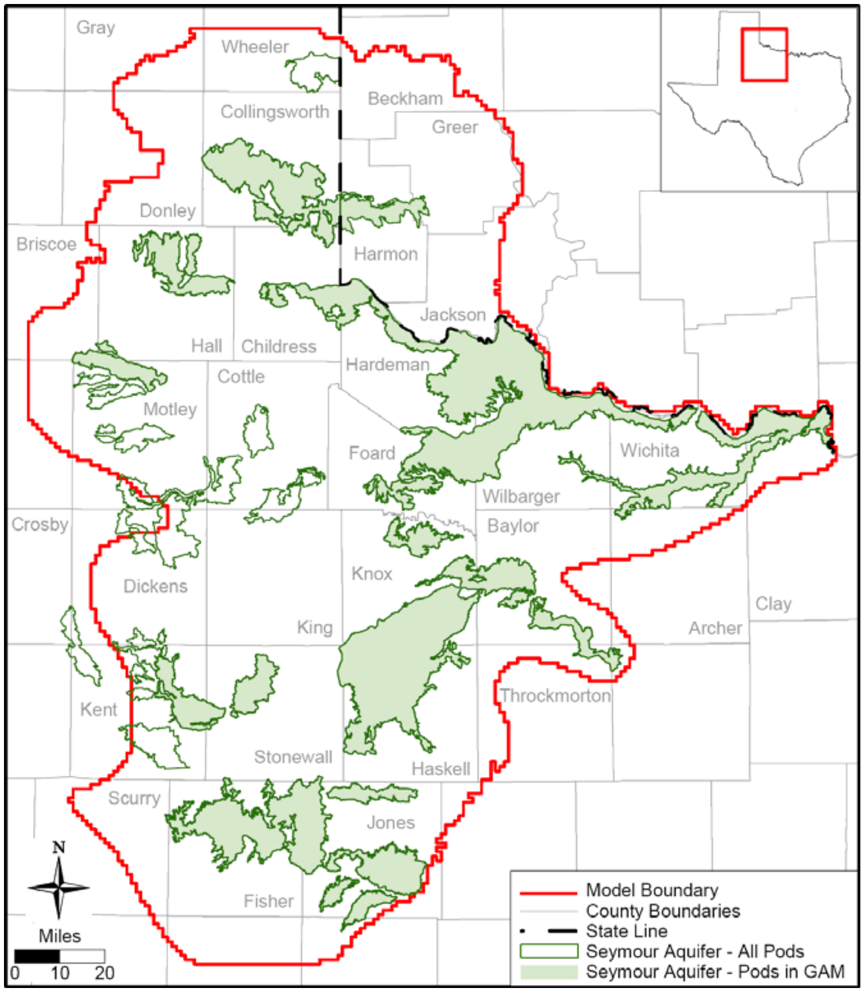
Another important finding was that soil storage rather than irrigation method was the dominant factor influencing leaching potential of a given area. This finding suggests that future implementation of BMPs should be prioritized to areas with low soil storage capacity/ high leaching potential soils.

Continued work is needed to improve conditions in the Seymour Aquifer. Educational programs on irrigation management and nutrient management are needed to encourage regular soil testing, better managed irrigation systems, and account for nitrate levels in irrigation water when determining N fertilization needs. In conjunction with these educational programs, soil testing and water testing should be provided. If nitrate in the aquifer can be “mined” using irrigation, substantial cost savings can be realized by producers while potentially improving the quality of the water in the aquifer.

INTRODUCTION

Problem/Need Statement

Figure 1. Seymour Aquifer Region (TWDB 2004).



The Seymour Aquifer is a shallow, unconfined aquifer formed by isolated pockets of alluvial deposits (Figure 1). It underlies over 300,000 acres in 20 counties in north central Texas and consists of discontinuous beds of poorly sorted gravel, conglomerate, sand, and silty clay deposited during the Quaternary Period by eastward-flowing streams. Thickness of these deposits varies greatly throughout the aquifer; however, most are less than 100 feet thick. In isolated areas in the northern parts of the aquifer, the formation may be as thick as 360 feet. Most of the aquifer is unconfined; but, artesian conditions may occur where the water-bearing zone is overlain by clay.

The lower, more permeable part of the aquifer produces the greatest amount of groundwater. Yields of wells average about 300 gal/min and range from less than 100 gal/min to 1,300 gal/min, depending on saturated thickness. Over 3,000 wells furnish water for irrigation, livestock, domestic, and municipal use. Although recharge is primarily through rainfall capture, no significant water-level declines have occurred in the aquifer.

Water in the aquifer ranges from fresh to slightly saline; however, higher salinity problems do occur. Salinity has increased in heavily pumped areas to the point where the water has become unsuitable for domestic and municipal uses. Natural salt pollution in the upper reaches of the Red and Brazos river basins prevents full use of the water. Additionally, brine pollution from earlier oil field activities has resulted in localized contamination of ground- and surface-water supplies.

The biggest water quality concern in the Seymour Aquifer is the widespread high nitrate concentrations that exceed drinking water standards. Hudak (2000) found that median nitrate levels in Knox, Haskell, Baylor, Hall, Wichita, Wilbarger, and Fisher counties exceeded the federal safe drinking water standard (10 mg/L NO_3-N). Nitrate levels in 77% of wells in Knox County exceed federal safe drinking water standards with some wells exceeding 300 mg/L NO_3-N (Hudak 2000). This is a concern because although 90% of the water pumped from the aquifer is used for irrigation, it is also used as a municipal water source for the communities of Vernon, Burkburnett, and Electra and rural families in the region.

According to the Texas Environmental Almanac (TCPS 1995), the high nitrate concentrations in the Seymour Aquifer are caused partly by natural phenomena and partly by pollution from septic tanks, cesspools, feedlots, and agriculture.

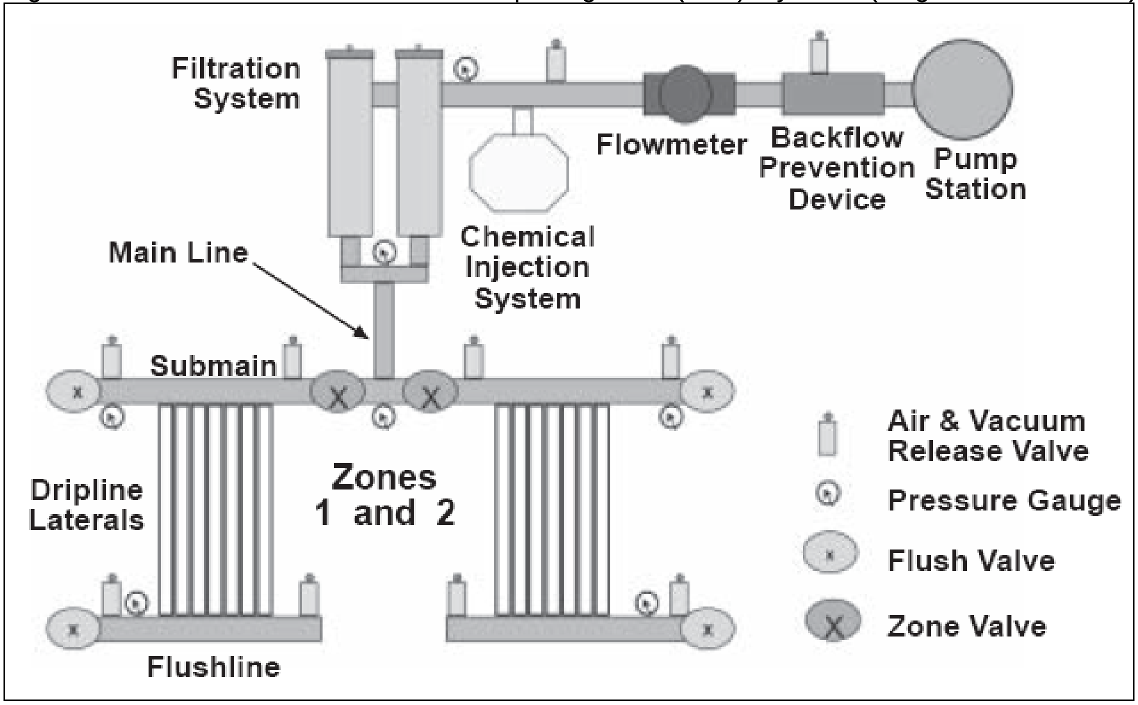
General Project Description and Goals

To address water quality concerns of the Seymour Aquifer, the Texas State Soil and Water Conservation Board (TSSWCB) worked cooperatively with the Haskell, Wichita-Brazos, and California Creek Soil and Water Conservation Districts (SWCDs); U.S. Department of Agriculture - Natural Resources Conservation Service (NRCS); Texas AgriLife Extension Service (AgriLife Extension); Texas A&M AgriLife – Texas Water Resources Institute (TWRI); Rolling Plains Groundwater Conservation District; and Texas AgriLife Research (AgriLife Research) to encourage the installation of subsurface drip irrigation (SDI) systems as a BMP to improve water quality (i.e. reduce nitrate) and increase water quantity in the Seymour Aquifer.

Subsurface drip irrigation systems are low-pressure systems (Figure 2) that provide water and nutrients directly to the plant root zone through built-in emitters on polyethylene tubes that are buried below the soil surface. These systems are designed to apply small amounts of water on a frequent basis to avoid large swings in the moisture content of the soil and maintain soil moisture content at a level that is optimal for plant growth and root development. Key elements of a SDI system are the laterals, filtration components, chemical injectors, flow meters, pressure gauges, and system controllers. Other needed components include pressure and vacuum relief valves, check valves, backflow prevention valves, field control valves, and pressure regulators. The key component of a SDI system is the lateral (tapes or tubes), which is placed in the crop root zone and delivers water to the crop through emitters embedded in the polyethylene tubes (Neufeld et al. 1997).

Chemical injection capabilities are important to SDI systems. Chemicals must be injected periodically to keep the system operating as designed by removing precipitates and bacteria and by inhibiting root intrusion into the emitters. Chemical injectors may also be used to inject fertilizer and/or soil activated pesticides directly into the root zone. This has been shown to increase the effectiveness of the nutrients, resulting in lower fertilizer application rates and reduced potential for offsite nutrient losses (Neufeld et al. 1997).

Figure 2. Schematic of Subsurface Drip Irrigation (SDI) System (Rogers et al. 2003)



Water filtration (Figures 3 – 5) is extremely important and plays a major role in determining the expected life of a SDI system. All SDI systems require some type or combination of filtration to remove suspended particles from the water, which could plug the emitters (Neufeld et al. 1997).

Figure 3. Hydrocyclone sand separators.

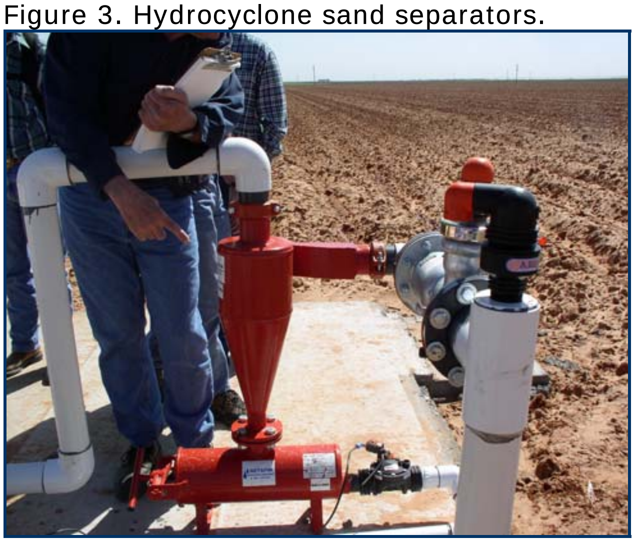


Figure 4. Manual disc filters, pressure gauges, and valves. Interior of manual disc filters showing plastic rings stacked together which create the cylindrical filter element. During filtration, the rings are compressed together effectively, filtering the water and protecting the system from clogging.

Figure 5. Sand media filters are preferred when silt and fine sand are problems with the irrigation water. System controllers (right panel) are programmed to set the length of time and time of day and/or day of week fields are to be irrigated.

Flow Meters are used to monitor the quantity of water being applied to a field. Pressure gauges are used to insure the system is operating at the designed pressure for the tape/tubing used. System controllers (Figure 5) can turn the system on and off several times a day or on any day of the week, or the system can be automated to the degree that irrigation is automatically scheduled based on real time weather information (Neufeld et al. 1997).

Properly designed and managed systems have been shown to maintain or potentially improve crop yields and quality, while saving water, fertilizer, energy, and money (Neufeld et al. 1997; Rogers et al. 2003). Phene et al. (1992) showed that deep percolation losses and runoff can be reduced with SDI systems. Their data showed that except for directly beneath the drip tubes, the direction of the soil hydraulic gradient was upward.

As a result, soil water remains in the root zone for use by growing plants and is not lost to deep percolation. Similarly, soil water data collected by Hutmacher et al. (1992) in a study on alfalfa suggested little or no potential for deep percolation losses under SDI. Additionally, Phene et al. (1992) found that after three years of raising tomatoes and cantaloupes, some accumulation of nitrate-N occurred at the soil surface; however, only a small amount leached below the root zone. Since soil water remains in the root zone, groundwater contamination and runoff from nonpoint sources containing agricultural contaminants is reduced if not eliminated entirely. Therefore, it is expected that the installation of SDI in the Seymour Aquifer could impact groundwater quantity and quality by:

1. reducing the percolation of irrigation water into the aquifer (and any associated nutrients and pesticides),
2. increasing irrigation efficiency thus increasing quantity of water in the aquifer, and
3. "mining" nitrates from the irrigation water itself.

To encourage the adoption of this expensive practice, the project provided:

- technical and financial assistance (i.e. cost-share) to replace existing center pivot, sprinkler, or row-water irrigation systems with SDI in Haskell, Knox, and Jones counties;
- evaluation of the effectiveness of SDI; and
- education programs and demonstrations of methods for reducing nitrate infiltration and improving irrigation efficiency.

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SUBSURFACE DRIP IRRIGATION INSTALLATION

In order to encourage irrigators to implement SDI to reduce nitrate infiltration, a traditional voluntary-based incentive program and technical assistance was provided to producers to develop and implement TSSWCB-certified Water Quality Management Plans (WQMPs). The WQMPs developed by the SWCDs and reviewed by the TSSWCB ensured that they achieved a level of pollution prevention or abatement consistent with state water quality standards.

In addition to SDI, other BMPs were implemented to reduce nitrate levels, including irrigation management, nutrient management, integrated pest management (e.g., sprayer calibration, incorporation banding, follow label), and conservation tillage. However, only implementation of SDI received cost-share.

The Haskell, Wichita-Brazos, and California Creek SWCDs were allocated $450,000 to provide cost-share to irrigators for conversion of existing irrigation systems to SDI. The maximum cost-share rate was set at 60% of the cost of the SDI and the maximum cost-share amount producers were eligible to receive was set at $30,000. Cost-share was based on actual cost not to exceed average cost of the practice. Highest priority was given to the replacement of the least efficient irrigation systems. Feasibility of successful installation was also considered.

In August 2004, TSSWCB representatives met with the Haskell, California Creek and Wichita-Brazos SWCDs, AgriLife Research, and TWRI to finalize the Seymour Aquifer CWA §319(h) project. A SWCD technician was hired in September 2004 and trained by the NRCS and TSSWCB. Cost-share practice amounts were set and approved by the TSSWCB Dublin Regional Office.

The Haskell, Wichita-Brazos, and California Creek SWCDs, with assistance from NRCS, assembled and sent out news releases and program information through USDA-Farm Service Agency (FSA) county newsletters and local newspapers in each county in October 2004 announcing the availability of assistance for implementing WQMPs/BMPs (Appendix E). Applications were received and qualified priority producers were accepted. The first application was accepted in October 2004.

The SWCD technician provided landowners information on WQMPs and BMPs, and worked with the NRCS and TSSWCB Dublin Regional Office to develop 17 certified WQMPs, install 1,071 acres of SDI (441-Irrigation System, microirrigation), implement irrigation management on 1,821 acres, and implement nutrient management on 2,570 acres (Table 1). The locations of each WQMP are included in Appendix A. To ensure that the implementation schedules in the WQMPs were followed and funds were properly administered, the SWCD technician conducted status reviews on all WQMPs. Annual status reviews will continue to be conducted by the TSSWCB Dublin Regional Office at a rate of 10% of the WQMPs each year.

Table 1. BMPs implemented through WQMPs.

Application #	County	Acres	PRACTICES	328 - Conservation Crop Rotation	344 - Residue Management - Seasonal	590 - Nutrient Management	595 - Pest Management	449 - Irrigation Water Management	441 - Irrigation System, Microirrigation	442 - Irrigation System, Sprinkler	443-Irrigation System Surface & Subsurface	412 - Grassed Waterways	528A - Prescribed Grazing	340 - Cover Crop	330 - Contour Farming	645 - Upland Wildlife Habitat Management	561 -Heavy Use Area Protection	562 - Recreation Area Improvement
				ac.	ac	ac.	ac.	ac	ac.	ac.	ac.	ac.	ac.	ac.	ac.	ac.	ac.	ac.
001	Jones	98.5		96.1	96.1	98.5	98.5	51.8	52			2.4	46.7					
004	Jones	82.2		82.2	82.2	82.2	82.2	82.2	82.2					82.2				
005	Jones	155.4		155.4	155.4	155.4	155.4	105.8	105.8					155.4				
006	Jones	160.5		142.8	142.8	142.8	142.8	112.7	112.7							17.7		
007	Jones	162.0		98.2	98.2	142.2	142.2	83.9	47.9	36.0			60.0			4.0		
008	Jones	73.5		25.8	25.8	65.3	65.3	48.4	25.8	22.6					39.5		8.2	
002	Haskell	276.6		276.6	276.6	276.6	276.6	232.9	39.9	193.0								
003	Haskell	94.6		94.6	94.6	94.6	94.6	94.6	94.6									
004	Haskell	327.7		234.9	234.9	319.7	319.7	144.2	43.3	100.9			129.1					
005	Haskell	168.8		163.4	163.4	167.3	168.8	161.4	62.0	99.4		3.9	106.8				1.5	
006	Haskell	85.3		85.3	85.3	85.3	85.3	85.3	49.8	31.7	3.8			49.8				
007	Haskell	468.0		164.8	164.8	204.5	204.5	20	20.0				309.8		19.7	163.1		23.3
001	Knox	76.7		76.7	76.7	76.7	76.7	63.6	63.6									
002	Knox	77.8		77.8	77.8	77.8	77.8	77.8	20.8		57.0							
003	Knox	357.0		187.1	187.1	356.7	356.7	300.4	95.0	113.3	92.1		169.6					
004	Knox	91.0		91.0	91	91.0	91.0	91	91.0									
005	Knox	183.6		133.7	133.7	133.7	133.7	65	65.0				45.1				4.8	
	TOTALS	2,939.2		2186.4	2186.4	2570.3	2571.8	1821	1071.2	596.9	152.9	6.3	867.1	287.4	59.2	184.8	14.5	23.3

SUBSURFACE DRIP IRRIGATION EVALUATION

OBJECTIVE

Texas AgriLife Research (AgriLife Research) assessed impacts of conversion from furrow and/or pivot irrigation to SDI on N concentration and water quantity.

MATERIALS AND METHODS

Description of Study Area

The study was conducted on six privately owned fields in the Rolling Plains area of North-Central Texas (33° 27’ N, 99° 36' W, 450 m above mean sea level). The fields are cultivated in a cotton-winter wheat rotation system and ranged in size from 16 to 40 hectares with nearly flat topography (0 – 1 % slope). Four of the fields were located within 2 km of each other while the other two were 20 – 30 km away. The soils found in the fields were from the Miles (Fine-loamy, mixed, superactive, Typic Paleustalfs) and Abilene (Fine, mixed, superactive, thermic Pachic Argiustolls) series. These soils are the dominant soil series of the area and are alluvial soils characterized by very deep, well-drained profiles that can extend to depths of greater than 2 m. At field capacity, the average water content of these soils is approximately 0.31 m^3/ m^3. These soils are of great significance because they are the primary channels for recharge to the underlying Seymour Aquifer, which supplies all the irrigation water and more than 90% of potable water to the area. The climate in the area is semi-arid with average annual precipitation of 610 mm and potential evapo-transpiration (PET) of approximately 1780 mm. Most of the precipitation occurs within the cotton growing season (April – October) as sporadic high intensity thunderstorms. Crop water requirement is supplemented by pivot or SDI.

Soil Characterization and Variability

Electromagnetic induction (EMI) using the EM38, operated in the vertical dipole mode, was used to measure field-scale spatial variability of soil bulk electrical conductivity (ECa) across each of the six study fields. EM38 surveys were conducted prior to the 2005 growing season along 10-m transects between rows. Based on the measured ECa range, 5-10 sampling locations were selected from each field. The maximum range of ECa values were used because we wanted to capture the maximum soil variably of each field. Intact samples were subsequently collected at each sampling location to a depth of 1.5 m, in depth increments of 0-0.3, 0.3-0.5, 0.5-0.7, 0.7-1.2 and 1.2-1.5 m. Standard laboratory methods were used to determine selected soil properties for each depth increment and sampling locations. Bulk density was measured for the first year. Clay content was determined using the hydrometer method (Gee and Bauder, 2002), pH was measured from a 1:1 soil:water / soil:1N KCl solution, and soil solution salinity (ECw) was measured from 1:2 soil:water extract. Regression analysis was used to determine soil property or properties influencing ECa response.

Estimation of N Loss by Leaching

Seasonal nitrate loss at each sampling location was estimated using an N balance approach. The quantity of N leached (kg N ha^{-1}) was calculated as:

$$N_{leached} = N_f + N_i + N_{pp} – N_{ph} - N_h$$

where, N_f is fertilizer N added during the season, N_i is irrigation N, N_{pp} is soil pre-plant N, N_{ph} is soil post-harvest N, N_h is nitrogen harvested (seed and lint N). Net mineralized N was considered to be constant throughout the 3-year study. This was confirmed by there being no significant change in organic N from year to year. All input parameters were in kg N ha^{-1}. It was assumed that (i) other N losses such as volatilization, run-off and erosion were negligible; (ii) all fertilizer N was nitrified to nitrate; (iii) the return of inorganic N from mineralization was constant over the 3 year study; and (iv) N contributed by precipitation and seed was negligible.

Fertilizer N applied was calculated using the type and application rate of the fertilizer. Fertilizer application rates were collected from farmer interviews. Nitrate input from irrigation was calculated from the concentration of N in irrigation water and the volume of water applied. Irrigation water samples were collected biweekly or as often as possible while the farmers were irrigating and stored in a freezer for later analysis. Samples were analyzed for both nitrate and ammonium to determine total inorganic N. It was assumed that organic N was negligible in water samples. Pre-plant and post-plant N were determined from soil samples collected before planting and after harvesting, respectively. Plant N was determined from hand-picking seed and lint over a 1 m^2 area at the location that each soil sample was collected. Rainfall for each field was collected with tipping bucket rain gauges.

For 2006, drought and farmer management required a change in sampling design for two of the paired fields. The farmer decided against continuous cotton and planted wheat in fall 2005 on two of the SDI and pivot fields. However because of drought, the wheat did not emerge in the SDI fields (Drip 2 and Drip 3), but did emerge on the pivot fields (Pivot 2 and Pivot 3). We maintained collection of N on the original SDI fields but used adjacent pivot fields that were planted in cotton (under the same producer and management) for N monitoring (soil sampling, management, and yield collection). In 2007, sampling returned to the original pivot fields.

RESULTS AND DISCUSSION

Field Scale Impacts of Conversion from Pivot to SDI Irrigation on N and Water Levels

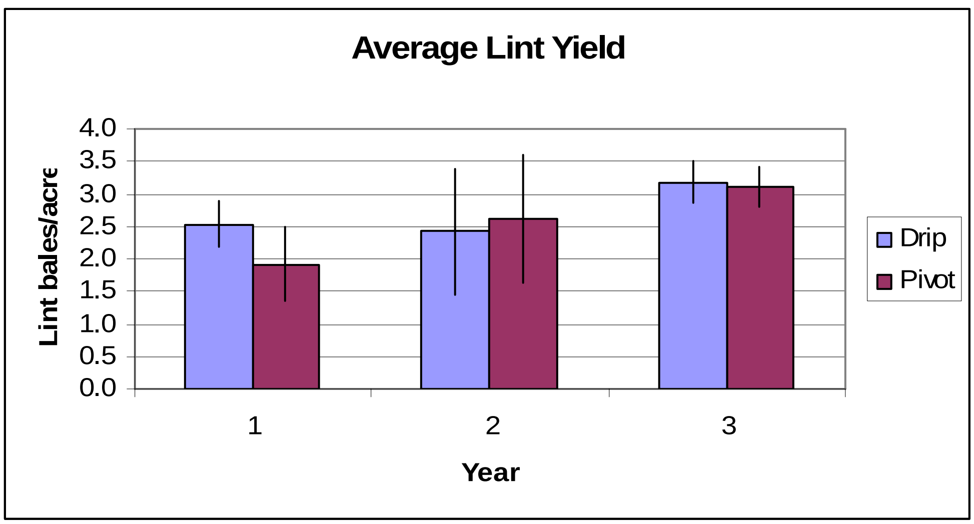
The fields that were monitored over the 3-year period were actual producer fields. Nitrogen balances of plot-sized (m^2) data usually have a very high variability. This variability is so high that significant differences between treatments are difficult to find (Brye et al, 2002). The temporal and spatial variability of N in the fields monitored for this project was high as well, which was no surprise given the spatial and temporal variability of the system (Table 2). Though there was no significant difference in the inorganic N balance between pivot irrigation fields and drip irrigation fields in the study, the data (Appendix B) do point to import trends that should be considered when developing management plans to reduce potential N leaching in cotton fields in the Seymour Aquifer.

Table 2. Size of fields monitored in Subtask 4.2.

Field Number	Irrigation type	Size, acres
100	drip	63
200	pivot	108
300	drip	96
400	pivot	59
500	pivot	48
600	drip	58
700	pivot	60
800	pivot	49

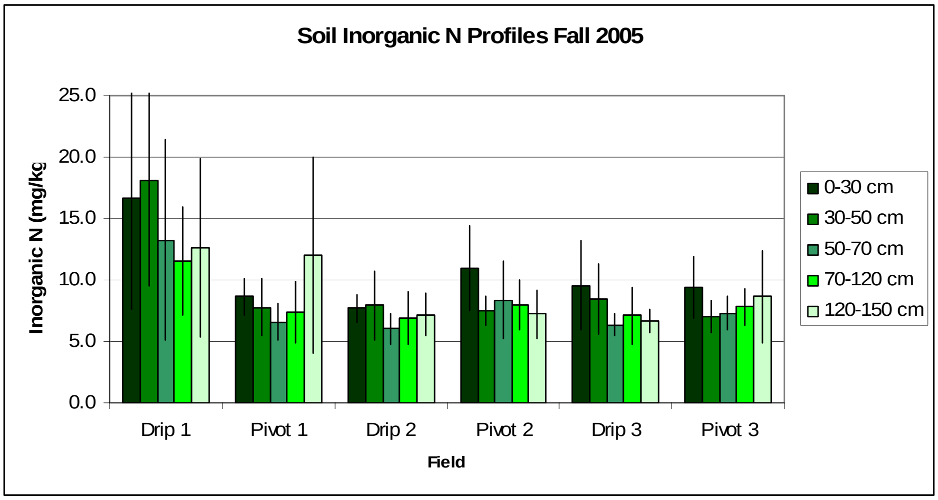
Years 2005 and 2006 were normal to dry precipitation years during the growing season, and post-harvest N concentrations were higher in the soil than 2007. During the 2007growing season, precipitation was unusually high. As a result, less than half of the normal amount of irrigation was applied to the fields and the average lint yield was higher by 0.5 bales/acre compared to the previous 2 years (Figure 6). The lower post-harvest N concentration in the 2007 soil samples is attributed to both higher N removal by harvest and lower N additions from decreased irrigation.

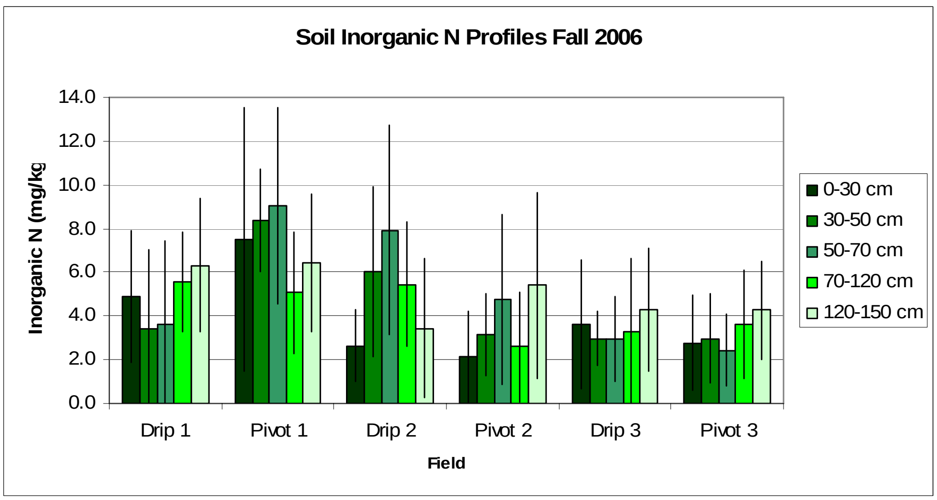
Figure 6. Average lint yield for 3 years of pivot and drip irrigation in monitored fields. Lines on the bar graph indicate standard deviation.

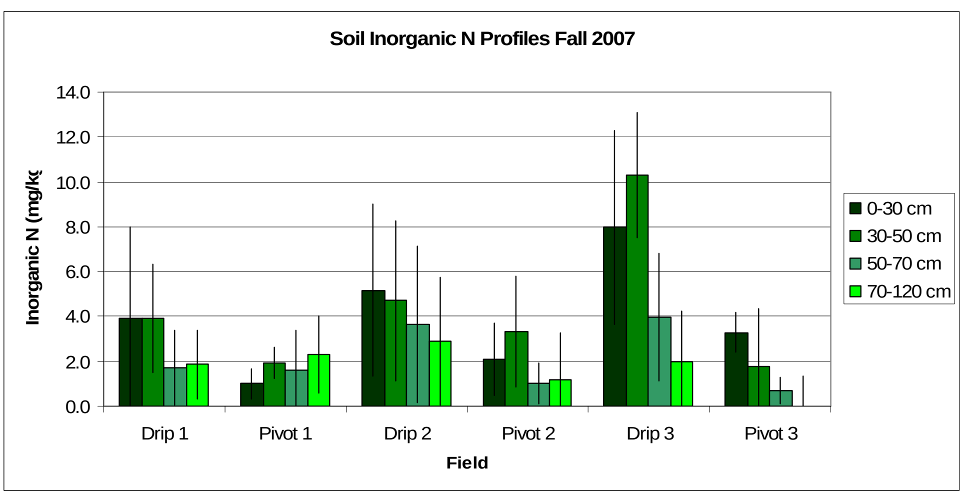


If inorganic N was actually leaching below the root zone, we hypothesized that we would see a build up in soil N concentration at soil depths below the cotton root zone. The majority of cotton roots can be found within 1 m of the soil surface, and under irrigated conditions, most of the root mass stays near the wetted, irrigated portion of the soil. Inorganic (nitrate) N concentrations in the soil after cotton harvest are shown in Figure 7. There was no significant build-up in N concentration in the deeper soil; additionally there was really no trend of increasing or decreasing soil N with depth. Nitrogen in the 120-150 cm soil depths is assumed to be eventually lost to leaching. Also, if the winter and spring recharge of soil moisture is significant, the N in soil depths 70-120 cm will likely leach as well. However at the time of collection in 2007, the soil was too dry to soil sample beyond 120 cm.

Figure 7. Nitrate concentrations in the soil each year after cotton harvest. Lines on the bars indicate standard deviations.

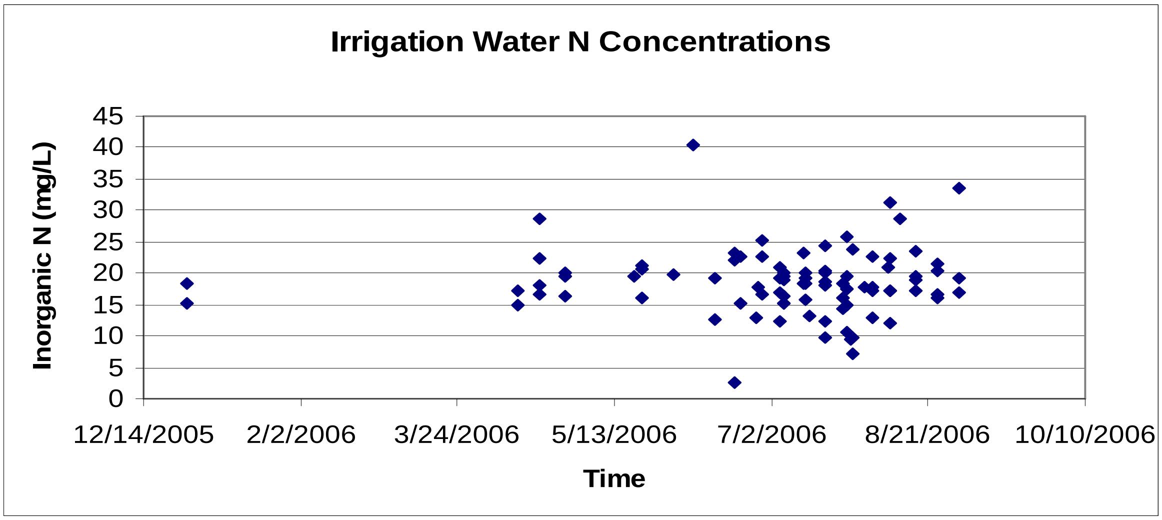






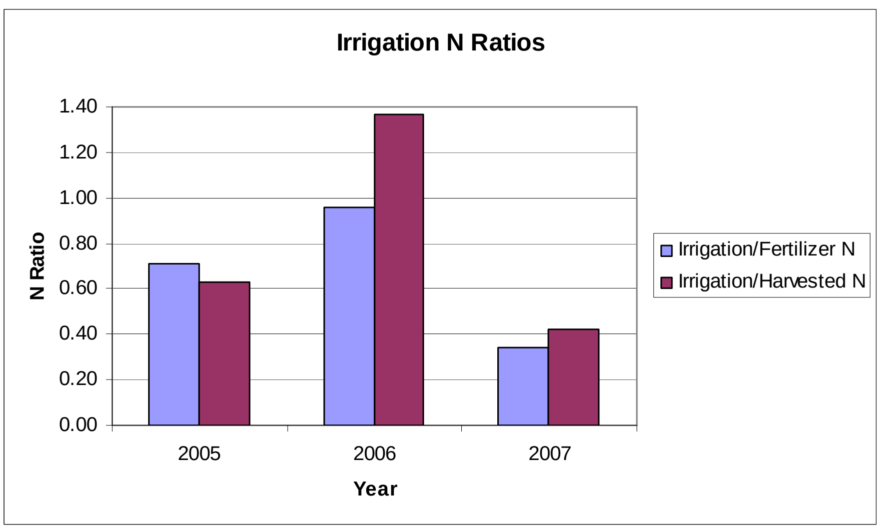
The irrigation water was surprisingly high in nitrates (Figure 8). Nitrate concentration ranged from 3 to 41 mg L^{-1}, and averaged 19 mg L^{-1}. Through regression analysis and ANOVA, there was no significant difference in N concentration between irrigation units, and no temporal trends could be found. Personal communications have indicated a belief that nitrate concentrations increase throughout the season. The plot of 2006 nitrate concentrations does not show a temporal trend. The 2005 data did not either. In 2007, there was very limited irrigation.

Figure 8. Irrigation water NO_3 levels in samples collected from 3 pivot and 3 SDI systems (2006). Since there was no trend per irrigation system, all samples are plotted together.



Because of the high concentrations in the irrigation water, irrigation was found to be a significant contributor to the field-scale nitrate budgets (Figure 9). Irrigation water contributed from 40 to 130% of the amount of N harvested from the field. Very little irrigation was required in 2007; hence, 2007 had a lower N contribution. Equally interesting are the blue bars in Figure 9 that show irrigated N levels were equal to the fertilization levels in 2006.

Figure 9. Ratio of N applied through irrigation water to total fertilizer applied N and amount of N removed through harvesting cotton.



To examine the potential N load that can be leached to the aquifer, it is useful to compare total inorganic N in the soil profile (kg of N ha^{-1}) after harvest with N. The residual soil N indicates the amount of N available for leaching between harvest and spring planting if the entire soil profile were to be leached. The fallow season between continuous cotton rotations can provide months of considerable leaching risk especially if there is substantial rainfall during this time. Figure 10 shows the residual soil nitrate after harvest for pivot and drip irrigation fields over the 3 year study. The end of the first year (2005) showed the highest N-leaching potential, with most fields reaching about 150 kg N ha^{-1}. Most importantly, the cotton crop removed 80-100 kg N ha^{-1} in 2005. Essentially, there was still enough N in the soil to potentially provide N for one more crop at the same harvest N (Figure 11). In 2005, the drip field from the first pair of fields did have significantly higher N than the pivot irrigation, but this result was not found to be consistent for the following years.

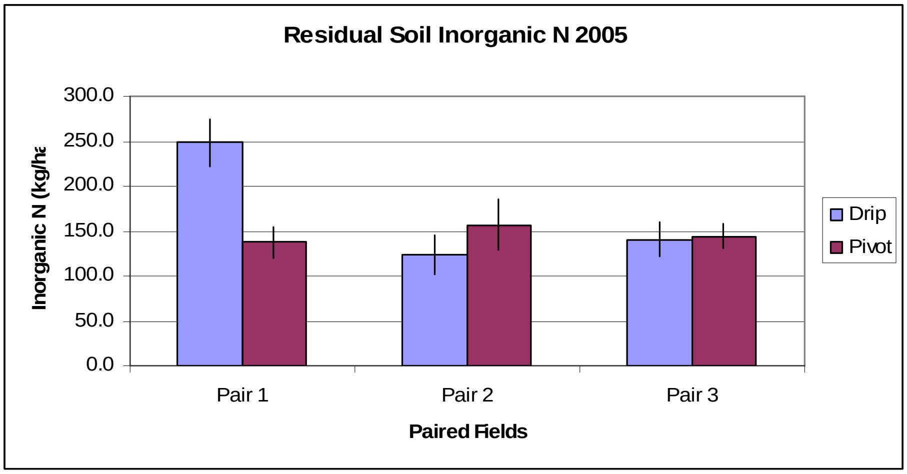
In 2006, total residual soil N ranged from 20 to 163, and averaged 97 kg N ha^{-1}. In all but drip field 3, there was still enough residual soil N to cover twice the N requirements of the crop. In 2007, the abundance of N left in the soil was much less; however, there was still enough residual N to provide for a 2 bale per acre harvest (Figures 10 and 11).

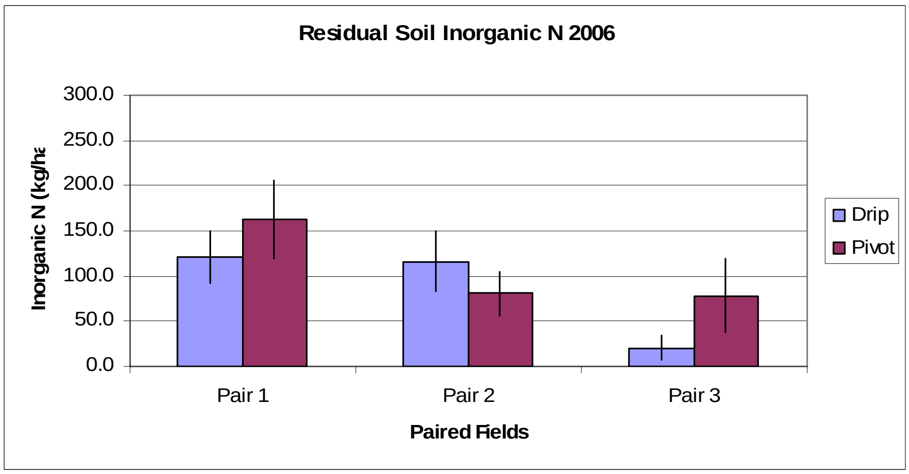
Impacts of Conversion to SDI at the Project and Aquifer Scale

Irrigation data were not sufficient to model the water balance (and subsequent N-leaching) within the 10% accuracy required to estimate water drainage and subsequent leaching. Growing season (2006) leachate was impossible to collect below the cotton root zone. This indicates that if leaching does occur, it occurs in wet years and during the fallow season when roots are not pulling water out of the soil profile. Based on inorganic N (nitrate) concentrations in the soil after harvest (Figure 7), the soil can have N concentrations of 0-10 mg kg^{-1}. The higher post harvest N concentrations occur after dry to normal precipitation years and indicate situations where the potential for N leaching out of the root zone and ultimately into the aquifer exists.

Some modeling of potential leaching was performed. The model used a basic potential evapotranspiration (ET) model, weather data from the Munday, TX weather station (this weather station, which was less than 5 miles from the furthest field, was subsequently shut down after 2005), irrigation data from the farmers, and a GIS platform that included soil coverages from SSURGO 2.1 (see report in Appendix C). Though this modeling effort was not sufficient to obtain absolute values for leaching, several conclusions were drawn. The first result suggests that for given precipitation and irrigation input, soil-water storage rather than irrigation method was the dominant factor influencing leaching potential of a given area. Thus, the sandier the soil and less water storage it has, the higher its leaching potential. This suggests that future implementation efforts should be prioritized towards those soils with low water storage capacity and high leaching potential. Secondly, areal extent (total acreage) of a soil series, rather than soil type was found to control the total volume of water leached beyond a given depth. In other words, if there is extensive acreage of a given soil with low leaching potential, that soil can still be a major contributor to the volume of water leached, providing this type soil extends over a large area of the aquifer. Finally, although not confirmed by field sampling, the model results suggested that leaching is approximately twice as likely under pivot irrigation as under sub-surface drip irrigation.

Figure 10. Total N remaining in the soil after cotton harvest. Lines on the bars indicate standard deviations.





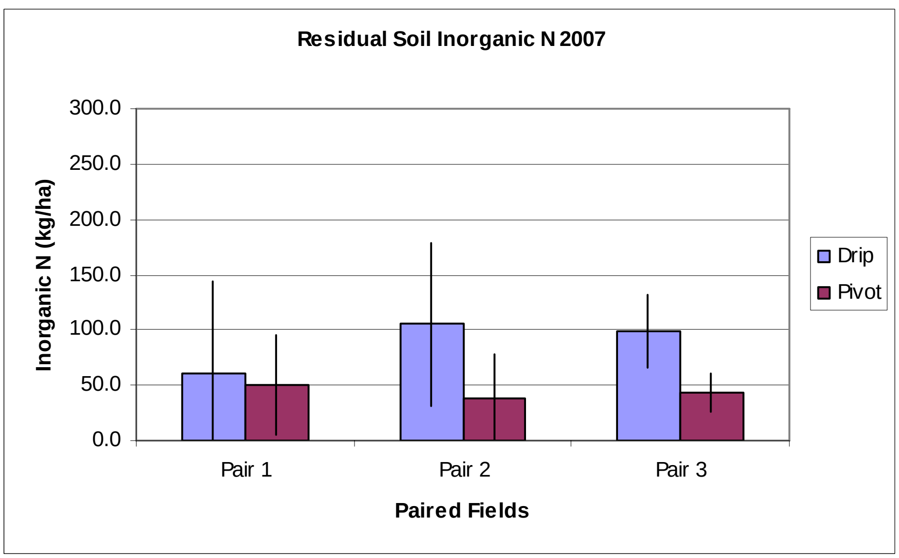
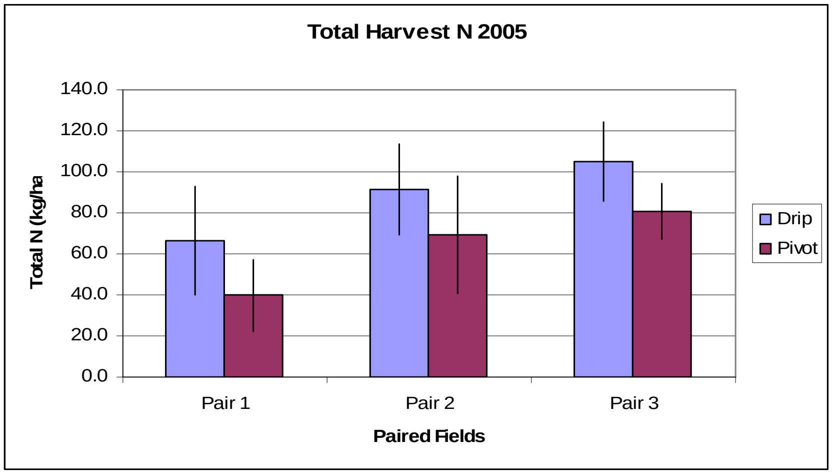
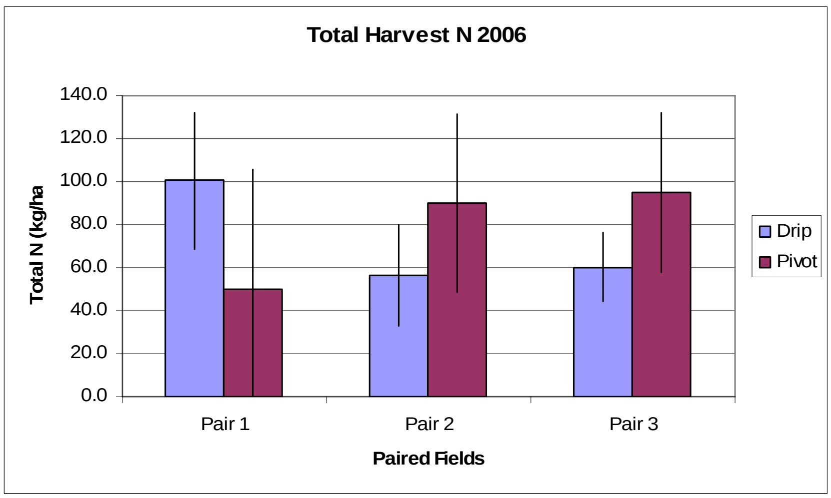
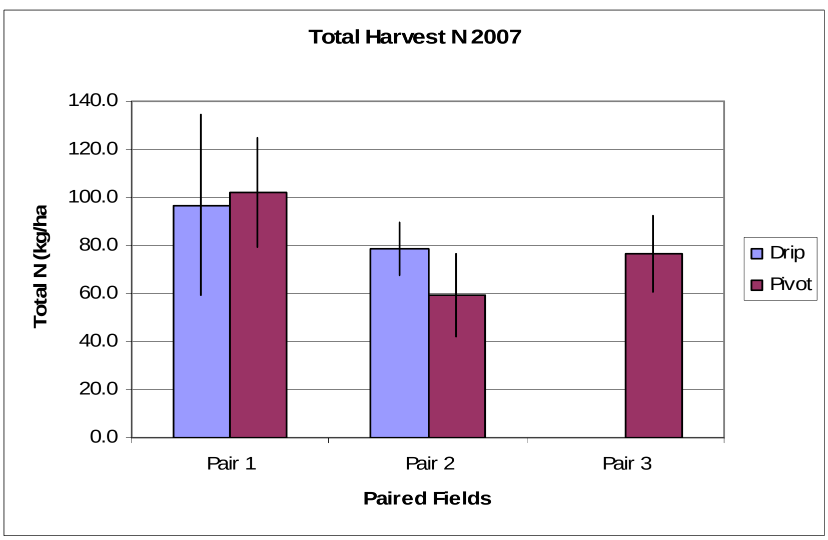


Figure 11. Annual N removal for each field through cotton lint and seed harvest. Lines on bars indicate standard deviations. Harvest numbers are missing for 2007 Drip Field 3; but, gin reports show yield was similar to Drip Field 2 in 2006.







Based on results of the 3-year study, conversion from pivot to SDI alone will probably not significantly affect nitrate in the aquifer. There were no significant differences between the N budgets of SDI and pivot irrigation systems in the producer fields that were monitored. The literature documents that SDI is more water efficient (Table 3) than flood/furrow and sprinkler/spray irrigation systems. Because of SDI's higher water delivery efficiency, the potential to deliver less N from irrigation water is possible. However, N delivered to roots of plants via SDI is assumed to be more efficient than other irrigation systems. Conversion to SDI comes at a high price, however, with installation costs of converting from furrow irrigation to SDI ranging from an estimated $1000 to $3000/ac-ft of water saved (based on $0.42-$0.66 ac-ft/ac savings) or $100 to $300/ac-ft of water per year over 10 years.

Table 3. Irrigation Efficiency and Cost

Irrigation Type	**Application Efficiency**	**Installation Cost**
	%	**$/ac**
Flood/Furrow	40-80	10-15
Sprinkler/Spray	65-90	300-400
LEPA	85-95	325-425
Subsurface Drip	85-99	700-1200

However, based on our findings and observations of producer behavior, the easiest way to reduce inorganic N in the Seymour Aquifer hydrologic system is to account for the inorganic N being delivered to the field through irrigation. The results of this study indicate that N may be reduced in the aquifer by producers accounting for the amount of inorganic N in the irrigation water as part of their nutrient management plans. Particularly, in a dry year when a lot of water is being added to the field through irrigation, we found irrigation water N loads to *exceed* harvest N removal by 30% on average.

This can be a tremendous financial benefit to producers while helping "mine" N from the aquifer. Based on estimates prepared by Texas AgriLife Researcher Dr. Paul DeLaune (2008), each ppm (mg/L) of nitrate N in irrigation water will add 0.23 lb/ac of N with each inch of water applied. Thus, if the nitrate concentration in well water is 20 ppm and 12 inches of irrigation water is applied, then a total of 55 pounds of nitrate will be provided (Table 4). This is enough to produce one bale of cotton or 3000 lb/ac of grain sorghum. Fifty-five pounds of N is worth $42.90 (assuming N at $0.78/lb). Thus, by taking credit for N, the producer could save $42.90 per acre irrigated while maintaining current levels of production.

Nitrate crediting is a sound economic and agronomic practice. When used properly, growers can maintain yields, reduce fertilizer costs, and help clean up groundwater. The only significant yield loss from reducing N fertilizer applied occurs when the expected water nitrate credit is not actually received from the applied irrigation water.

Table 4. Nitrate Applied Through Irrigation

	Inches of Water Applied				
Well Water NO_3	6	12	18	24	30
(ppm)	lbs N/acre				
5	7	14	21	28	35
10	14	28	41	55	69
15	21	41	62	83	103
20	28	55	83	110	138
25	34	69	104	138	173

Based on two years of biweekly measurements of inorganic N in the irrigation water, no temporal trend of nitrate concentration was found. In other words, the nitrate concentration did not have an increasing or decreasing concentration throughout the growing season. Hence, if farmers were to use irrigation water as an N source, they should monitor the N concentration regularly until a reliable average concentration is determined. AgriLife Research suggests that water samples be collected at least twice during the first year for each well to account for possible variability. In subsequent years, a single sample should be sufficient for each well. This should be collected in conjunction with soil sampling. With knowledge of N levels in the soil and irrigation water, along with historical irrigation rates, the most cost-efficient nutrient management plan can be developed (DeLaune, 2008).

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SUBSURFACE DRIP IRRIGATION DEMONSTRATION

Objective

To generate and extend new knowledge to enhance BMPs for nutrient and irrigation management within the Seymour Aquifer region of the Texas Rolling Plains, a 14-acre SDI system was established at the Texas AgriLife Research Station at Chillicothe. This site provided demonstration and education of BMPs to reduce nitrate infiltration, limit irrigation runoff, and promote protection and prudent use of a limited groundwater resource. This demonstration site had a direct impact on the area's groundwater. It educated producers possessing irrigated crop production capabilities of the most efficient and state–of-the-art water delivery system to plants, reduced the potential for return flow of irrigation water into the aquifer (return irrigation water flow has the potential to transport nutrients and pesticides into groundwater), provided options to increase the size of irrigated crop production with a producer's limited groundwater resource, and demonstrated new, potential cropping systems that can increase economic returns and thereby enhance quality of life. Through on-site education events at Chillicothe, the geographical area reached by the education activities was expanded to include Wilbarger, Hardeman, and other surrounding Counties.

Design and Installation of the SDI System at Chillicothe

The SDI system (Figure 12) was designed and installed by Eco-Drip Subsurface Drip Irrigation (Eco-Drip, Garden City, TX[1]). The system included six series, each with 12 individually-controlled plots for a total of 72 plots. The area of each plot is about 0.20 acre. Drip tapes were set at 40 inch spacing and placed 12-14 inches below the surface using a GPS RTK guidance system that included auto-steer capability (Figure 13).

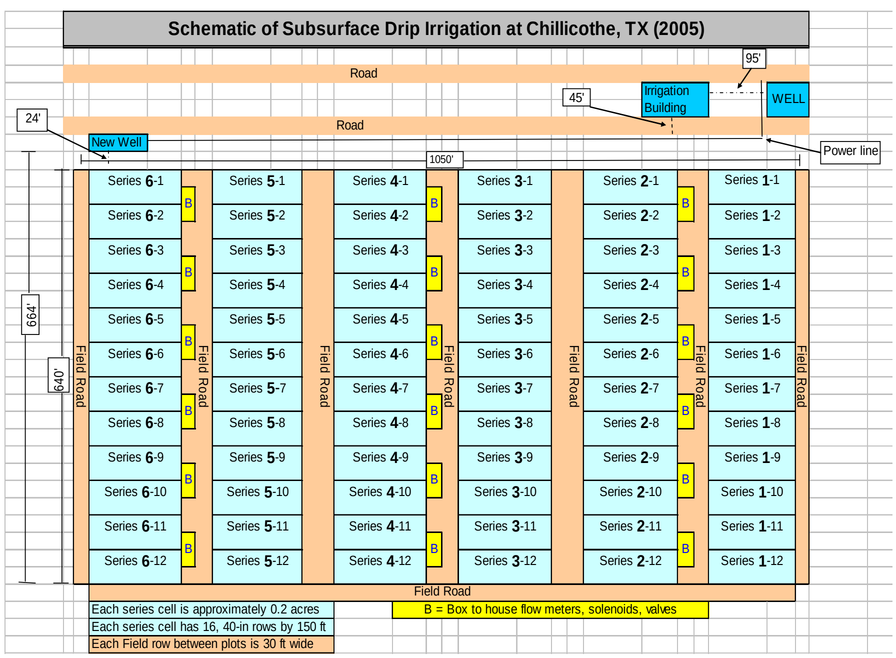


Figure 12. Schematic of the SDI system at Chillicothe, Texas.

[1] Trade names and company names are used for the convenience of the reader and do not imply endorsement by Texas AgriLife Research and Texas AgriLife Extension Service over comparable products or companies.

Figure 13. GPS Auto-steer technology was used to bury tapes 12 to 14 inches deep on 40-inch centers with sub-inch accuracy, Chillicothe, Texas, 2006. Left panel: GPS monitor; middle panel: installing drip tape; right panel: installed tape with sub-inch accuracy.

This allowed drip tapes to be spaced apart within sub-inch accuracy. In 2007, Chillicothe acquired its own GPS auto-steer system to use this technology for expanded SDI research. This precision is essential to maintain known traffic patterns and to be able to seed crops directly over the drip tapes. Series 1 and 2 were specially designed to switch from 40-inch to 80-inch drip line spacing, depending on research requirements. These 72 individually controlled plots provide substantial flexibility for evaluation of various BMPs, cropping systems, and management techniques to educate producers on practices to protect the aquifer.

Installation commenced in May 2006 and was completed in July 2006. A cotton crop was planted before final completion of the system, since planting date is critical for cotton. The system had several leaks and other items that had to be repaired before the system was completely functional.

<u>Preliminary Soil Sampling</u>

Soil sampling for residual nitrate levels was conducted in April 2006 prior to SDI establishment (Figure 14). Soil cores were extracted with a Giddings Soil Sampler (Giddings Machine Company, Inc., Fort Collins, CO) attached to a small tractor. Cores were taken to 5 feet and separated at 1-foot intervals, thereby providing five sub-cores for nitrate analyses by Olsen Labs (Olsen's Agricultural Laboratory, Inc., McCook NE.). This field has been in continuous furrow-irrigated cotton for many years.

Figure 14. Location of sites at Chillicothe sampled for nitrate prior to SDI establishment.

Nitrates levels were exceptionally high at most sites and averaged 376 lb nitrate per acre in a 5-foot depth (Table 5). Data averaged over the 12 sampling sites showed higher levels of nitrate at the 4- and 5-foot levels. Fertilizer has been applied to irrigated cotton each year regardless of yield potential for that season. From these data, it appears that this practice exceeded cotton yield requirements for many years, allowing nitrates to accumulate.

Table 5. Nitrate levels in pounds per acre at five separate soil depths and 12 random soil sampling sites across the Chillicothe, TX subsurface drip irrigation site (April 2006).

Soil Sampling Data													
Sampling Site													
Depth	1	2	3	4	5	6	7	8	9	10	11	12	**Avg**
(inches)	--------------------------------Nitrate N (lbs/ac)--												
0 -12	85	63	53	76	69	59	91	63	50	64	89	65	**69**
12 - 24	45	19	28	102	25	102	39	33	45	35	41	32	**46**
24 - 36	58	30	28	269	19	245	39	42	87	29	27	34	**76**
36 - 48	58	44	41	209	23	390	58	61	83	72	19	88	**96**
48 - 60	54	38	64	54	19	281	130	70	68	138	21	153	**91**
Total	**300**	**194**	**214**	**710**	**155**	**1077**	**357**	**269**	**333**	**338**	**197**	**372**	**376**

Two water samples from two wells were tested for nitrate in December 2007 using an Auto Analyzer, Model San++ (Skalar, P.O. Box 3237, 4800 DE Breda, The Netherlands). The four water samples averaged 19.7 ppm, and this level is considered high. Therefore, over time, the addition of N fertilizer plus nitrates from the irrigation water may exceed the yield requirements for furrow-irrigated cotton at Chillicothe. Additional soil samples will be taken in 2008.

Factors Preventing Determination of Cotton Yield Potential

In 2006, the cotton crop received considerable damage from hail in June and prognosis was poor (Figure 15). It was too late to replant cotton, so it was decided to allow the surviving plants to re-grow. Within a month, surviving plants made exceptional re-growth (Figure 15). However, it was understood that yield loss was inevitable as would have occurred with a late seeded cotton crop. Late season rainfall was high and contributed to excellent plant development. Even with hail-damaged cotton, estimated yields were quite respectable at 2 bales per acre (Table 6).

Table 6. Seasonal rainfall, yield, and lint grade of SDI cotton at Chillicothe, TX (2006).

Rainfall	May-July	Aug-Sept	Total (inches)
(inches)	4.53	9.11	13.64
Irrigation (seasonal)			5.25
Total available water			**18.89**
Yield	2 bales/acre		
Lint grade	good - excellent		

Figure 15. Hail-damaged cotton on 19 June 2006 (left panel) followed by recovery 17 July 2006 (right panel).

In 2007, herbicide (2,4-D) drift from a neighboring farm damaged the cotton crop under SDI. Damage occurred mid-season. Some recovery in boll set was noted, but yield loss occurred, nevertheless. Bolls that had been set prior to herbicide damage did not abort, but nearly all flowers failed to set fruit in the damaged region of the plant (Figure 16). As expected, yield was substantially reduced given the amount of total available water during the growing season, but lint quality was good to excellent (Table 7).

Figure 16. Herbicide drift damage to drip-irrigated cotton (left panel). Right panel shows lack of boll development in middle of plant due to chemical damage at time of flowering.

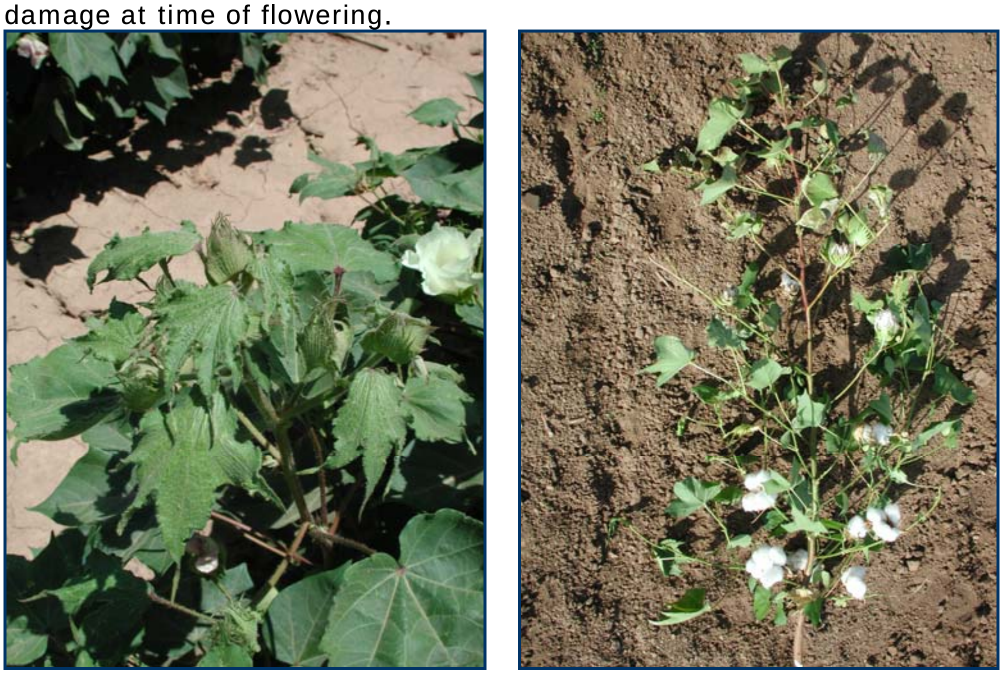


Table 7. Seasonal rainfall, yield, and lint grade of SDI cotton at Chillicothe, TX (2007).

	May-July	Aug-Oct	Total (inches)
Rainfall (inches)	11.91	3.92	15.83
Irrigation (seasonal)			6.94
Total available water			**22.77**
Yield			1.7 bales/acre
Lint grade			good - excellent

Preliminary Forage Production under SDI

The newly established SDI system is extremely versatile and has potential for crop production besides cotton. In May 2007, forage plots were established to determine the suitability of SDI on production of high quality forages for beef cattle, dairy, and horse operations. High quality hay for the high-dollar horse market may be a suitable crop under SDI, since a high return is desirable to offset the cost of SDI installation. Since certain perennial forages require an establishment period, full season production potential will not be known until the end of 2008. Nevertheless, forage development (Figure 17) and short-season forage production in 2007 under four irrigation treatments were good (Table 8). Forage quality determinations will be conducted in 2008.

Figure 17. Forage development under SDI. Four irrigation treatments and four high quality forages were established in May 2007 at Chillicothe, TX; photo taken 19 September 2007.

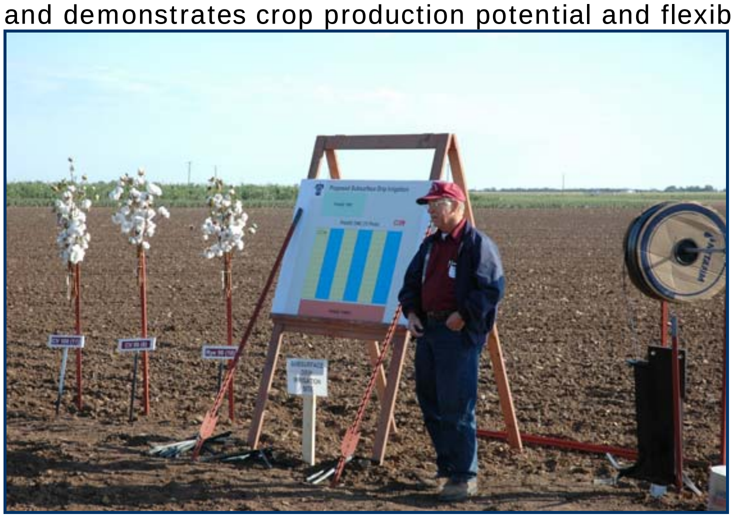
Table 8. Late-season forage production (lb/ac) under four irrigation treatments [based on percent evapotranspiration (ET) replacement] for four high quality forages: Eastern Gamma Grass, Tifton 85 Bermudagrass, Brown Midrib Forage Sorghum, and WW B-Dahl Old World Bluestem, Chillicothe, TX, 2007.

Seasonal Forage Production, 2007						
		Irrigation Treatment (% ET replacement)				
		0	33	66	100	
Forage	**No. cuttings**	----------------------- lb/ac --------------------------				
						Average
Eastern Gamma	1	6290	10900	7280	8390	**8210**
Tifton 85	2	5030	4390	4550	4390	**4590**
Brown Midrib	2	5960	7610	6050	7260	**6720**
WW B-Dahl	3	8460	9410	6870	8060	**8200**

Education and Demonstration Outreach

On 29 September 2005, the Chillicothe Research Station held its 100th Year Anniversary as an agricultural research station. Approximately 200 participants, including producers, researchers, extension personnel, agribusiness, and news media, from Wilbarger, Hardeman, and surrounding counties were involved in the morning program activities. A field tour included a stop in the proposed SDI study area that was supported by 319(h) funding through the Texas State Soil and Water Conservation Board (Figure 18). The benefits of drip irrigation as a means of using limited groundwater, reducing nitrate leaching, eliminating runoff, and efficiently managing groundwater and land resources were emphasized. Company representatives were also on hand to discuss the more technical aspects of SDI installation.

Figure 18. Field day at the Chillicothe Research Station. Dr. John Sij explains the SDI system and demonstrates crop production potential and flexibility of SDI.



More than 100 participants were at the field day held on April 10, 2008 at Chillicothe (Appendix E). A field stop took place in the completed drip area. Intensive cropping systems, tillage systems, and forage production under SDI were highlighted. A Proceedings/Field Day Handout was generated for distribution to participants. There were 41 participants at the Irrigation Training Program held in Chillicothe on August 19, 2008 (Appendix E). This program, supported by the Texas Water Development Board, and organized by TSSWCB, AgriLife Research, AgriLife Extension, and TWRI, discussed the use of center pivot and subsurface drip irrigation technology, the availability of cost-share programs for producers, proper irrigation timing, and accounting for nitrate levels in irrigation water when determining fertilization rates.

On August 20, 2008 the AgriLife Research Station at Chillicothe was visited by two teachers (one math and the other science) traveling from Louisiana to Arizona. They saw the research sign on the highway and were interested to learn more of what was being researched at the Chillicothe station. Their goal was to develop a PowerPoint presentation to use as a teaching tool in their classrooms. The teachers viewed different crops and cropping systems that included no-till, cover crops, and conventional-till systems under subsurface drip irrigation. The irrigation system and irrigation practices were explained as a way to manage water resources more efficiently under drip systems verses some pivots and furrow irrigation. They observed and took photos of the drip house, controllers, drip tape, emitters, and filters. They received pointers on how the controllers were programmed and how weather data were used to schedule irrigation for various crops. Precision farming techniques using a GPS, autosteer system to plant, spray, and map fields were explained. The teachers were extremely impressed with these modern technologies and our advances in agricultural production. They took many pictures. Their science programs will reach many young students for years to come, and hopefully they will credit the Chillicothe education and research programs funded in part by the Seymour Aquifer supplemental grant.

The general public can access information and project reports on SDI at the following web sites: http://www.tsswcb.state.tx.us/managementprogram/seymour and http://twri.tamu.edu/project-info/SeymourAquifer/.

In addition, quarterly reports and a year-end final report will be developed for the Texas State Support Committee of Cotton Incorporated that has provided grant support for a 2008 tillage systems study under SDI. Also, grant reports on the state's 2008 Cropping Systems Initiative will be generated over the course of a funded 2-year cropping systems SDI study. Within the last year funding from outside grants and contracts have exceeded the initial investment of $33,500 by more than a third, indicating the strong support from industry, state government, and commodity groups in the value of SDI as an educational and demonstration tool in improving agricultural production in the Texas Rolling Plains. Since the establishment of the initial drip system, an additional 18 acres were placed under drip at Chillicothe. Other specialty crops to be produced under contract arrangements using SDI in 2008 include experimental heat-tolerant corn hybrids, advanced Canola breeding lines, and food-grade black sorghum. Thanks to the financial support of TSSWCB and EPA, SDI offers producers additional crop production options to enhance economic returns, conserve groundwater resources, use and manage nitrates in groundwater, and improve their quality of life.

SUBSURFACE DRIP IRRIGATION EDUCATION

In addition to demonstrations and field days held at Chillicothe, a number of additional educational events were held for irrigators in the Haskell, Wichita-Brazos, and California Creek SWCDs to improve grower knowledge and understanding of BMPs for nutrient and irrigation management and how their operation may affect water quality and quantity in the Seymour Aquifer. Educational programs and information (Appendix E) were delivered through the SWCD technician and AgriLife Extension in cooperation with the TWRI, AgriLife Research, TSSWCB, NRCS, and Rolling Plains Groundwater Conservation District.

Extension began by evaluating existing resources. Based on this evaluation, a Nutrient Management Weblinks Document (Appendix D) was assembled for distribution at educational events.

An informational meeting for participating producers was held in Stamford, Texas on February 10, 2005 with 27 in attendance. Dr. Dana Porter (AgriLife Research) and representatives from Eco-Drip, presented a program on drip irrigation. Eco-Drip representatives discussed installation and operation, while Dr. Porter presented a program on water quality. Available funding, cost share assistance to producers, WQMPs, and BMPs were discussed with interested producers. In addition, the SWCD technician made several trips with participating producers in January, February, and March of 2005 to fields with existing drip systems to discus operation, installation of BMPs, nutrient management, cover crops, and no-till or minimum till practices.

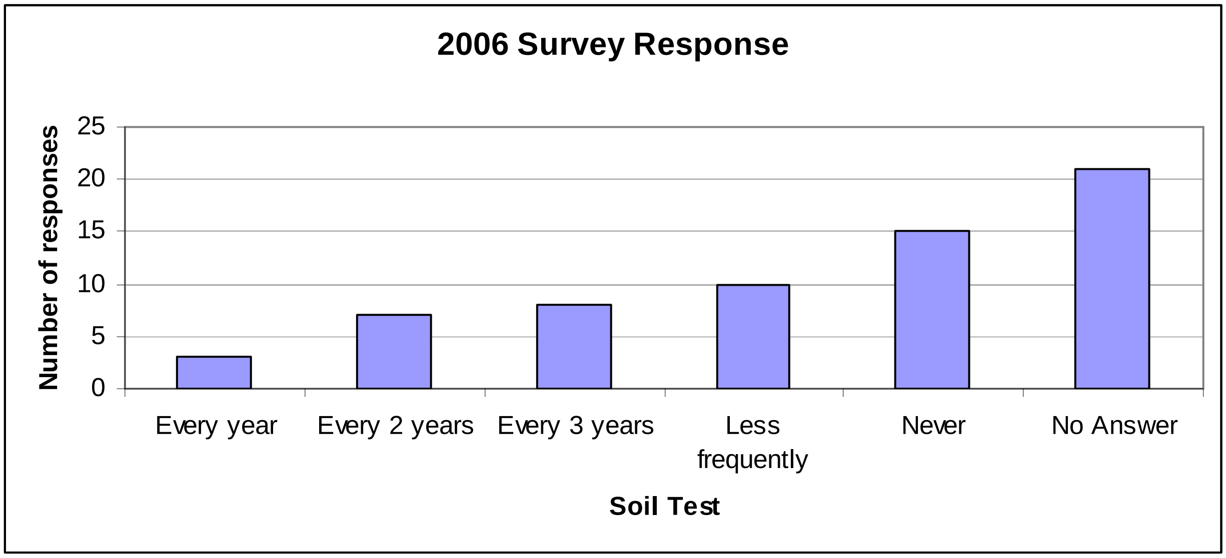
To keep the SWCDs and groundwater district updated on project activities, the SWCD technician attended all Haskell, California Creek and Wichita-Brazos SWCD meetings and Rolling Plains Groundwater Conservation District meetings from August 19, 2004 through August 31, 2008.

On January 11, 2006, AgriLife Extension hosted the Central Rolling Plains Ag Conference in Haskell. Counties involved included Haskell, Jones, Knox, Baylor, and Throckmorton. The 101 participants were provided an “Update on the Seymour Aquifer Project” and completed a survey on crop production and fertilizer use. Sixty-four farmers completed the survey. The survey showed the need for nutrient management education and incentives for soil testing as the majority of producers didn’t soil test at least once every 3 years (Figure 19).

On January 16, 2007, AgriLife Extension hosted the Central Rolling Plains Ag Conference in Stamford. At this program, the 77 participants were provided information on “How to use ET” for irrigation management.

On January 14, 2008, AgriLife Extension hosted the Central Rolling Plains Ag Conference in Haskell. At this program, the 123 participants were provided information on “Irrigation Technology.” Other topics included crop production update, cattle and wheat economies, cotton economics and management, sesame as an alternative crop, and an update on laws and regulations.

Figure 19. Results of a 2006 survey on how frequently soil tests were obtained and results used.



CONCLUSIONS

As anticipated, this project served as a catalyst to encourage the installation of subsurface drip irrigation (SDI) systems. Considerable interest has been generated in SDI and other more efficient irrigation methods through the efforts of project partners. Through technical and financial assistance provided by the project through the TSSWCB and Haskell, Wichita-Brazos and California Creek SWCDs, SDI systems were installed by 17 producers on over 1,000 acres. In addition, irrigation management was implemented through the WQMPs developed on over 1,800 acres and nutrient management was implemented on over 2,500 acres.

As hoped at the outset of the project, NRCS began providing funding for improving irrigation efficiency. Shortly after the initiation of the 319(h) project, the Seymour Aquifer Special Emphasis Area was established in FY2004 to improve irrigation efficiency and conserve water resources in Haskell, Knox, Baylor, Wilbarger, Hardeman and Foard counties. This program continues today replacing, updating, and reorganizing irrigation systems to improve efficiency and reduce the amount of water used from the aquifer. NRCS has provided more than $16 million dollars for this Special Emphasis Area to date. Installing efficient irrigation pipelines to deliver irrigation water to existing systems and installing center pivot sprinklers or converting existing systems to meet LPIC, LESA and/or MESA sprinkler systems or drip irrigations systems reduces the amount of water being lost to leaks and inefficient systems and reduces the amount of water used from the aquifer. In addition to the Seymour Aquifer Special Emphasis Area, a number of SWCDs identified improving irrigation efficiency as a priority County EQIP Resource Concern eligible for County Base EQIP funding.

In addition to implementing BMPs, a very important component of this project was conducting educational programs and demonstrations. Subsurface drip irrigation systems require careful management to function properly. Additionally, as seen from the results of the 2006 survey showing that a majority of producers do not soil test at least once every 3 years, there is a critical need for nutrient management education. Subsequently, the primary focus areas of the educational programs were nutrient management and irrigation management. Through seven programs conducted between 2005 and 2008, AgriLife Research and AgriLife Extension provided educational programs and demonstrations to 671 participants. The establishment of the permanent SDI demonstration site at Chillichothe will ensure that these programs are sustained for many years to come, and offer producers additional crop production options to enhance economic returns and water quality, and improve their quality of life.

Although not confirmed by field sampling, which showed no significant difference between the N budgets of SDI and pivot irrigation, model results suggest that leaching is approximately twice as likely under pivot irrigation as under SDI. The model results are consistent with the findings of Phene et al. (1992) and Hutmacher et al. (1992). However, based on results of this project, conversion from pivot to drip irrigation without better nutrient management will not significantly affect nitrate in the aquifer. In order to reduce inorganic N in the Seymour Aquifer hydrologic system, the inorganic N being delivered to the field through irrigation needs to be accounted for in nutrient management plans.

Irrigation water can be high in nitrates, ranging from 3 to 41 mg L^{-1}, and averaging 19 mg L^{-1} in the fields evaluated. Thus, irrigation water is currently a significant contributor to field-scale nitrate budgets. Irrigation water contributed from 40 to 130% of the amount of N harvested from the field. Thus, by taking credit for the N in irrigation water, producers can potentially help reduce nitrates in groundwater. Unlike drinking water, high nitrates in irrigation water may be considered an untapped N resource that can be a substantial benefit, financially, to producers.

Another important finding was that soil storage rather than irrigation method was the dominant factor influencing leaching potential of a given area. Thus, the sandier the soil the less water storage capacity it has and the higher its leaching potential. This suggests that future implementation of BMPs should be prioritized to areas with low soil storage capacity/high leaching potential soils.

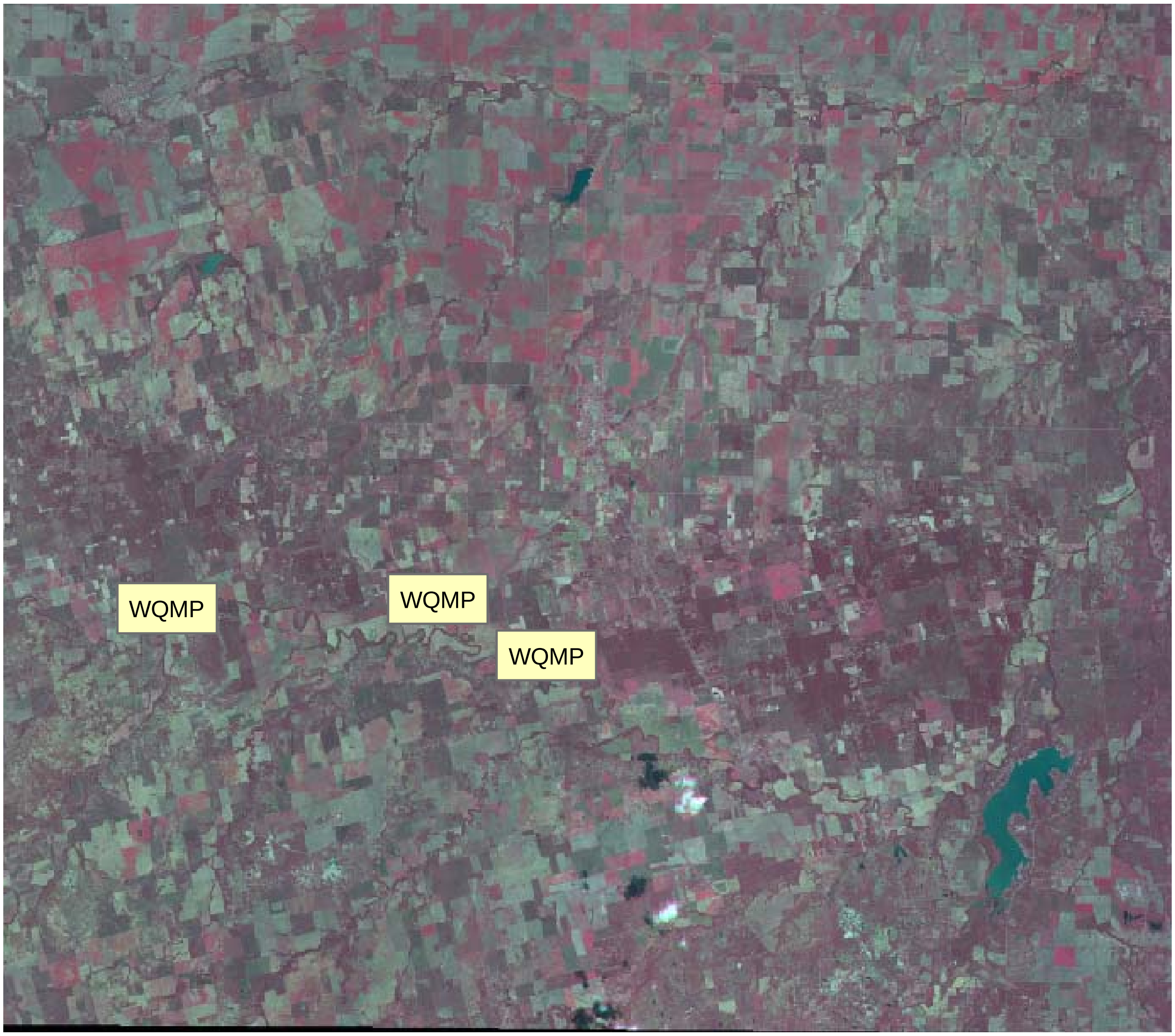
Residual soil N indicates the amount of N available for leaching between harvest and spring planting, if the whole soil profile were to be leached. The highest post-harvest N concentrations occurred after dry to normal precipitation years, indicating situations where the potential for N leaching out of the root zone and ultimately into the aquifer exists. The fallow season between continuous cotton rotations can provide months of considerable leaching risk, especially if significant rainfall occurs during this time. However, there was no significant buildup in N concentration in the deeper soil; additionally there was no obvious trend of increasing or decreasing soil N with depth. Thus, this study indicated that if leaching does occur, it occurs in wet years and during the fallow season when roots are not extracting water from the soil profile.

Finally, published literature documents that SDI is more water efficient than flood/furrow and sprinkler/spray irrigation systems. Local observations indicate that most SDI systems are being implemented in areas previously furrow irrigated or in areas not suitable for pivot irrigation. Conversion from furrow irrigation to SDI has the greatest potential to yield benefits in terms of water savings and water quality. Although the initial costs of implementing this practice are high, long-term (10 years) water yields from converting from furrow to SDI systems are approximately $100 to $300/ac-ft of water. However, issues with cotton root rot and some cultural practices hamper implementation on a greater scale.

Continued work is needed to improve conditions in the Seymour Aquifer. Educational programs on irrigation management and nutrient management are needed to encourage regular soil testing, better manage irrigation systems, and account for nitrate levels when determining N fertilizer needs. In conjunction with these educational programs, soil testing and water testing should be encouraged. If nitrate in the aquifer can be “mined” using irrigation water, substantial cost savings can be realized by producers while potentially improving quality of the water in the aquifer.

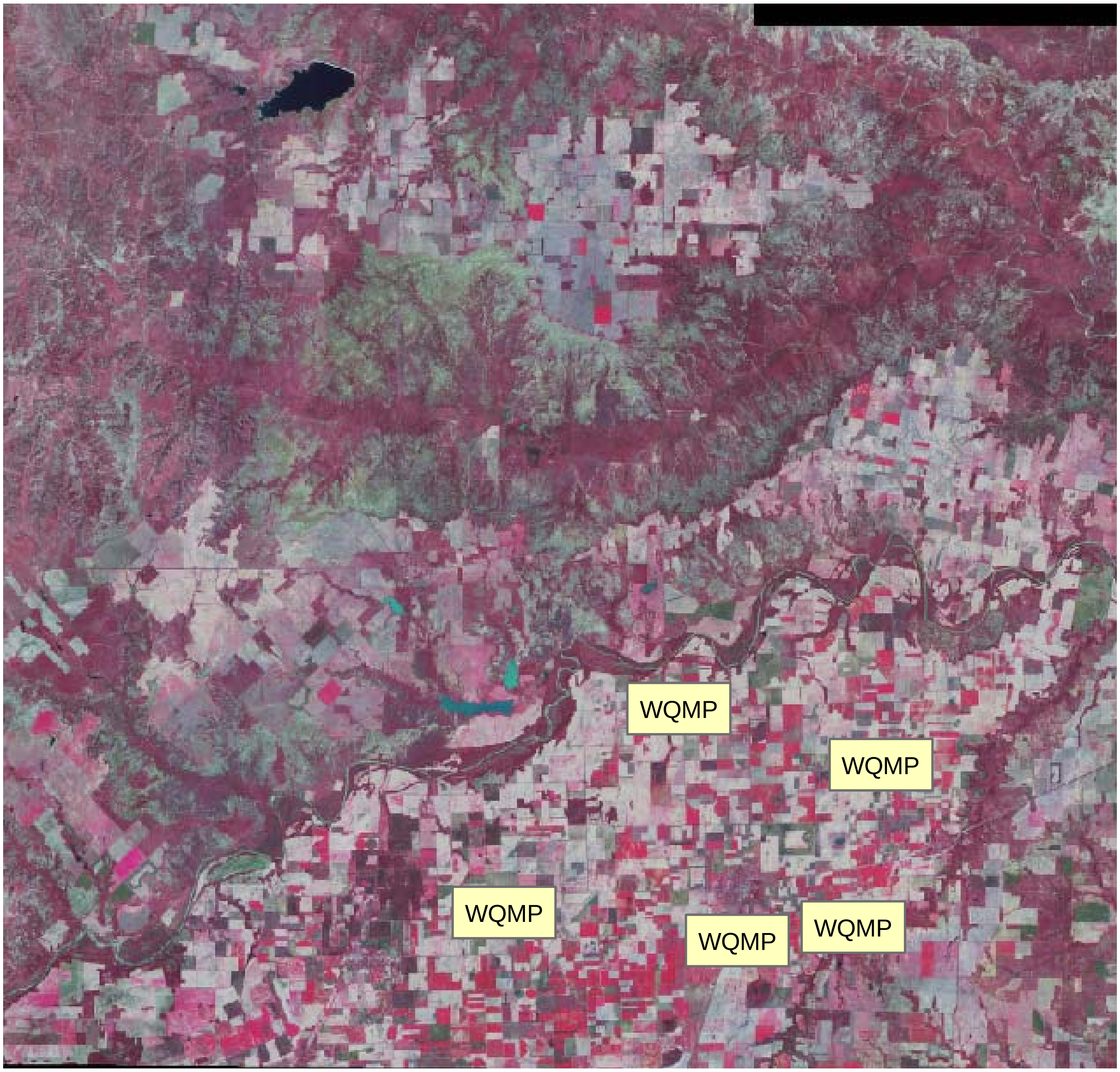
APPENDIX A

Location of WQMPs implemented in Jones, Haskell and Knox Counties



JONES COUNTY WQMP LOCATIONS

HASKELL COUNTY WQMP LOCATIONS



KNOX COUNTY WQMP LOCATIONS

APPENDIX B

Summary of N Balance Data for the Three Fields Over Three Years

Summary N Balance

Drip Field 1	2005		2006		2007	
	Mean	SD	Mean	SD	Mean	SD
			N kg/ha			
Residual Soil	266	146	114	71	91	71
Fertilizer	70		96		96	
Irrigation	51		118		38	
Total N input	387	146	328	71	225	71
Crop uptake	67	26	100	32	97	32
Post harvest	248	104	121	29	61	29
Potential leachable	**72**	**127**	**118**	**82**	**70**	**82**

Pivot Field 1	2005		2006		2007	
	Mean	SD	Mean	SD	Mean	SD
			N kg/ha			
Residual Soil	198	61	154	54	132	37
Fertilizer	49		96		96	
Irrigation	31		93		66	
Total N input	278	61	343	54	294	37
Crop uptake	40	17	50	56	102	23
Post harvest	138	36	163	43	51	24
Potential leachable	**105**	**69**	**130**	**63**	**142**	**45**

Drip Field 2	2005		2006		2007	
	Mean	SD	Mean	SD	Mean	SD
			N kg/ha			
Residual Soil	116	14	159	49	100	33
Fertilizer	73		111		111	
Irrigation	59		65		22	
Total N input	247	14	335	49	220	47
Crop uptake	91	22	57	23	79	11
Post harvest	124	22	117	34	105	58
Potential leachable	**36**	**38**	**162**	**48**	**36**	**43**

Pivot Field 2	2005		2006		2007	
	Mean	SD	Mean	SD	Mean	SD
			N kg/ha			
Residual Soil	184	10	73	10		
Fertilizer	60		111		111	
Irrigation	41		74		25	
Total N input	284	10	258	10	136	0
Crop uptake	69	29	90	42	59	17
Post harvest	157	36	81	25	39	26
Potential leachable	62	58	87	60		

Drip Field 3	2005		2006		2007	
	Mean	SD	Mean	SD	Mean	SD
			N kg/ha			
Residual Soil	144	43	155	40	62	25
Fertilizer	73		111		111	
Irrigation	56		79		26	
Total N input	273	43	345	40	199	25
Crop uptake	105	19	60	16	79	0
Post harvest	141	27	21	14	99	23
Potential leachable	**31**	**40**	**264**	**37**	**22**	**33**

Pivot Field 3	2005		2006		2007	
	Mean	SD	Mean	SD	Mean	SD
			N kg/ha			
Residual Soil	188	28	76	13		
Fertilizer	60		111		111	
Irrigation	39		181		34	
Total N input	287	28	368	13	145	0
Crop uptake	81	14	95	37	76	16
Post harvest	144	21	78	41	43	5
Potential leachable	**66**	**38**	**195**	**57**		

APPENDIX C
Modeling Report

INTRODUCTION

Nitrogen in the form of nitrate (nitrate-N) is the most pervasive contaminant of groundwater in Texas and the United states (Scanlon, 2003; Nolan et al., 2002). Although nitrate-N contamination in groundwater has been attributed to numerous different sources, including leaky septic tanks and oxidation of atmospheric N_2, the primary source of contamination in areas of high agricultural activity is leaching of artificial fertilizer or mineralized soil organic matter. It is estimated that less than 50% of the nitrogen fertilizer applied annually to croplands are taken up by crops. Most of the applied nitrogen remains in the soil as residual nitrogen. In the event of excessive rainfall or poor irrigation management, most of the residual soil nitrogen, often in the form of nitrates, can be leached below the plant root zone and eventually into underlying aquifer systems.

Agriculture has been implicated in nitrate contamination of groundwater in several parts of the US and the world (Spalding and Exner, 1993; Strebel et al., 1989). Increase in groundwater nitrate-N concentrations from less than 5 mg L^{-1} in 1947 to 12 mg L^{-1} in 1974 in Merrick County, Nebraska was attributed primarily to the increase application of commercial fertilizers to croplands (Gormly and Spalding, 1979; Spaldimg et al., 1978). Contamination of the Seymour aquifer, in north-central Texas is also believed to be caused from agricultural activity (Hillin and Hudak, 2003). Of the nine major Texas aquifers, the Seymour aquifer was found to have the highest concentrations of nitrate (Hudak, 2000). More than half the wells in this aquifer have nitrate-N concentrations above the USEPA's maximum contaminant level (MCL) of 10 mg L^{-1}, recommended for drinking water sources (Ewing, Jones & Pickens, 2004; Hillin and Hudak, 2003). Although 90% of the water pumped is used for irrigation, the Seymour also serves as the only source of potable water for a number of small municipalities and homes.

Implementation of nutrient and irrigation best management practices have been suggested as ways of reducing the potential for nitrate to leach beyond the crop root zone. One BMP that have received considerable attention, in recent years is the conversion from pivot and flood irrigation to subsurface drip irrigation (SDI). A major advantage of SDI is its greater efficiency (90-95%) compared to pivot irrigation (75-85%) and flood (<75%). The greater efficiency of SDI reduces irrigation water requirements and subsequently the potential for water and nitrate to leach below the root zone. Despite its efficiency, assessment of the overall feasibility and benefits of converting to SDI at scales greater than at the field level is difficult. The lack of a comprehensive assessment tool as well as the high initial cost of SDI ($800-$1000) compared to other irrigation methods have led to reluctance in farmers adopting SDI. The objective of this study was to use readily available soils, irrigation and weather data to develop a geospatial framework in ArcGIS for assessing the benefits of converting between irrigation methods. The frame work will be applied to a section of Seymour aquifer to evaluate the effects of converting from pivot to drip irrigation on leaching potential (estimated as deep drainage) in cotton over a twenty week period. An additional goal of this project was to determine, for the study area, the optimal degree of conversion required to reduce leaching potential to an acceptable level i.e. if an aquifer-wide conversion was more feasible compared to a selective conversion approach where only fields in the most sensitive areas were converted to SDI.

MATERIALS AND METHODS

Description of Study Area

The study was conducted on a section of the Seymour aquifer referred to as the Seymour hydrologic unit area (HUA) (Figure 1). The Seymour HUA, covers an approximate area of 110,000 hectares of Haskell and Knox counties in the Rolling plains area of North-central Texas (33° 27’ N, 99° 36' W, 450 m above mean sea level). More than 75 % of the HUA is cropland, of which about 34,000 hectares is under irrigation. The major crops cultivated in area are cotton, peanut, wheat and sorghum with most of the land either flood or pivot irrigated. Average depth to groundwater is about 8 m, but can range from 1 to 18m. In addition to the relatively shallow depth to groundwater, soils overlying the aquifer are generally very deep and well-drained with medium to high infiltration rate. Under conditions of high rainfall or over irrigation the potential for contaminants leaching to the groundwater is great.

The climate in the area is semi-arid with average annual precipitation of 610 mm and potential evapo-transpiration (PET) of approximately 1780 mm. Most of the precipitation occurs during the cotton growing season (April – October) as sporadic high intensity thunderstorms. Scanlon (2003) estimated a recharge rate of 5-33 mm per year for the Seymour aquifer. Most of this recharge is believed to be from infiltration of rainfall through the soil into the aquifer. In addition to nitrate-N contamination, which has been found in more than 70% of the wells in the HUA, the USGS has also reported cases of arsenic, cadmium, selenium, fecal bacteria and pesticide contamination.

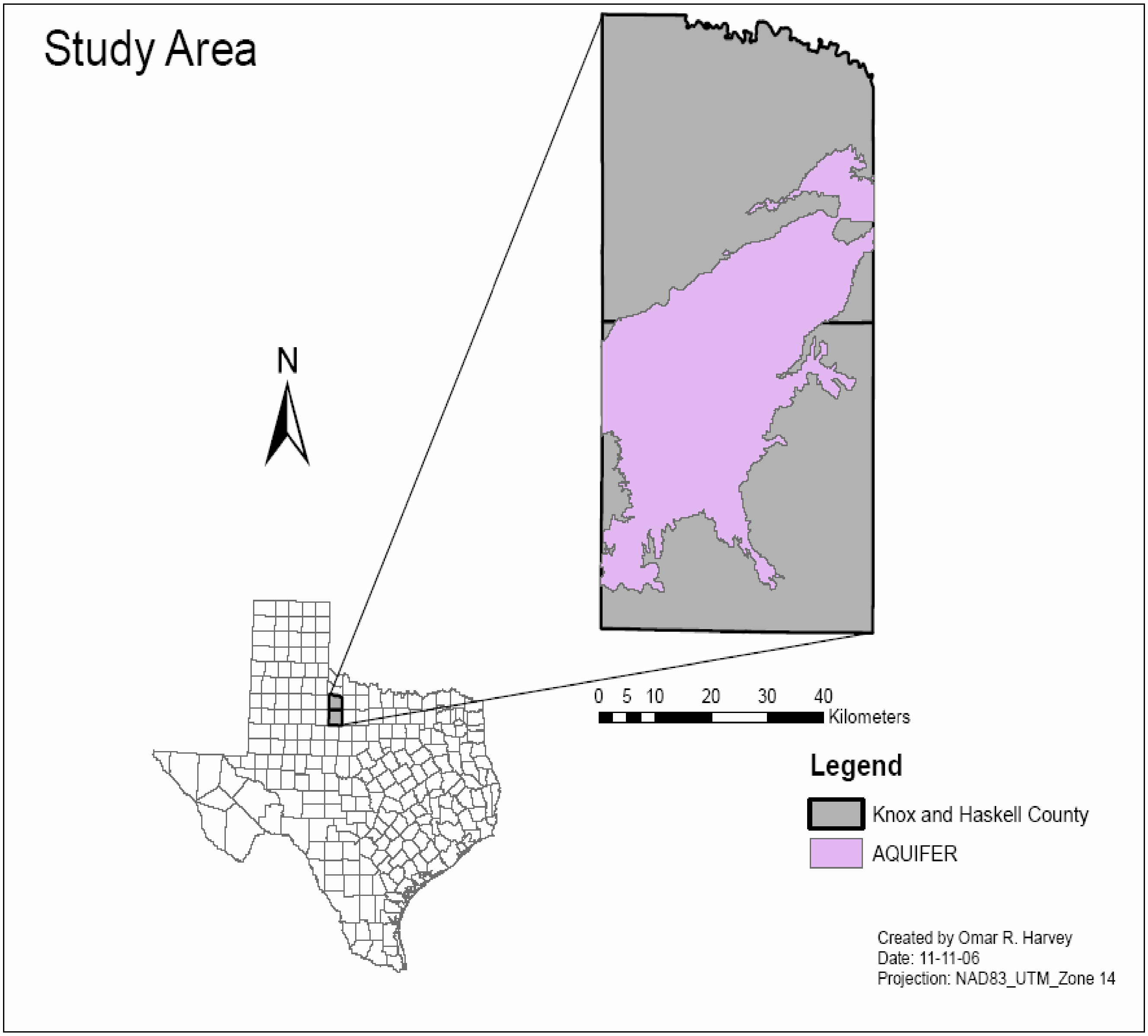


Figure 1. Map of study area showing Seymour aquifer hydrologic unit area (HUA).

Data Requirement and Collection

Data requirement was determined by considering a simple water balance approach for estimating deep drainage. Components of the water balance are shown in Figure 2. It was assumed that all the water entering or leaving the system can be accounted for by the processes shown. By applying the mass balance equation, Input – Output = 0, the water balance can be calculated as,

$$P + I - ET - DD - RO - \Delta S = 0 \qquad [1]$$

where P is precipitation , I is irrigation , ET is evapotranspiration, DD is deep drainage, RO is runoff and ΔS, is the change in soil storage over the period of interest. All the components of the water balance are in depth units. By re-arranging equation 1 and assuming that run-off is negligible or equal to zero, deep drainage can then be calculated as:

$$DD = P + I - ET - \Delta S \qquad [2]$$

Equation 2 indicates that the amount of water that will drain below a certain soil depth is dependent on the amount added through rainfall or irrigation, the amount that is lost through evapotranspiration and the water storage capacity of the soil to the depth of interest. Estimates or measured values for these parameters are therefore required to assess leaching potential beyond the root zone. Additionally, land-use information for identifying areas where different irrigation practices are employed is also needed, as well as study area boundary files. To ensure that the assumption of negligible or zero run-off is valid the study area should be relatively flat or large enough such that cross boundary flow can be considered negligible. In this case an elevation map of the study area may be required.

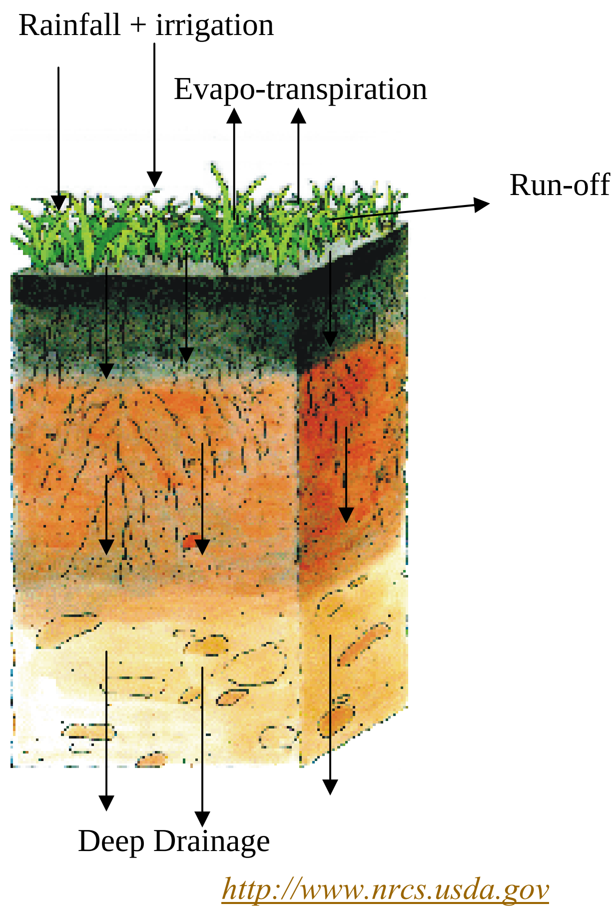


Figure 2. Components of the water balance used to evaluate leaching potential.

For the Seymour aquifer all the required data, described above, were easily accessible and free of charge. The data used in this study was for the 2005 cotton growing season (May – October). Precipitation and reference ET data were obtained from the Irrigation Technology Center's, Texas evapotranspiration network database (http://texaset.tamu.edu/), which has a weather station on the Seymour aquifer. To obtain estimates of actual ET for cotton under SDI and pivot irrigation , the reference ET was multiplied by crop co-efficients. For pivot irrigation crop co-efficients were obtained from the Texas ET network, while for SDI crop coefficients were calculated as a function of growing degree days (DeTar, 2004). Irrigation data were obtained from farmer's record and it was assumed that, on average, all other farmers followed a similar irrigation regime. Another possible source of weather data was the National Weather Database collected at nearby airports.

Soils and landuse data were obtained for Knox and Haskell counties from the NRCS soils datamart database (http://soildatamart.nrcs.usda.gov/). Soils data was obtained as shapefiles in SSURGO 2.1 format and landuse was obtained as 2005 National Agricultural Imagery Program (NAIP) aerial photographs. Aquifer boundary shapefile was obtained from Texas Water Development Board (www.twdb.state.tx.us/) and, county shapefiles and elevation (DEMS) from Texas Natural Resource Information System (www.tnris.state.tx.us/). The distribution of soil by series is shown in Fig. 2.

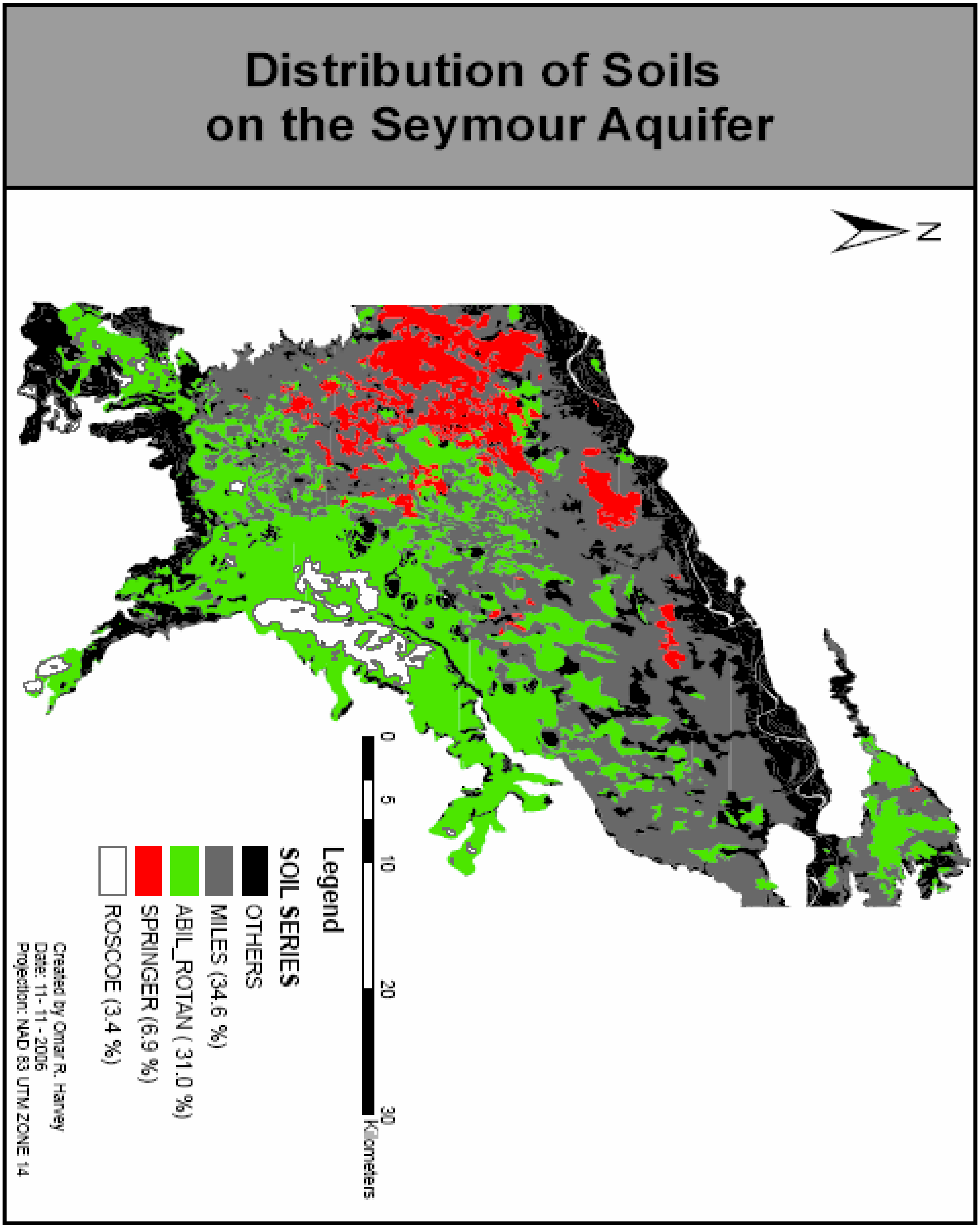


Figure 2. Distribution of soils by series in study area showing major soil series by area (numbers in parenthesis).

Soil storage capacity as a function of depth was calculated using soil texture information from soil series profile description (obtained from county soil survey report) and storage parameters from Rawls et al. (1992). A summary of soil series description and storage parameters used in calculation is shown in Tables 1 and 2, respectively. Calculated storage capacity for selected soil series is shown in Table 3. Precipitation, irrigation, and ET for each two week interval as well as twenty week cumulative values were compiled into tables, imported into ArcGIS and then joined to the study area soils layer.

Table 1. Soil texture as a function of depth for selected soil series

Depth (cm)	Soil Series							
	Miles	Abilene-rotan	Springer	Altus	Winters	Hardeman	Enterprise	Sagerton
	Textural class§							
0-30	fsl	cl	lfs	fsl	fsl	fsl	fsl	cl
30-50	scl	c	lfs	fsl	sc	fsl	fsl	c
50-100	scl	c	fsl	scl	sc	fsl	fsl	c
100-150	scl	c	fsl	scl	sc	fsl	fsl	cl
150-180	scl	cl	fsl	fsl	cl	fsl	fsl	cl
180-200	scl	cl	fsl	fsl	cl	fsl	fsl	cl
200-250	fsl	cl	fsl	fsl	cl	fsl	fsl	cl

§ cl, clay loam; c, clay; scl, sandy clay loam; fsl, fine sandy loam; lfs, loamy fine sand; sc, sandy clay.

Table 2. Soil storage capacity by textural class

Textural class	Storage capacity ($cm\ cm^{-1}$)
fsl	0.11
scl	0.11
c	0.13
cl	0.12
lfs	0.07
l	0.15
sil	0.20
sicl	0.05
sc	0.10

Table 3. Calculated soil storage capacity as a function of depth for selected soil series.

Depth (cm)	Soil Series							
	Miles	Abilene-rotan	Springer	Altus	Winters	Hardeman	Enterprise	Sagerton
	Soil storage (cm)							
0-30	3.3	3.6	2.1	3.3	3.3	3.3	3.3	3.6
0-50	5.5	6.2	3.5	5.5	5.3	5.5	5.5	6.2
0-100	11.0	12.7	9.2	11.0	10.3	11.0	11.0	12.7
0-150	16.5	19.2	14.7	16.5	15.3	16.5	16.5	18.7
0-200	22.0	25.2	20.2	22.0	21.3	22.0	22.0	24.7
0-250	27.5	31.2	25.5	27.5	27.3	27.5	27.5	30.7

Site Selection and Deep Drainage Calculation

Most of the pivot irrigated land on the aquifer was concentrated around, the Seymour aquifer “irrigation corridor”, a diagonal area running from the south-west to north-east end of the HUA (Figure 3). This area is likely to be where most of the conversion from pivot to drip irrigation occurs. The entire area was gridded with 8 km by 6 km (4000 ha) pixels. The topography of the area was generally flat, suggesting that the assumption of negligible or no run-off was valid. Based on the aerial photograph the irrigation corridor was divided into three irrigation management units or IMUs, each covering an area of 16000 ha (4 grid pixels). Figure 4 shows the soil distribution in each IMU.

The precipitation, irrigation, ET and soil storage tables were joined to each IMU and the field calculator used to develop expressions for calculating deep drainage based on equation 2 (Figure 12). Deep drainage was calculate as depth of water (cm) and as volume of water (ac-ft) drained below a soil depth of 250 cm. Deep drainage in depth was used to compare leaching potential as a function of soil series and, drainage volume was used to compare leaching potential between IMUs.

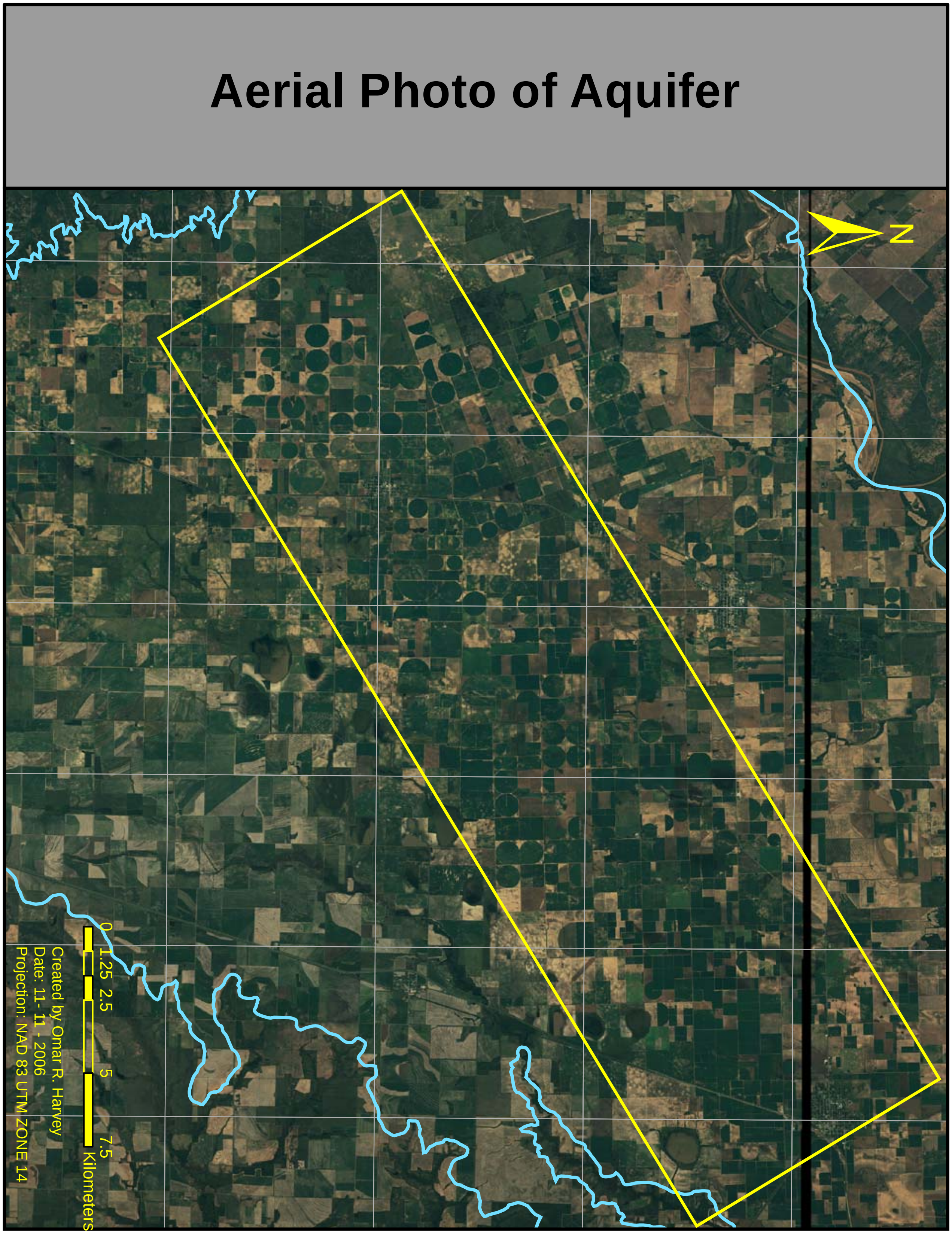


Figure 3. Aerial photograph of the study area showing area of high concentration of pivot irrigated land (yellow diagonal rectangle). Blue lines indicate aquifer boundary.

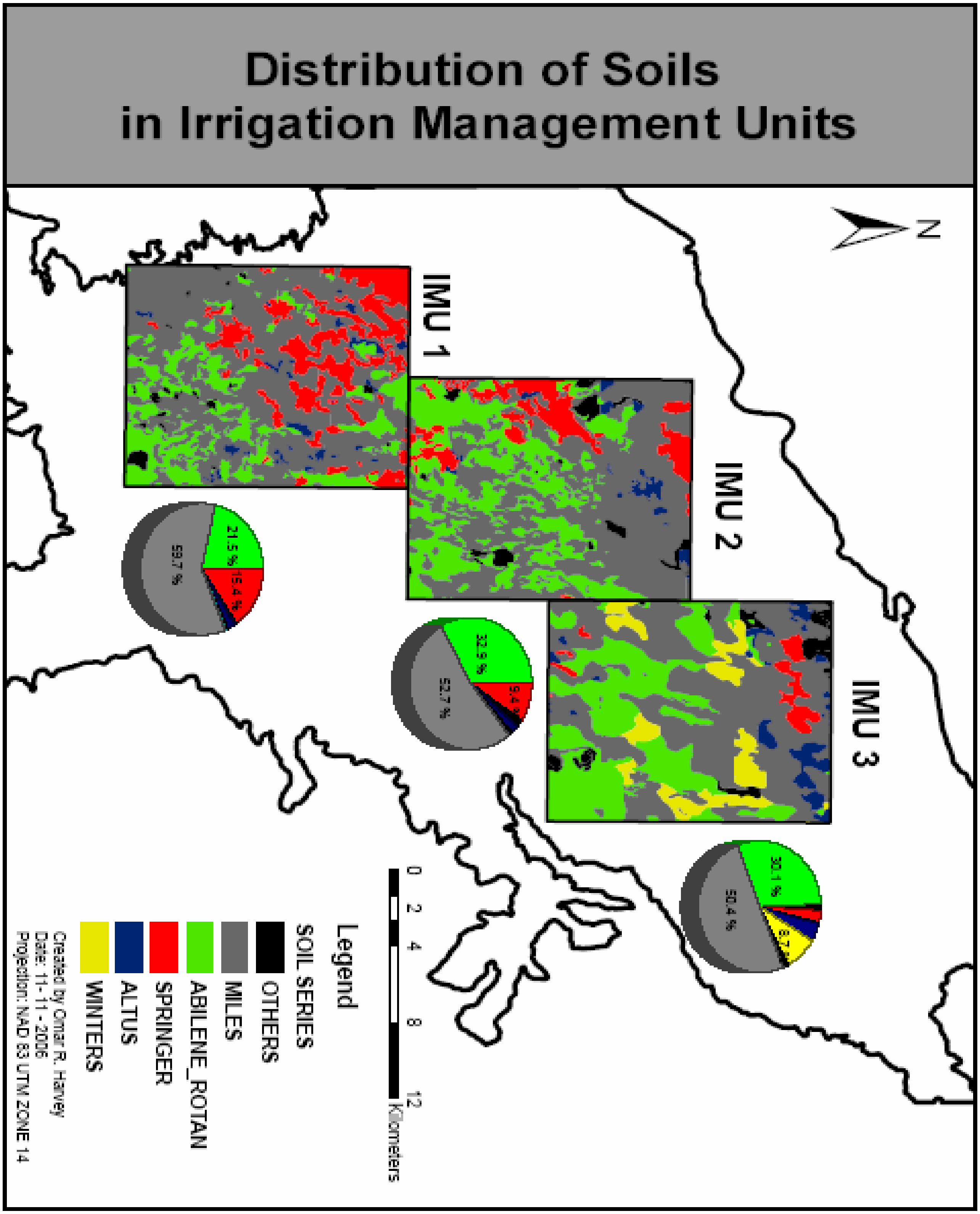


Figure 4. Distribution of soils in irrigation management units (IMU). Pie charts show percent of total IMU area covered by each soil series.

RESULTS AND DISCUSSION

The dominant soil series overlying the Seymour hydrologic unit area are Miles, Abilene-Rotan and Springer (Figure 1). Together they account for more than 70 % of the HUA and 80-95% of the irrigation management units and are generally coarse-textured, range from loamy fine sands to clay loams and have water storage capacity of approximately 28, 31, and 26 cm respectively (Table 1 and 3). Leaching potential follows the order Springer > Miles > Abilene-Rotan (consistent with calculated storage capacity) and was estimated to be 10, 8, 6 cm under subsurface drip irrigation and 17, 16 and 15 cm under pivot irrigation, respectively. These results also suggest that leaching is approximately twice as much likely under pivot irrigation than under sub-surface drip irrigation. The quantity of water applied over the 20 week study period was the same for both irrigation methods suggesting that soil storage capacity rather than irrigation method was the dominant factor influencing leaching potential between soil series (Table 4).

Total estimated deep drainage was approximately 10,000 and 22,000 ac-ft under SDI and pivot irrigation, respectively. Deep drainage was similar for all three irrigation management units (Figures 5-7). That deep drainage values were similar in all IMUs was surprising since there was a greater percentage of Miles and Springer series in IMU1 and IMU2 compared to IMU3. This suggests that although the soil series affect the leaching potential, the volume of deep drainage contributed to total leaching potential is dependent on the areal extent of a soil series.

Table 4. Total water input and output over study period for subsurface drip and pivot irrigation.

	Pivot	Sub-surface drip
Precipitation (cm)	45.2	45.2
Irrigation (cm)	34.9	35.0
Evapotranspiration (cm)	57.7	49.6

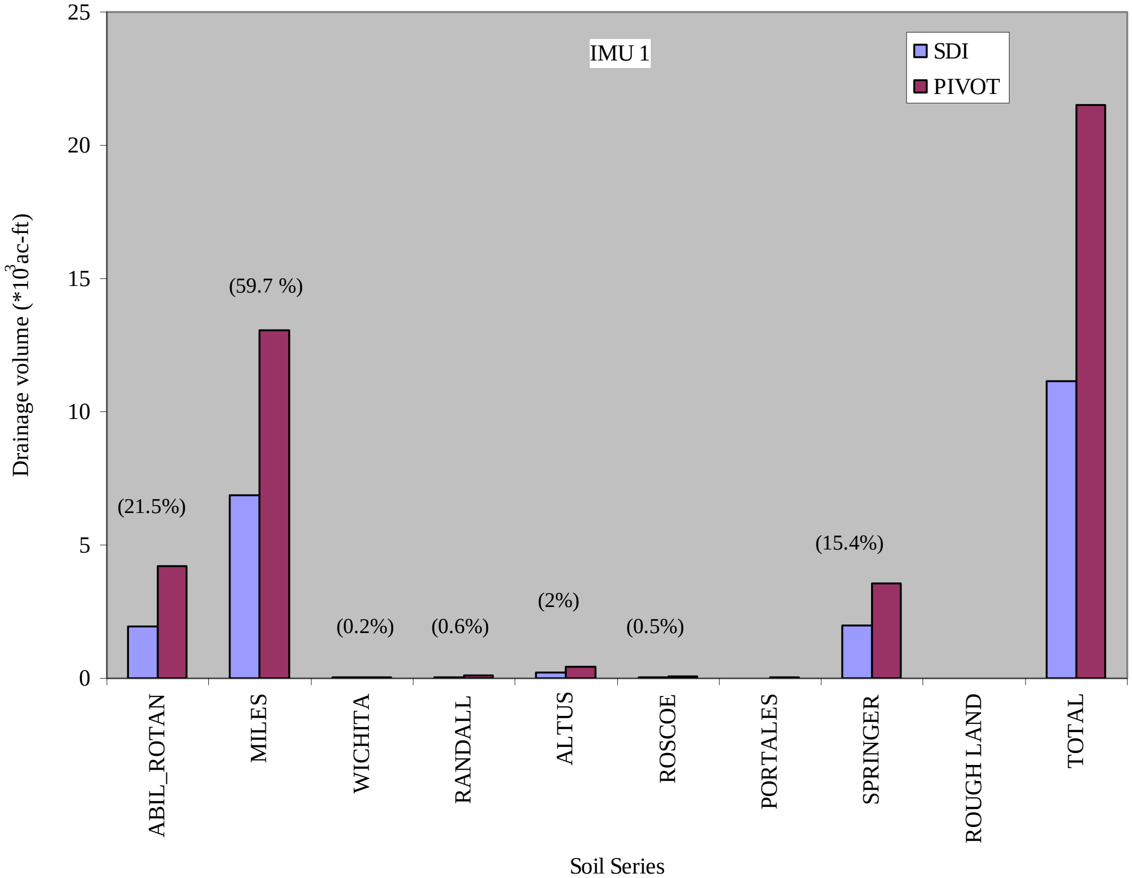


Figure 5. Estimated deep drainage for irrigation management unit 1 (IMU1) showing contribution of different soil series to total drainage volume. Numbers above the bars indicate percent of IMU covered by soil series.

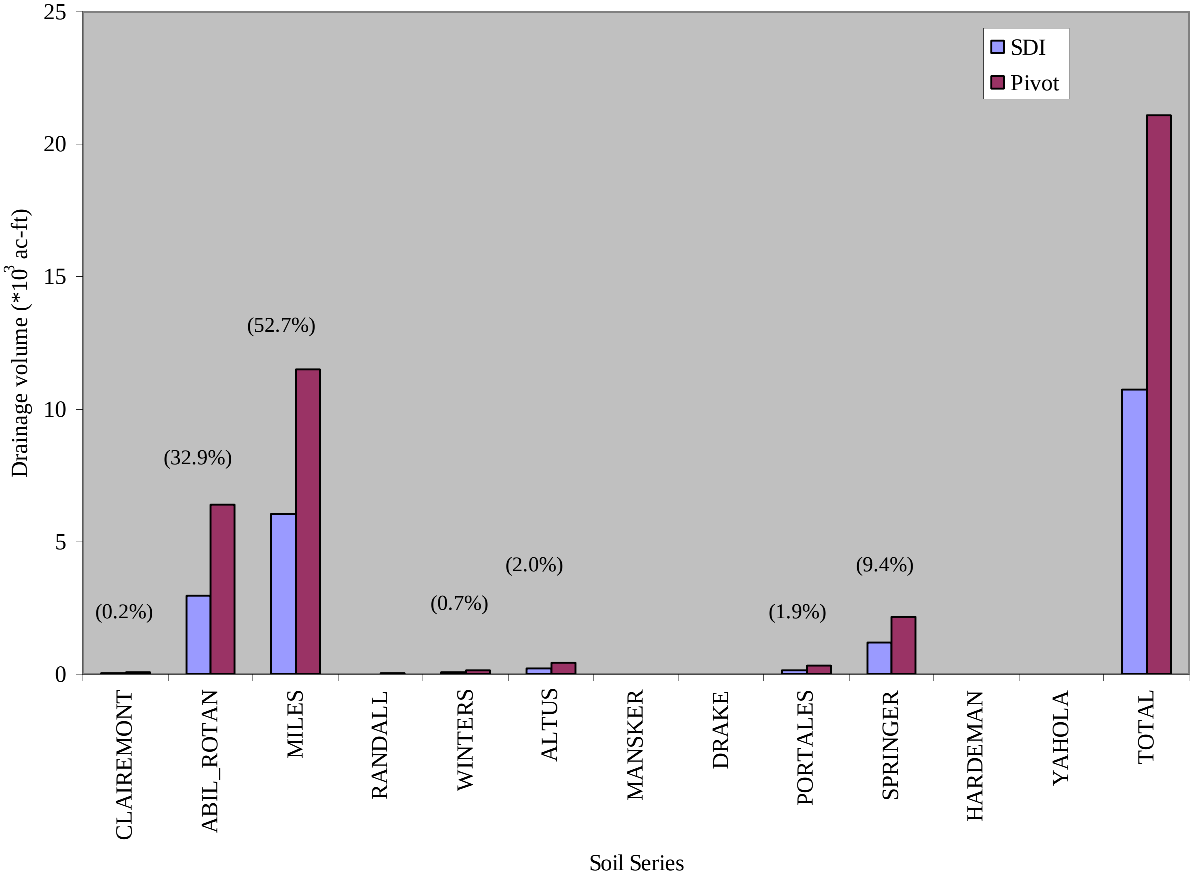


Figure 6. Estimated deep drainage for irrigation management unit 2 showing contribution of different soil series to total drainage volume. Numbers above the bars indicate percent of IMU covered by soil series.

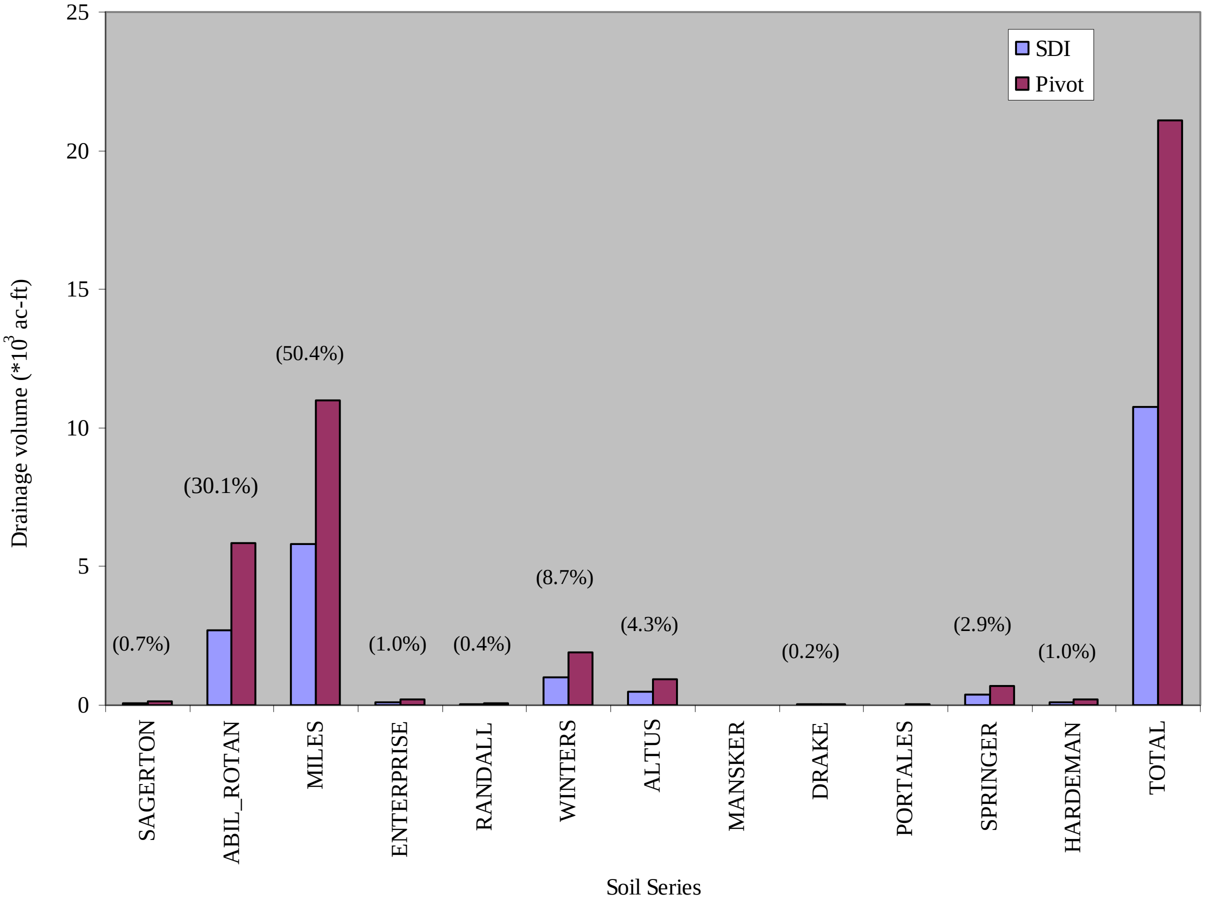


Figure 7. Estimated deep drainage for irrigation management unit 3 showing contribution of different soil series to total drainage volume. Numbers above the bars indicate percent of IMU covered by soil series.

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APPENDIX D
Nutrient Management Resources

Nutrient Management Resources

Website/Publication	Link
The Texas Nutrient Management Website	http://nmp.tamu.edu/
Texas Water Resources Education	http://texaswater.tamu.edu/
Nutrient Management - NRCS	http://www.nrcs.usda.gov/technical/nutrient.html
Comprehensive Nutrient Management Plan - Colorado	http://www.extsoilcrop.colostate.edu/Soils/cnmp/index.html
Comprehensive Nutrient Management Plan - Georgia	http://pubs.caes.uga.edu/caespubs/pubcd/B1185.htm
Developing a Nutrient Management Plan - Illinois	http://iah.aces.uiuc.edu/pdf/Agronomy_HB/12chapter.pdf
Nutrient Management Plan - Iowa	http://www.extension.iastate.edu/Publications/NMEP8.pdf
Comprehensive Nutrient Management Plan - Nebraska	http://cnmp.unl.edu/
Nutrient Management - Penn State	http://pubs.cas.psu.edu/PubSubject.asp?varSubject=Nutrient%20Management
Why a nutrient management plan? West Virginia	http://www.wvu.edu/~agexten/forglvst/why.htm
Agriculture and Agri-Food Canada Nutrient Management Planning	http://www.agr.gc.ca/pfra/water/nutrient_e.htm
Managing Crop Nutrients Through Soil, Manure, and Effluent Testing	http://publications.tamu.edu/publications/Animal_Wastes/L-5175.pdf

Nutrient Management Resources

Website/Publication	Link
What Happens to Nitrogen in Soils	http://publications.tamu.edu/publications/Soils/E-59%20What%20Happens%20to%20Nitrogen%20in%20Soils.pdf
Phosphorus Too Much and Plants May Suffer	http://publications.tamu.edu/publications/Soils/L5241%20%20Phosphorus-Too%20Much%20and%20Your%20Plants%20May%20Suffer.pdf
Testing Your Soil - How to Collect and Send Samples	http://publications.tamu.edu/publications/Soils/L-1793%20Testing%20Your%20Soil.pdf
Calculating Fertilizer Needs for Your Lawn	http://publications.tamu.edu/publications/Turfgrass/Calculating%20Fertilizer%20Needs.pdf
Reducing the Risk of Groundwater Contamination by Improving Livestock Holding Pen Management	http://publications.tamu.edu/publications/Water/B-6031%20Reducing%20the%20Risk%20-%20Livestock%20Holding.pdf
Reducing the Risk of Groundwater Contamination by Improving Fertilizer Storage	http://publications.tamu.edu/publications/Water/B-6026%20Reducing%20the%20Risk%20-%20Fertilizer%20Storage.pdf
Reducing the Risk of Groundwater Contamination by Improving Household Wastewater Treatment	http://publications.tamu.edu/publications/Water/B-6029%20Reducing%20the%20Risk%20-%20Household%20Wastewater%20Trmt.pdf
Reducing the Risk of Groundwater Contamination by Improving Wellhead Management and Conditions	http://publications.tamu.edu/publications/Water/B-6024%20Reducing%20the%20Risk%20of%20Groundwater%20-%20Wellhead%20Mgmt.pdf

Nutrient Management Resources

Website/Publication	Link
Reducing the Risk of Groundwater Contamination by Improving Pesticide Storage and Handling	http://publications.tamu.edu/publications/Water/B-6025%20Reducing%20the%20Risk%20-%20Pesticide%20Storage.pdf
Reducing the Risk of Groundwater Contamination by Improving Petroleum Product Storage	http://publications.tamu.edu/publications/Water/B-6027%20Reducing%20the%20Risk%20-%20Petroleum%20Product.pdf
Reducing the Risk of Ground Water Contamination by Improving Hazardous Waste Management	http://publications.tamu.edu/publications/Water/B-6028%20Reducing%20the%20Risk%20-%20Hazardous%20Waste.pdf
Reducing the Risk of Ground Water Contamination by Improving Livestock Manure Storage and Treatment Facilities	http://publications.tamu.edu/publications/Water/B-6030%20Reducing%20the%20Risk%20-%20Livestock%20Manure.pdf
Reducing the Risk of Ground Water Contamination by Improving Milking Center Wastewater Treatment	http://publications.tamu.edu/publications/Water/B-6032%20Reducing%20the%20Risk-Milking%20Center.pdf

APPENDIX E
News Releases and Publications

News Release
September 24, 2004

Haskell Soil & Water Conservation District
607 N 1st St. East, Suite B
Haskell, TX 79521
(940)864-8516 ext. 4

Sign Up For Project 319 Drip Installation

The Haskell, Wichita Brazos, and California Creek Soil & Water Conservation Districts are now accepting applications for Drip Irrigation Cost Share installation. Applications are available at the SWCD office from 8:00 a.m. to 4:30 p.m. Applications will be accepted thru November 1, 2004. Qualifying farms will be awarded contracts on a point system basis.

The maximum cost-share per contract is $30,000. To be eligible for a contract the land has to have a history of irrigation and have a minimum of 4 gallons per minute per acre of available water. Eligible producers can receive 60% cost share to install the systems not to exceed $1000.00 per acre.

Contact Dale Carroll at the SWCD office for additional information.

10-7-2004

Haskell SWCD
607 North 1st Street East
Haskell, Texas 79521

[940] 864-8516 ext.4

News Release
October 7, 2004

Cost Share Assistance Available for Drip Irrigation

Applications for cost share assistance are currently being taken at the **Haskell, Wichita-Brazos, California Creek Soil and Water Conservation district** offices. The offices are located in Haskell, Anson, and Knox City USDA Service Centers.

To be eligible for cost share assistance the land must be cropland, have a history of irrigation and have wells that produce at least 4 gallons per minute per acre. Cost share rate is 60% based on an average cost of $1,000.00 per acre. Each contract is limited to a maximum of $30,000.00. Applications will be accepted until November 1, 2004.

For more information call the Haskell SWCD at 864-8516 ext. 4, Wichita-Brazos at [940] 658-3526 ext.3, California Creek SWCD at {325} 823-3371 ext. 4.

Drip irrigation program signup applications accepted til Nov. 1

The Haskell, Wichita Brazos and California Creek Soil and Water Conservation Districts are accepting applications for Drip Irrigation Cost Share installation. Applications are available at the SWCD office from 8:00 a.m. to 4:30 p.m. Applications will be accepted through Nov. 1. Qualifying farms will be awarded contracts on a point system basis.

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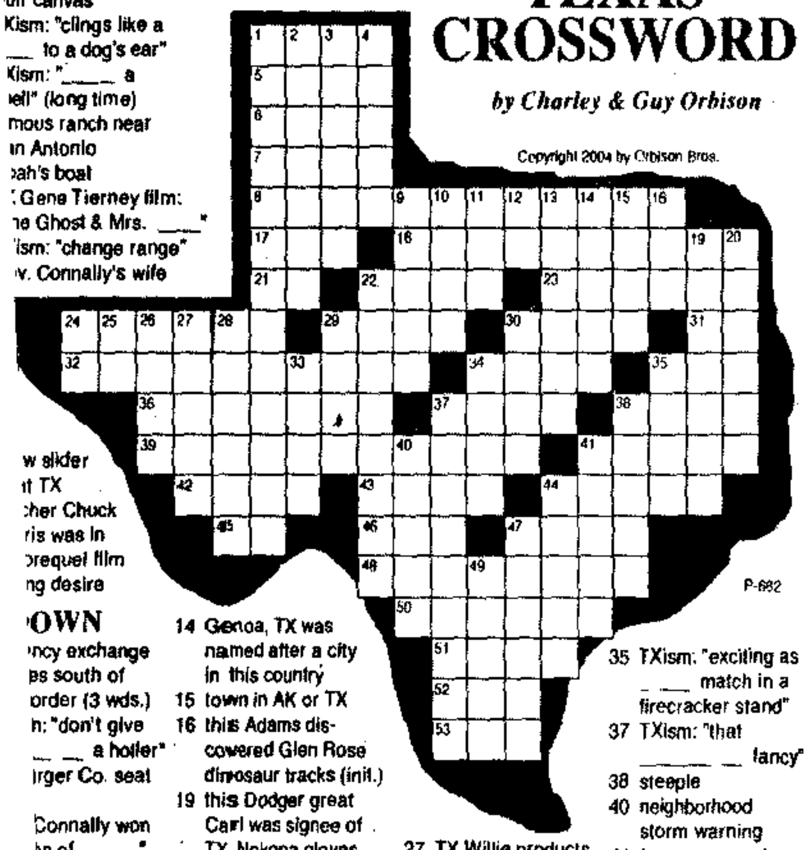
Contact Dale Carroll at the SWCD office for additional information.

The Original TEXAS CROSSWORD

by Charley & Guy Orbison

Copyright 2004 by Orbison Bros.



P-692

orn-bearing
uff canvas
Kism: "clings like a
___ to a dog's ear"
Kism: "____ a
ell" (long time)
mous ranch near
n Antonio
ah's boat
Gene Tierney film:
e Ghost & Mrs. ____"
ism: "change range"
v. Connally's wife

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t TX
her Chuck
ris was in
prequel film
ng desire

OWN

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es south of
order (3 wds.)
h: "don't give
__ __ a holler"
rger Co. seat

Connally won
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VII
rney '43 film:
en Can ___"

14 Genoa, TX was named after a city in this country
15 town in AK or TX
16 this Adams discovered Glen Rose dinosaur tracks (init.)
19 this Dodger great Carl was signee of TX Nokona gloves
20 handsome
22 San Antonio gallery: "The ...
27 TX Willie products
28 TXism: "call __ _ ___" (quit)
29 boot underrid-
35 TXism: "exciting as _ ___ match in a firecracker stand"
37 TXism: "that ______ __ fancy"
38 steeple
40 neighborhood storm warning
41 luxury space at Texas Stadium
44 this TX Dennis

Sign Up For Projet 319 Drip Installation

The Haskell, Wichita Brazos, and California Creek Soil & Water Conservation Districts are now accepting applications for Drip Irrigation Cost Share installation. Applications are available at the SWCD office from 8:00 a.m. to 4:30 p.m. Applications will be accepted thru November 1, 2004. Qualifying farms will be awarded contacts on a point system basis.

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Contact Dale Carroll at the SWCD office for additional information.

O'Brien sets

Financial Focus

By Joe McMeans

What Do All Those Indexes Mean, Anyway?

The Dow Jones Industrials...the NASDAQ Composite...the S & P 500...The Russell 2000... The list of stock market indexes goes on and on. But how much attention should you pay to all these lists? Actually, if you know the basics of these indexes, you may be able to gain some insights that can help you make better investment decisions.

Some popular indexes

By reading financial publications, you can find a broad listing of stock market indexes. But here, in a nutshell, are a few of the more popular ones:

* Dow Jones Industrial Average - The Dow Jones Industrial Average, comprised of 30 leading companies, is often considered the one index that indicates the general state of the market.

* NASDAQ Composite Index -The NASDAQ tracks the stocks on the National Association of Securities Dealers Automated Quotation System (NASDAQ) ...

Political Calendar

The following have authorized *The Knox County News* to announce their candidacy for public office.

Knox County Judge
JOE LOWE - D
TRAVIS FLOYD - R

Knox County Tax Assessor/Collector
LINDA PARKER - D
BUD HOGAN - R

Political Advertising Paid For By The Above Named Candidates

Sign up for project 319 drip installation

The Haskell, Wichita Brazos and California Creek Soil & Water Conservation Districts are now accepting applications for Drip Irrigation Cost Share installation. Applications are available at the SWCD office from 8:00 a.m. to 4:30 p.m. Applications will be accepted through November 1, 2C Qualifying farms will be awarded contracts on a point system basis.

The maximum cost-share per contract is $30,000. To be eligible for a contract he land has to have a history of irrigation and have a minimum of 4 gallons per minute per acre of available water. Eligible producers can receive 60% cost share to install the systems not to exceed $1000.00 per acre.

ROLLING PLAINS EXPRESS

HASKELL COUNTY FSA

OFFICE HOURS: 8:00 A.M. TIL 4:30 P.M. MONDAY THRU FRIDAY

PHONE 940 864-[illegible] VOICE 940 864-3095 FAX

E-Mail US At: Glenn.Brzozowski@[illegible]

COUNTY COMMITTEE: Joe Wheatley, [illegible], [illegible]le Turner

County Executive Director: Glenn R. Brzozowski Farm Loan Manager: Larry P McDaniel

Volume 04 Issue [illegible] October 19, 2004

COST SHARE ASSISTANCE AVAILABLE FOR DRIP IRRIGATION

Applications for cost share assistance are currently being taken at the Haskell, Wichita-Brazos, California Creek Soil and Water Conservation district offices. The offices are located in Haskell, Anson, and Knox City USDA Service Center

To be eligible for cost share assistance the land must be cropland, have a history of irrigations and have wells that produce at least 4 gallons per minute per acre. Cost share rate is 60% based on an average cost of $1,000.00 per acre. Each contract is limited to a maximum of $30,000.00. Applications will be accepted until November 1, 2004

For more information call the Haskell SWCD at 864-8516 ext 4, Wichita-Brazos at (940) 658 3526 ext 3, California Creek SWDC at (325) 823-3371 ext.4

COUNTY COMMITTEE ELECTION

Nominations for the county committee election in LAA3, were due in the county office by the close of business September 3. Joyce Robertson of Weinert and Joe Wheatley of Haskell have been nominated for LAA3 election. The election ballots will be mailed out starting November 8. Voters have until December 6 to return their ballots to the county office. Elected committee members and alternates take office on January 1, 2005.

Voters are asked to vote for only the candidate of their choice. Write-ins on the ballot are acceptable. Please keep in mind, the return envelope must be signed in the space provided in order for the ballots to be considered valid for count.

Prospective Voter Requirements If you're on the mailing list for this newsletter, the chances are you are an eligible voter. Anyone who meets the requirements in 1 or 2, plus 3, below, is eligible to vote.

1. Be of legal voting age and have an interest on a farm or ranch as either of the following:
   - An owner, operator, tenant, or sharecropper, or
   - A partner in a general partnership or member of a joint venture that has an interest in a farm as an owner, operator, tenant, or sharecropper:

2. Not of legal voting age, but supervises and conducts the farming operation on an entire farm.

3. Eligible to participate in any FSA program that is provided for by law, regardless of the status of funding.

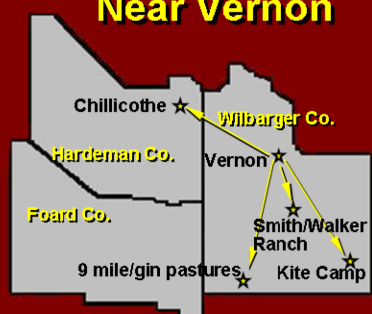
Discrimination Prohibited No person shall be denied the right to vote because of race, color, national origin, sex, religion, age, disability, political beliefs, sexual orientation or marital or family status.

Contact the county office if you have questions about voter eligibility.

FIELD DAY COMMITTEE

Jimmy Barnett
Todd Baughman
James Brockriede
Janet Case
Paul DeLaune
Heather Easterling
Clifford Graf
David Jones
Donald Kelm
Kay Ledbetter, Proceedings Editor
Gene Obenhaus
Mike Phillips
Bill Pinchak
Jackie Rudd, Co-Chair
John Sij, Co-Chair
John Sweeten
Horace Jo Tabor III
Alan Waggoner
Trudy Wallace
Eldon Whitman

Research Locations Near Vernon



Other Research Locations:

- Lake Lewisville – Lewisville
- Richards Ranch – Jacksboro
- Pittman Ranch – Muenster
- Bear Creek Ranch – Aledo
- R.A. Brown Ranch – Throckmorton
- Buck Creek Project – Childress, Collingsworth, and Donley Counties

Texas AgriLife Research and Extension Center

TEXAS A&M SYSTEM
CHILLICOTHE/VERNON

ROLLING PLAINS SPRING FIELD DAY

AgriLIFE RESEARCH
Texas A&M System
Improving Life Through Science and Technology.

AgriLIFE EXTENSION
Texas A&M System
Improving Lives. Improving Texas.

ROLLING PLAINS SPRING FIELD DAY
CHILLICOTHE RESEARCH STATION
CHILLICOTHE, TEXAS
APRIL 10, 2008
"AGRICULTURE IS LIFE"

8 - 9 a.m. **Registration and refreshments**
8:50 a.m. **Welcome, announcements, instructions for tour**
(Donald Kelm, District Extension Administrator, Texas AgriLife Extension Service)

9 - 10:45 a.m. **Field Tours**
1st departure @ 9 a.m.
2nd departure @ 9:20 a.m.

STOP 1: "Small Grains Breeding and Cultivar Advances for the Rolling Plains," Dr. Jackie Rudd (Wheat Breeder, Texas AgriLife Research) and Dr. Amir Ibrahim (Small Grains Breeder, Texas AgriLife Research)

STOP 2: "Subsurface Drip Irrigation: Potential for Rolling Plains Agriculture," Dr. John Sij (Agronomist, Texas AgriLife Research)

STOP 3: "Mesquite: Plague or Renewable Biofuel Resource?" Dr. Jim Ansley (Rangeland Ecologist, Texas AgriLife Research)

STOP 4: "Fertilizer: It's Application and Management," Dr. Sam Feagley (State Soil Environmental Specialist, Texas AgriLife Extension Service) and Dr. Paul DeLaune (Environmental Soil Scientist, Texas AgriLife Research)

11 a.m. Reassemble at Headquarters Barn
Dr. John Sweeten — moderator

11- 11:10 a.m. "Texas Energy Update"
Representative Rick Hardcastle, District 68

11:10 - 11:20 a.m. "Farm Bill Provisions Update"
Lewis Britt (Office of Congressman Mac Thornberry)

11:20 - 11:50 a.m. "It's Almost In The Bin…Now What Do I Do?"
Stan Bevers (Extension Economist, Texas AgriLife Extension Service)

Noon -1 p.m. **Catered Lunch** (Food With A Flair)
Introductions and comments: Dr. John Sweeten (Resident Director, Texas AgriLife Research, Amarillo/Vernon)

Keynote Address—"Wheat and Sorghum R&D Initiatives within AgriLife Research: Platforms for Genetic Gains," Dr. Bill McCutchen (Associate Director, Texas AgriLife Research)

Continuing Education Units (3) available for Texas pesticide license holders and Certified Crop Producers.

FIELD DAY SPONSORS

AgriPro	Jacks Farm Equipment
Bank of Vernon	Kelly Propane & Fuel
BASF	Osborne's
Bolton's Crown Quality, Inc.	Red River Ranch Supply
DuPont Crop Protection	Sesaco
Farmers Co-Op—Chillicothe	Texas Wheat Producers Board
Farmers Co-Op—Vernon	Waggoner National Bank
First National Bank, Chillicothe	Waggoner & Sons Electric
Hardeman Grain & Seed	Wright Insurance Agency
Herring National Bank	W.T. Waggoner Estate

Agenda

Chillicothe, Texas
August 19, 2008

8:00 – 8:30	Registration
8:30 – 8:40	Welcome and Introductions *John Sij*
8:40 – 8:50	Overview of Information Resources *Dana Porter, Extension Agricultural Engineer at Lubbock*
8:50 – 9:15	Soil Moisture Management, ET networks and Other Tools *Dana Porter, Extension Agricultural Engineer at Lubbock*
9:15 – 9:45	Cost-Share Update - EQIP Program; Water Quality Management Plan Program Overview *Reggie Quiett, NRCS District Conservationist* *Judy Albus, TSSWCB*
9:45 – 10:00	Break
10:00 – 10:30	Legislative Update Regarding Water Issues *Jack Campsey, Gateway Goundwater Conservation District* *Mike McGuire, Rolling Plains Groundwater Conservation District*
10:30- 11:00	Water Quality Considerations *Paul DeLaune, AgriLife Research Environmental Soil Scientist*
11:00 – 11:30	Irrigation Management and Timing *Robert Lemon, Extension Agronomist*
11:30 – 12:15	Applications of center pivot & micro-irrigation technologies: *Cy McGuire, Eco-drip* *Andy Brumley, Waggoner and Son Electric, Inc*
12:15 – 1:15	Lunch On Site
1:30 – 2:30	Center Pivot irrigation demonstration in the field *Andy Brumley, Waggoner and Son Electric, Inc* *Producer Discussion*
2:30	Break & Move to next site
2:30 – 3:30	Microirrigation (drip irrigation) demonstration in the field *Cy McGuire, Eco-drip* *Producer Discussion*