2012 North Plains Corn Irrigation Demonstration Project: Efficient Profitable Irrigation in Corn (EPIC)

Kenny et al., 2013

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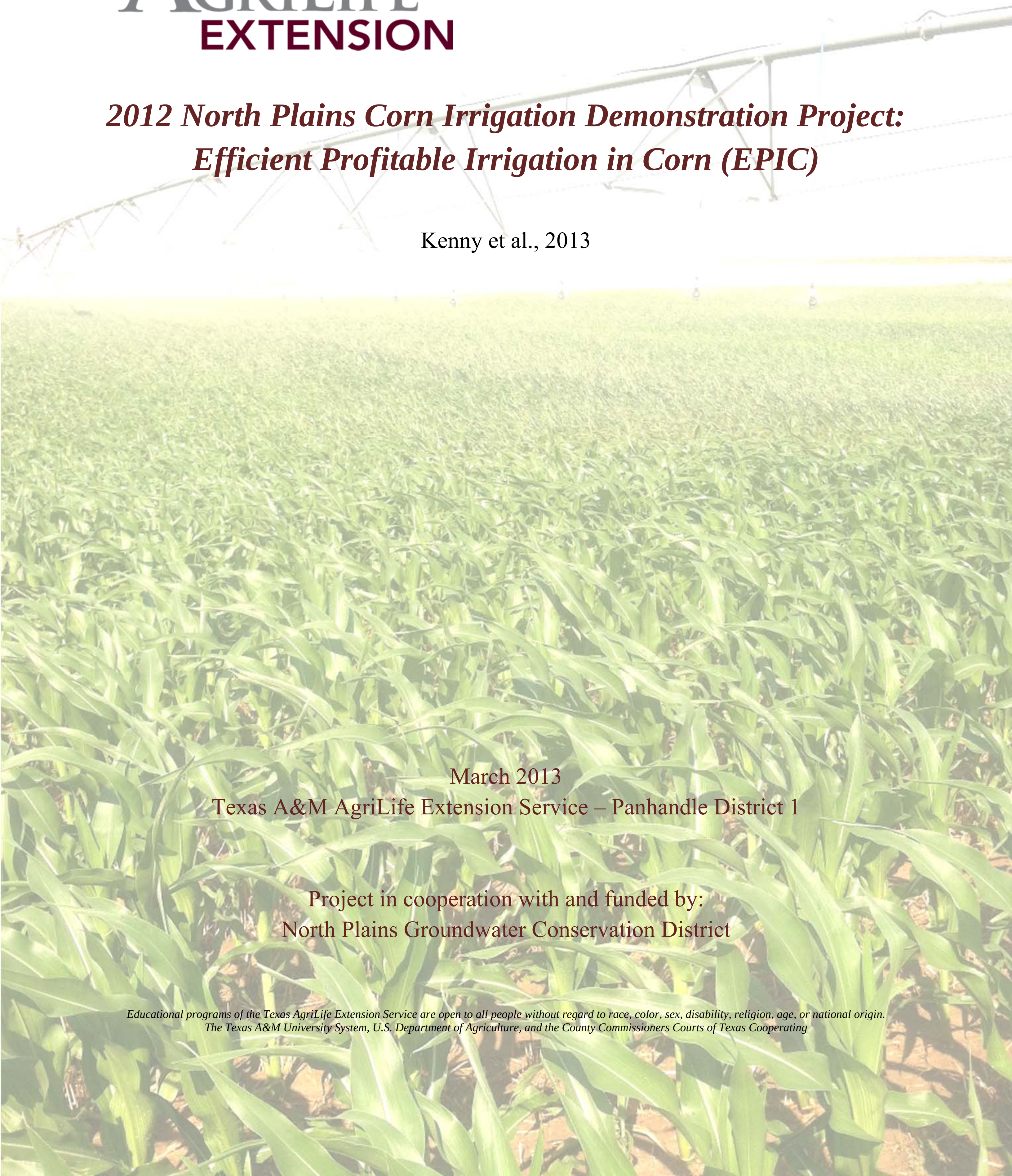
Texas A&M AgriLife Extension Service – Panhandle District 1

Project in cooperation with and funded by:
North Plains Groundwater Conservation District



Front cover picture:
Lipscomb County EPIC Plot. Photo taken by Nicholas Kenny.

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Table of Contents

List of Figures

List of Tables

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Nicholas Kenny, Scott Strawn, J.R. Sprague, Marcel Fischbacher, Michael Bragg,
Kristy Synatschk, Brad Easterling Brandon McGinty, Jody Bradford

Executive Summary

Efficient Profitable Irrigation in Corn (EPIC) is a results demonstration effort conducted by the Texas A&M AgriLife Extension Service and funded primarily by the North Plains Groundwater Conservation District. The foundation of EPIC is the principle of managing irrigation water for maximized profitability as a means for making optimal economic and agronomic use of the water resource, namely the Ogallala Aquifer. EPIC targets grain corn producers who historically employ efficient irrigation systems and solid agricultural practices in a production strategy focusing on maximized yields (revenue). EPIC is designed to be a multi-year, staged project that helps high-yield grain corn producers maximize their on-farm production potential and reduce applied irrigation water. Potential regional water savings under partial adoption of this practice is estimated to exceed 37,500 acre-feet or 12 Billion gallons annually.

EPIC's in-field, scientific approach utilized two side-by-side field plots (separate fields or split fields), maintaining one plot as a control and one plot as a treatment. Irrigation is managed on the treatment plot to meet two objectives; 1) maintain or improve yield as compared to the control and 2) reduce pumped irrigation water by one to four inches. In the second season, 2012, six (6) irrigated corn producers in the Texas North Plains became EPIC cooperators, contributing field-scale control and experimental plots, all farm operations, and all production costs with no monetary compensation from EPIC. The EPIC project provided Pivotrac monitoring (where applicable) with producer access and AquaSpy soil probes and AquaPlanner crop modeling without producer access in order to maintain the validity of the control plot. The control plot was titled the "Legacy" plot and was managed according to the specific producer's standard practice and the "EPIC" plot was managed with Texas A&M AgriLife inputs based on best management practices and information from management tools.

The 2012 EPIC results are tabulated below (EX1). In four of the five cooperator plots, grain corn yields were maintained and increased with a corresponding reduction in irrigation water applied. It is important to note that the design and scope of this project did not include on-site replication and the results were obtained primarily for the purpose of demonstrating a scientifically sound approach to managing water. Although very compelling, the results should be viewed anecdotally as local examples rather than conclusive scientific evidence.

EX1 - 2012 North Plains EPIC field results. Control plots are labeled "Legacy" and experimental plots are labeled "EPIC".

Location	Plot	Water (Inches) Irrigation[3]	Soil[4]	Precipitation[3]	Total	Yield (Bu/ Acre)	WUE[5]
Dallam[1]	EPIC	30.0	0.86	5.66	*36.5*	*274.0*	7.5
Hutchinson	Legacy	23.0	**2.14**	5.80	*30.9*	*255.8*	8.3
	EPIC	21.8	**4.18**	5.80	*31.8*	*272.9*	8.6
Lipscomb	Legacy	25.9	3.72	6.13	*35.8*	*97.5*	2.7
	EPIC	25.8	3.74	6.13	*35.6*	*136.1*	3.8
Moore[2]	East	19.0	3.75	9.94	*32.6*	*127.3*	3.9
	West	22.9	1.77	8.70	*33.4*	*131.7*	3.9
Ochiltree	Legacy	41.1	**(3.46)**	4.48	*42.1*	*236.7*	5.6
	EPIC	33.0	**(1.49)**	4.48	*36.0*	*265.3*	7.4
Sherman	Legacy	22.5	5.94	7.57	*36.0*	*219.7*	6.1
	EPIC	19.9	5.78	10.28	*36.0*	*243.2*	6.8

[1] The Dallam County field was managed similarly on both sides, following the basic EPIC protocol.
[2] The Moore County fields suffered severe hail damage on 14 June.
[3] Irrigation and precipitation totals were provided by AquaPlanner using PivoTrac monitoring records.
[4] Soil water was measured using early and late season gravimetric sampling at the Hutchinson and Ochiltree locations (**bold**). The soil water extraction at the remaining four fields was modeled by AquaPlanner. Negative values ( ) indicate more water in the soil late in the season compared to the early measurement.
[5] WUE refers to water use efficiency defined as bushels of corn per inch of TOTAL water (bu/ inch)

Early season indications and project concept promotion was accomplished through four corn irrigation field days during August, conducted in Morse, Perryton, Etter, and Dalhart, Texas on August 21, 22, 23, and 24, respectively. The total recorded audience during these meetings was approximately 200 people and up to five continuing education units offered at each venue.

This project is designed to be repeated for two additional seasons, through 2014, funding pending. The EPIC protocol is also expected to be expanded to other irrigated grain corn production areas through the Southern High Plains.

2012 North Plains Corn Irrigation Demonstration Project: Efficient Profitable Irrigation in Corn (EPIC)

Nicholas Kenny[1], Scott Strawn[2], J.R. Sprague[2], Marcel Fischbacher[2], Michael Bragg[2], Kristy Synatschk[2], Brad Easterling[2], Brandon McGinty[2], & Jody Bradford[2]

Introduction

From the 2011 Panhandle Regional Water Plan Task 2 Report: Agricultural Water Demand Projections (Marek, 2009) submitted to the Texas Water Development Board, irrigated corn acreage accounts for 39% of the total irrigated acreage (approximately 475,000 acres) and accounts for 53% of the pumped water within Region A (21 counties). Corn is most concentrated in the four-county cluster including Dallam, Hartley, Moore, and Sherman Counties, accounting for approximately 380,000 acres (77% of Region A total corn acres) with a corresponding pumped water rate of 19 acre-inches per acre and a 67% water consumption share. Corn's predominance throughout Region A is credited primarily to the economic advantage that corn has shown over many other regional crops, specifically in areas with sufficient water capacity to produce high yielding corn.

In 2010, the Texas AgriLife Extension Service conducted a tertiary evaluation of irrigation scheduling strategies and management tools (Graf, 2010) that indicated that 1) corn can profitably be produced on less applied irrigation water than generally considered ideal (100% of Evapotranspiration), 2) corn producers with excess water availability tend to pump and apply more water than necessary, and 3) multiple irrigation management tools demonstrated potential for reducing irrigation water applied and increased producer profitability. Ancillary evidences indicated that many producers in corn cropping systems are receptive to increased irrigation management intensity to improve profitability.

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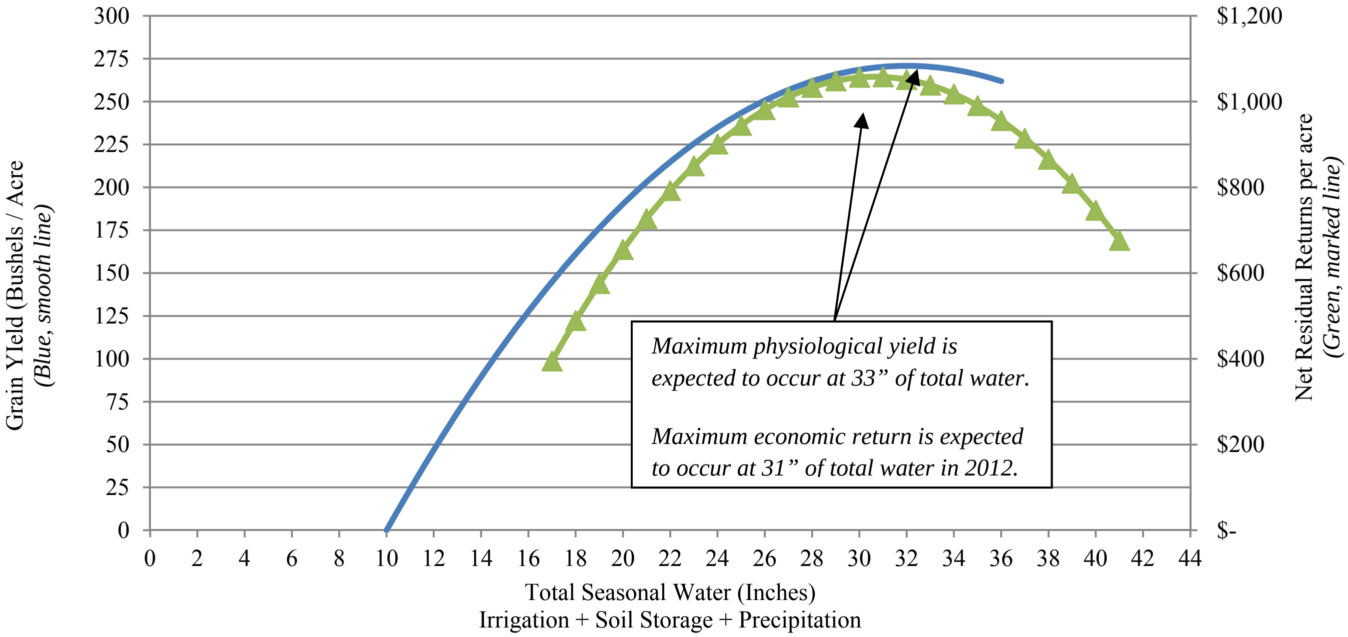
Figure 1: Texas North Plains Grain Corn Production Function (smooth blue line) and Net Per-Acre Grain Corn Residual Returns per unit of total Seasonal Water (marked green line). The production function was developed based on Texas North Plains field and research data including localized Agri-Partners Data. The economic component of this figure is derived from the *2010 Texas Crop and Livestock Enterprise Budgets – Texas High Plains*, adjusted for $6.50 per bushel of grain corn retail price and $4.00 per thousand cubic feet (MCF) natural gas purchase price. This chart is indicative of the 2012 production season, based on 5-inches of in-season precipitation and 4-inches of available soil water.



Efficient Profitable Irrigation in Corn (EPIC) is a results demonstration effort conducted by the Texas A&M AgriLife Extension Service and funded primarily by the North Plains Groundwater Conservation District. This project is designed to address the adoption of improved irrigation management strategies to increase water use efficiency, crop productivity, and production profitability. 2012 is the second year of the EPIC protocol within the North Plains Groundwater Conservation District.

Objective

The overall objective of the EPIC project is to demonstrate irrigation management methods to improve grain corn production profitability in the Texas North Plains. The primary operational objectives of the project are:

1. Reduce applied irrigation water by a total of one to four inches, and
2. Maintain or improve grain corn yield.

The identified goals of achieving these objectives are increased profitability and conserved water. The primary focus of this project is irrigation management with respect to high-end yields and maximized profits. The secondary applicable objective is the demonstration of the value and usefulness of multiple irrigation management tools, namely AquaSpy Soil Moisuture Probes, AquaPlanner modeling, and PivoTrac Monitoring.

Implications

The perception typically associated with reductions in irrigation water, either through capacity or regulatory restrictions, is that any reduction is accompanied by decreased yield and revenue. It is anticipated that effectively demonstrating the economic merit of strategic reductions in applied irrigation water will generate a production incentive to better manage the water resource. Within the eight counties of the North Plains Groundwater Conservation District, a timely reduction of one-inch of applied irrigation water across an estimated 450,000 acres (2011 USDA National Agricultural Statistics Service) leads to the potential mitigation of 37,500 acre-feet or greater than 12 billion gallons of water, annually.

Methodology and Study Activity

Task 1: Applied Research Demonstration Project

Six grain corn producers were identified and selected to participate in the EPIC project as cooperators, one from each of the following counties: Dallam, Hutchinson, Lipscomb, Moore, Ochiltree, and Sherman (Dallam Co. line). Each cooperator was responsible for providing one field-scale control plot and one field-scale experimental plot and incur all production costs associated with field operations with no monetary compensation from the EPIC project. One field plot per producer was identified as the "Legacy" or control plot and another field was identified as the "EPIC" or experimental plot, both similarly prepared and managed according to the cooperator's best management practices. All six cooperators participated in a pre-season project workshop held on 30 March 2011 at the North Plains Research Field at Etter and on 3 April at the Moore County Community Center in Dumas.

Table 1: 2012 EPIC cooperator field parameters

County	Plot	Acres	Tillage	Method	GPM	GPM / Acre	Variety	Plant Population	Planting Date	Previous Crop
Dallam[1]	East	67.5	No-till	LESA	700	5.19	*Pioneer 33Y74*	*24-32,000 VR*	1-May	Corn
	West	67.5	No-till	LESA	700	5.19	*Pioneer 33Y74*	*24-32,000 VR*	1-May	Corn
Hutchinson[1]	Legacy	67.2	No-till	LESA	850	6.32	*Pioneer 33D49*	*33,000*	24-Apr	Cotton
	EPIC	67.2	No-till	LESA	850	6.32	*Pioneer33D49*	*33,000*	24-Apr	Cotton
Lipscomb[1]	Legacy	60	Strip-till	MESA	600	5.00	*Channel 21413*	*27,000*	19-May	Triticale
	EPIC	60	Strip-till	MESA	600	5.00	*Channel 21413*	*27,000*	19-May	Triticale
Moore	East	120	Turbo-Till	LEPA	600	5.00	*Pioneer P1508*	*32,000*	14-May	Corn
	West	120	Turbo-Till	LEPA	600	5.00	*Pioneer P1508*	*32,000*	14-May	Corn
Ochiltree[1]	Legacy	61	Strip-till	LESA	850	6.96	*Pioneer 33D53*	*32,000*	3-May	Cotton
	EPIC	61	Strip-till	LESA	850	6.96	*Pioneer 33D53*	*32,000*	3-May	Cotton
Sherman	Legacy	118	Vertical	LEPA	575	4.87	*Channel 21696*	*32,000*	26-Apr	Corn
	EPIC	267	Vertical	LEPA	2000	7.49	*Channel 21696*	*32,000*	20-Apr	Corn

[1] The Dallam, Hutchinson, Lipscomb, and Ochiltree locations are split pivots.

Early and late season soil water capacity was measured using the microwave gravimetric method, utilizing published soil bulk densities for the Hutchinson, Lipscomb, and Ochiltree County locations. Soil bulk densities were acquired from the Natural Resource Conservation Service Web Soil Survey. Early samples were gathered very near planting and late samples were gathered between Black Layer and Harvest. The difference between the two was used to determine the soil water extraction by the crop during the cropping season. Soil water extraction was modeled by AquaPlanner for the Dallam, Moore, and Sherman County locations.

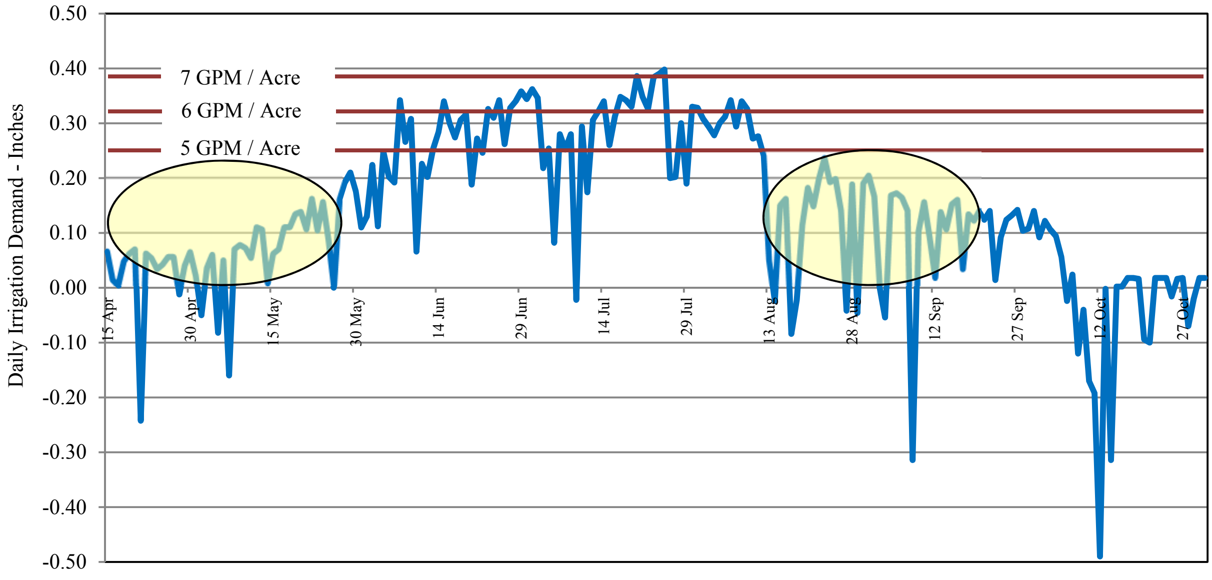
The Legacy and EPIC plots were established and managed similarly according to each producer's best management practices, including identical tillage practices, fertility, pest control, plant populations and varieties. The corn irrigation results demonstration consisted of a blind, side-by-side comparison of the Legacy and EPIC plots; the Legacy plot was irrigated according to the cooperator's standard practice (control) and the EPIC plot was irrigated according to recommendations from Texas A&M AgriLife Extension Service personnel based on solid management practices and tools. The principle EPIC strategy is to strategically eliminate early and/or late season irrigation applications where irrigation capacity exceeds crop water needs (Fig. 2) and eliminate mid-season irrigation applications where possible due to beneficial rainfall. Despite general drought conditions during the 2012 season, opportunities were available to implement the EPIC strategies. Recommendations provided for the EPIC plots were as follows:

Dallam County:	Early reductions not implemented due to herbicide timing
Hutchinson County:	Early season reduction of two irrigations
Lipscomb County:	Early, mid, and late season recommendations (partially implemented)
Moore County:	Early season reduction
Ochiltree County:	Reduction of early, mid, and late season irrigations
Sherman County:	Season-long, capacity limited reduction, mid-season shut-down

The EPIC plot irrigation decisions were made based on historical evapotranspiration (ET) models and real-time climatic data from the Texas High Plains Evapotranspiration Network (TXHPET), climatic prediction and ET models provided by AquaPlanner, soil water and root activity information provided by AquaSpy soil moisture probes, and by physical irrigation system and rainfall information provided by PivoTrac Monitoring equipment. Additionally, regular field visits and communication were upheld between all project leaders and participants, cooperators, and representatives from the aforementioned irrigation decision support tools. In order to remain non-invasive, communications between Texas A&M AgriLife County Extension Agents were instigated weekly (if needed) unless special conditions or insights arose.

Year-end operations and harvest were conducted using the cooperator's equipment and standard practices. Yield data was gathered from the composite of each plot in order to best capture field variations, except for the Hutchinson field where the plot was strip harvested.

Figure 2: Grain corn daily irrigation demand (Daily corn evapotranspiration minus average daily rainfall) from the Texas High Plains Evapotranspiration Network (TXHPET) weather station at the North Plains Research Field at Etter, Texas. 15 April planning date averaged from the 5-year period from 2005 – 2009. Horizontal lines demonstrate common irrigation system capacities and the highlighted areas identify periods where irrigation system capacities exceed the irrigation demands.



Replications and randomization was not included as part of EPIC's scope as this is a true results demonstration methodology, targeting process adoption. In order to avoid complication of the process in the view of the cooperating producers, the EPIC project leaders deemed it appropriate to approach this project from a minimalistic stand-point to show high-end corn producers that small non-complicated adjustments to management practices can return noticeable yield and profit increases.

Project Results and Discussion

Opportunities for timely reductions in applied irrigation events were identified on the EPIC plots in Dallam, Lipscomb, Hutchinson, Ochiltree, and Sherman Counties. The Moore county site received substantial, non-uniform hail damage in mid-June that compromised the control and EPIC comparisons. Both of these sites will be discussed further in this report. In the four typical situations, EPIC grain yields were improved in relation to the Legacy plot with reduced irrigation inputs (Table 2).

Table 2: 2012 North Plains EPIC field results. Control plots are labeled "Legacy" and experimental plots are labeled "EPIC".

Location	Plot	Irrigation[3]	Soil[4]	Precipitation[3]	Total	Yield (Bu/ Acre)	WUE[5]
		Water (Inches)					
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[2] The Moore County fields suffered severe hail damage on 14 June.
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[4] Soil water was measured using early and late season gravimetric sampling at the Hutchinson and Ochiltree locations (**bold**). The soil water extraction at the remaining four fields was modeled by AquaPlanner. Negative values ( ) indicate more water in the soil late in the season compared to the early measurement.
[5] WUE refers to water use efficiency defined as bushels of corn per inch of TOTAL water (bu/ inch)

Based on $4.00 per thousand cubic foot (MCF) natural gas during 2012, an average water pumping cost of *$4.00 per acre-inch* of water is used for coarse economic analysis (in a similar pumping scenario at $.09 / KWh electricity, a cost of $6.25 per acre-inch can be expected). The lowest basis price point for grain corn during 2012 occurred during October at approximately *$6.75 per bushel* of US no. 2 yellow corn. Based on the natural gas pumping costs and the lowest corn prices, experienced increases in profitability across the four typical EPIC plots were $120.23, $261.35, $225.45, and $169.03 per acre for the Hutchinson, Lipscomb, Ochiltree, and Sherman County Plots, respectively.

The results strongly indicate that is possible to reduce irrigation water applied to high production grain corn by a small increment and maintain or improve yields, ultimately improving grain corn production profitability.

Table 3: 2012 North Plains EPIC basic economic impacts. The difference in profit per acre is based on $6.75 per bushel grain corn and $4.00 per thousand cubic feet (MCF) natural gas

	Irr Reduction (inches)	Δ Yield (Bushels / acre)	Δ Profit ($ / Acre)
Hutchinson	1.2	17.1	$ 120.23
Lipscomb	0.2	38.6	$ 261.35
Ochiltree	8.1	28.6	$ 225.45
Sherman	2.6	23.5	$ 169.03

Dallam County

The Dallam County field followed the EPIC protocol across the entire field, producing a 274 bushel per acre yield on 30 inches of irrigation water and 36.5 inches of total water. This was the Dallam County cooperator's second year in the program and the technologies were made available throughout the season. Although reductions in water applied were possible early in the season solely on a water basis, an agronomic opportunity to reduce irrigation application did not occur at the Dallam site due to overlaps with early season herbicide applications. Variable rate planting and fertility were used on the Dallam plot.

Figure 3: Early season picture of the Dallam County field under the sprinkler at 3-4 leaf stage.

Hutchinson County

The Hutchinson County plot was divided into East and West portions. The west side of the pivot was the EPIC plot and was managed to reduce three irrigation events, one near Memorial Day and one irrigation event at termination. The recorded irrigation difference between the EPIC and Legacy plots of 1.2 inches although it is very likely that the actual total was 2.5 inches (two net irrigations). The EPIC plot produced a 17 bushel yield improvement over the Legacy plot. Although the irrigation inputs are very similar, since the field was managed to the needs of the EPIC side, the irrigation needs of the EPIC side were met more closely than the Legacy side. The EPIC yield was 273 bushel per acre and the Legacy Yield was 256 bushels per acre, both very respectable for this area and higher than previously produced on this field. This field was strip harvested in a generally North – South orientation, taking a 4.2 acre swath on the EPIC side and a 4.3 acre swath on the Legacy side, approximately 24 rows to the east and west of the dividing line for a physical buffer.

The Hutchinson County cooperator has agreed to pursue the next step in the EPIC protocol in 2013. This will entail full disclosure of the management tools and decision making process.

Figure 4: Mid-June field meeting at the Hutchinson County field near Pringle, Texas. Pictured from left to right: John Leib, James Leib, Jacob Leib, and Nich Kenny

Ochiltree County

The Ochiltree County site was the ideal location for the EPIC protocol to be demonstrated successfully; a high yield environment with excess irrigation system capacity. At this location, approximately 41 inches of irrigation water was applied to the Legacy plot, producing a very respectable 237 bushels, which is commonly considered the ceiling yield in this area. The EPIC plot produced 265 bushels from 33 inches of applied irrigation water, creating a profitability advantage of $225 per acre, while saving 8 inches of water per acre.

This plot was a split pivot application which did limit the management capability and affect the experiment. The EPIC plot received more water than prescribed as the pivot had to speed over the EPIC plot to avoid becoming stuck in a windshield wiper scenario in the Legacy Plot. The Legacy plot received more water than it would have typically received since the water not applied to the EPIC plot was subsequently applied to the Legacy plot.

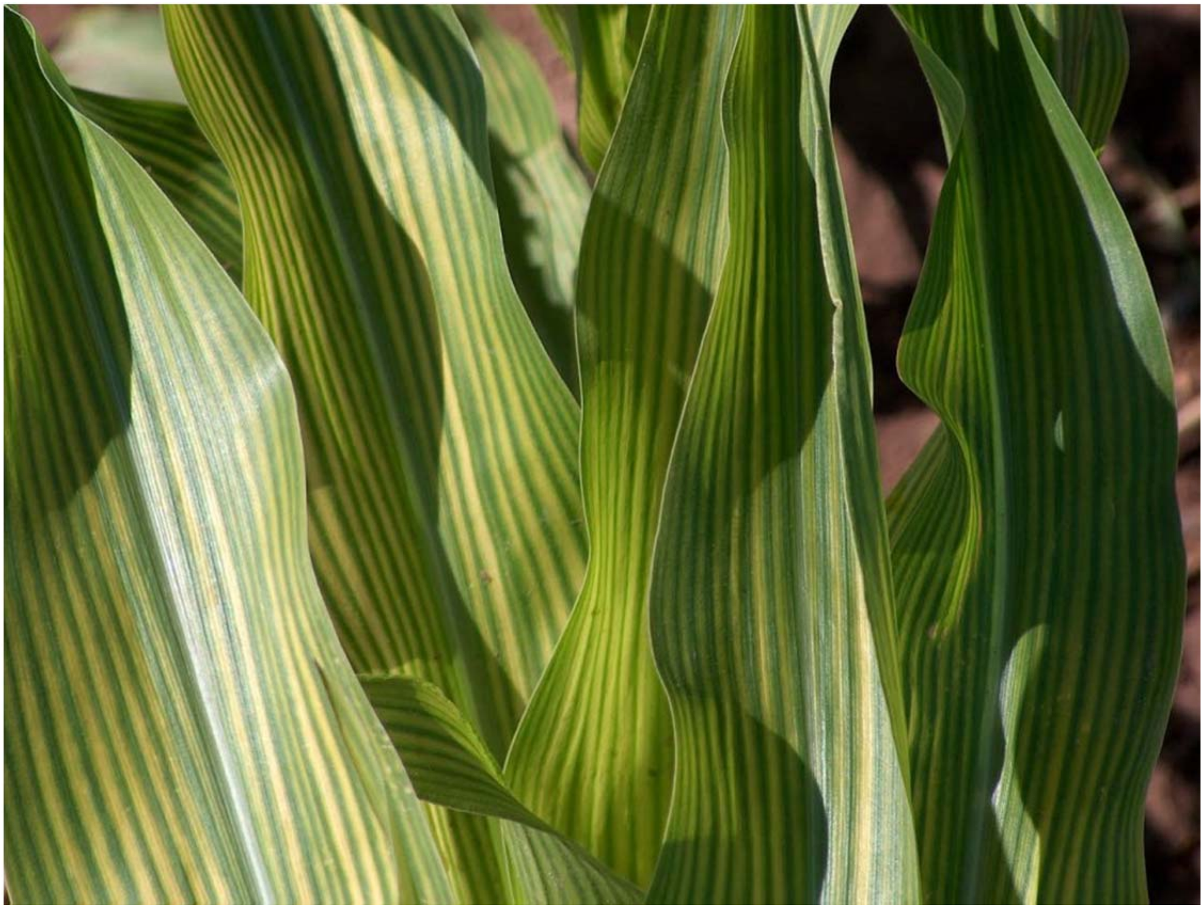
Explanations aside, the Ochiltree County site was overwatered on both sides. The EPIC plot reduced the saturation stresses and provided a yield much higher than the producer had previously experienced on this field. Ideally, the EPIC plot would have received approximately 28 inches of irrigation to completely mitigate saturation stresses and water lost to deep percolation. It is expected that yields would be maintained in the 260 bushel range under this protocol.

Producer feedback on this site is typical in that the cooperator and consultant were skeptical of the approach and hesitant to enact management changes. After demonstrating the methods, the producer has committed to repeat this project in subsequent seasons and it is expected that the producer will expand the EPIC strategy across his operation.

Comprehensive management for maximized Water Use Efficiency

Water Use Efficiency (WUE) is a measure that relates the crop yield to the amount of total water used in the production of the crop. WUE in grain corn is typically measured in units of bushels per acre-inch of total water. By definition, anything that affects the yield of the crop directly affects the crop's WUE and it becomes quite clear that maximizing a crop's water response requires a comprehensive agronomic effort. This point was made quite clear at the Lipscomb County site where soil conditions were less than ideal and historical fertility records were unknown. Early signs of iron chlorosis and micro nutrient deficiencies were evidenced as well as late season phosphate deficiencies. The cooperator at this location was a first year general manager who entered the season with the understanding he would be learning farm tendencies during the 2012 growing season.

Figure 5: Evidence of early season iron chlorosis at the Lipscomb County field.



The result of less than ideal agronomic conditions in the Lipscomb county plot produced the lowest yields in the 2012 EPIC program; 136.1 bushels per acre on the EPIC side and 97.5 bushels per acre on the Legacy side with 3.8 and 2.7 bushels per acre-inch of water, respectively. A few vital observations were made in this process that should be universally considered. The first is that in the stressed condition, the plants became stunted and lacked vigor, thus reducing the plant's transpiration needs. The effects of these stresses can be compounded by the application of additional water as saturated conditions can be created and nutrients can be lost to leaching. Although it is often thought that corn plants grow out of most early season chlorosis conditions, the damage is lasting due to very shallow root development early in the season and the physiological yield potential reduction during initiation. Additionally, it must be conceded that although water is typically our most limiting factor, it is certainly not the only limiting factor in many Texas North Plains production systems.

The primary factors that contribute to water use efficiency are irrigation amounts and crop genetics. The ancillary factors include irrigation timing and depth, soil fertility, soil health, water quality, pesticide and herbicide applications, agronomic factors such as planting dates and tillage practices, and ultimately, weather conditions. The EPIC project approach with the Lipscomb County producer will vary from the standard approach slightly in 2013 to address some of the ancillary factors in an effort to bring the entire field and farm up to a more desirable production level and water use efficiency standard.

Moore County

The Moore County Plots were hit by severe hail on approximately 14 June 2013 and the EPIC project was compromised. An interesting point about these plots, however, was that the crop stages remained very predictable and on their expected pace as the crop recovered from the damage. The water use implication is that since the plant has significantly less biomass and the same growth rate, a crop recovering from hail damage can be expected to use less water than a healthy crop for the remainder of the season. Yield reduction is to be expected, but it is conceptually important to understand that excess irrigation applied after damage cannot correct the damage inflicted nor replace the earlier growth biomass that has been lost. The yields on the Moore County fields were 127.3 and 131.7 bushels per acre, both fields producing corn at 3.9 bushels / acre-inch of water.

Figure 6: Severe hail damage at the Moore County field that occurred on approximately 14 June. The barren spot is a water channel within the western field.

Figure 7: Close-up view of hail damage at the Moore County field. Notice the tattered corn on the ground and the debris washed in.

Sherman County

The Sherman County plots demonstrated the EPIC premise ideally. The EPIC field received 19.9 inches of irrigation water and yielded 243 bushels per acre. The Legacy field received 22.5 inches of irrigation and yielded 219.7 bushels per acre. The profitability benefit of the EPIC field is $169 per acre. Both fields received pre-water applications using very deep passes with sprinklers in bubble mode and then received progressively deepening irrigations throughout the season.

Figure 8: Grain cart unloading grain from the Sherman County EPIC field.

Figure 9: Pre-watering in bubble mode near the Sherman County plot.

West versus East Yield Considerations

Each cooperator was asked to declare the EPIC and Legacy plots prior to the season. Following the trend from the 2011 season, the producers who split fields typically assigned the EPIC plot to the west side under the assumption that it will be under more extreme weather conditions. This experiment has borne out that the EPIC plots performed despite this presumed handicap. One theory is that the west side provides a substantial buffer to the east side and that, as a result, the east side is commonly over-irrigated while the west side's crop water needs are better matched. Further consideration should be given to preferential yields on the west side of production corn fields and the implementation of very basic variable rate irrigation to apply water more accurately to each side based on different water use needs.

Extended EPIC Application

During the 2012 season, a sorghum field in Ochiltree County and a corn field in Gray County were included in the EPIC project to expand the merits of the protocol. Both fields were entered based on the producers' desires to adopt the principles on their farm. The Gray County field was a success, producing 243 bushels per acre on an estimated 26 inches of irrigation water and 2 inches of pre-water. Following the EPIC protocol, the Gray County producer stated that this is his best yielding year ever, producing more crop on less water than historically applied.

The Ochiltree County sorghum field was removed from the trial due to multiple agronomic challenges during the season. The first challenge was that the field was non-intentionally double planted in areas, disrupting the water management from the beginning. Additionally, the sorghum template for the AquaSpy soil probe was altered during early August, to reflect a more accurate reading. The trouble was that the producer was managing the crop to the Template and ended up much farther behind then desired as the critical management point arrived. It is believed that the EPIC protocol should be pursued on sorghum going forward.

Figure 10: Ochiltree County sorghum field in July, demonstrating the double planting portion of the field.

Evaluation of Irrigation Management Technologies

From an economic and operational stand point, the three technologies included as part of the EPIC project, AquaPlanner, AquaSpy, and PivoTrac Monitoring, were considered instrumental in monitoring irrigation operations and making vital irrigation management decisions. A tertiary evaluation of CropMetrics variable rate irrigation prescriptions was initiated in the 2012 EPIC project, but not fully implemented as it was out of the scope of the EPIC protocol.

AquaPlanner

AquaPlanner crop modeling was used extensively in this project to provide pre-season and in-season irrigation strategies and record irrigation and rainfall records. A new feature to AquaPlanner in 2012 is the Critical Management Point (CMP) tool that identifies as what point the soil moisture profile should be full and at what point irrigation should be triggered to ensure a full profile without wasting water. The CMP tool also provided the irrigation termination point at the end of the season, based on the predicted amount of water necessary to complete the grain crop.

Figure 11: AquaPlanner season end-report for the Sherman County EPIC plot. Notice on the red marks on the chart that indicate the Critical Management Point (CMP).

AquaPlanner

Field Detail Report

R-Way Farms

R-1 Corn Early

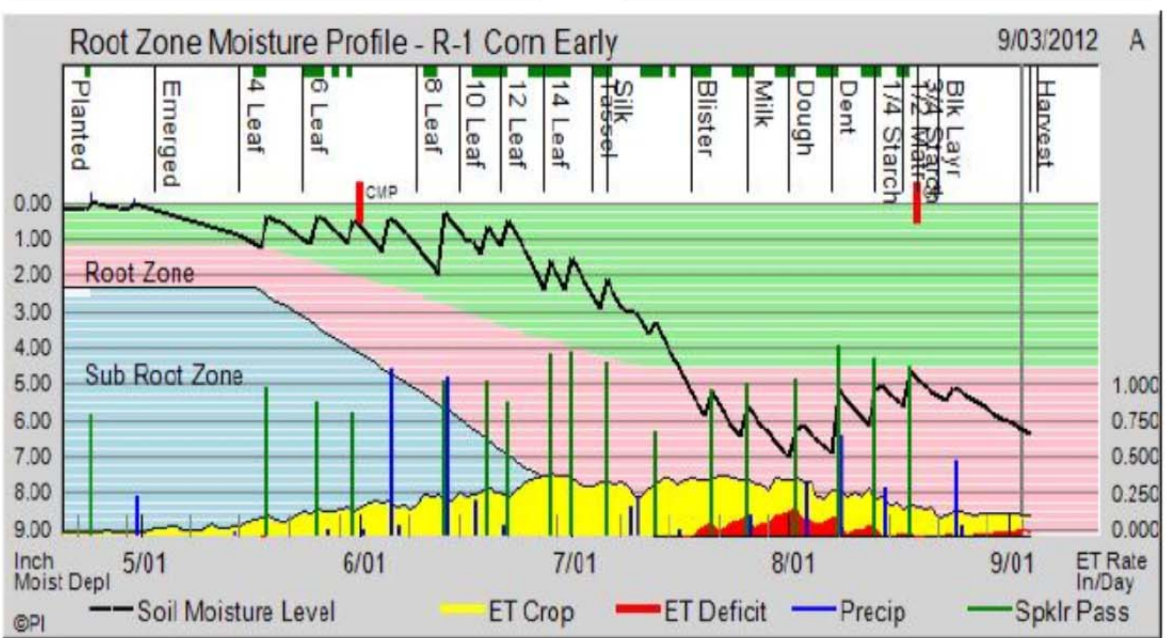
1/31/2013

Field Information

Item	Value
Field Name	R-1 Corn Early - 267ac.
Soil Type	Silty Clay Loam
Moisture Holding Cap.	2.30
Crop	Corn - Medium Season
Plant Date	4/20/2012
Plant Population	33000
Growth Stage	
System Status	OFF
Application Rate	2000 GPM - 7.5 GPM/Ac
Rotation Time	3.27 days
Inches per Pass	1.30 in
Cost per Inch	5.00
Distribution Eff.	90 %
Irrigate Application Rate	1.30
Budgetted Precipitation	80 Pct of Average
Full Irrigation Yield	240

Crop Production Statistics

Item	Crop YTD	% ET	Sched.
ET crop	31.96		2.17
ET net	28.39		1.70
Precipitation	5.70	18%	0.00
Applied Irr.	19.94	56%	0.00
Soil Water Used	5.78	18%	-0.95
Total Percent of ET	92%		83%
Net Precip	5.70		
Net Irr.	17.94		0.00
Percolation	0.36		
Irr. Cost / Acre	$99.68		$0.00
Heat Units	3039		
Crop Stage			
Mature Date	Aug 22		
Harvest Date			Sep 04
Yield Potential	86%		



AquaSpy

AquaSpy soil moisture probes are demonstrating increasing value in the Texas North Plains and were integral in multiple irrigation decisions as part of the 2012 EPIC project. In this demonstration project where larger capacity irrigation systems are targeted, one of the most helpful insights provided by AquaSpy probes is the leaching signature in over-irrigation settings. This was particularly evident in the Ochiltree County plot.

Figure 12: AquaSpy sum chart of the Ochilree County Legacy Plot. The horizontal blue line is considered the "full" line and the green stripe is provided as an irrigation template shaped to match seasonal crop water needs.

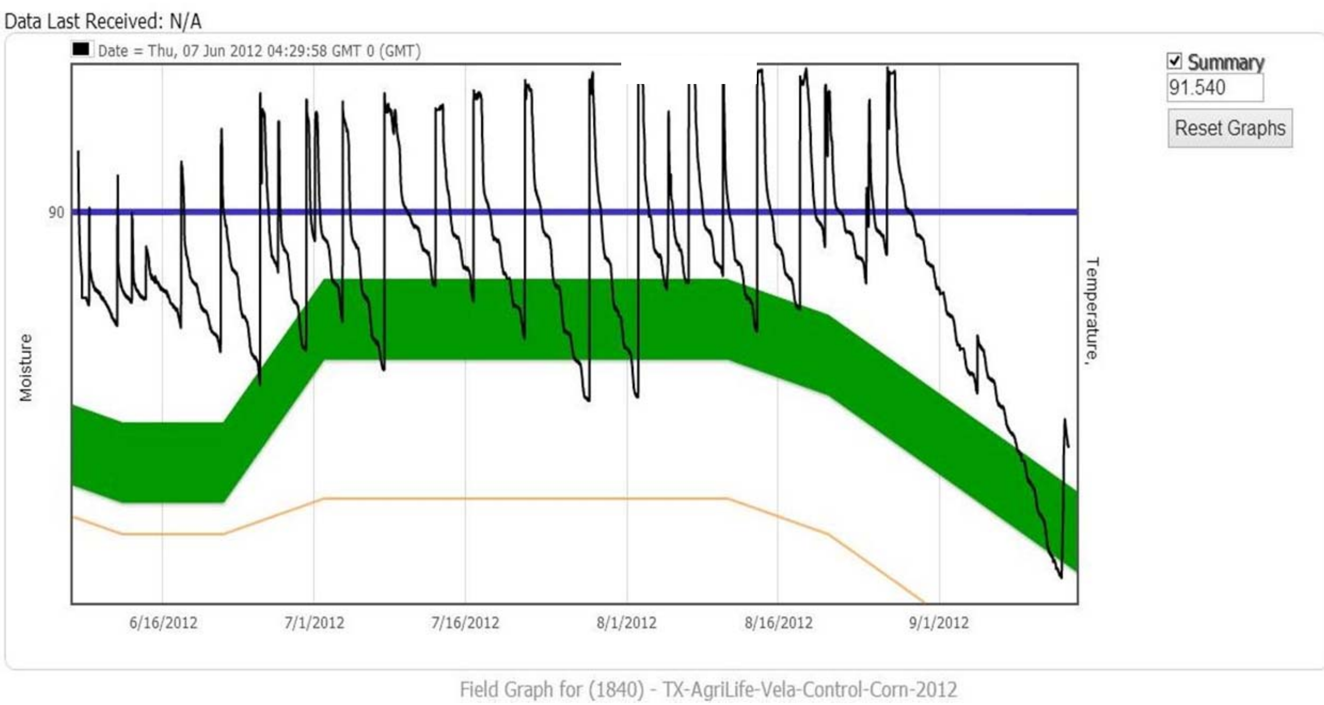
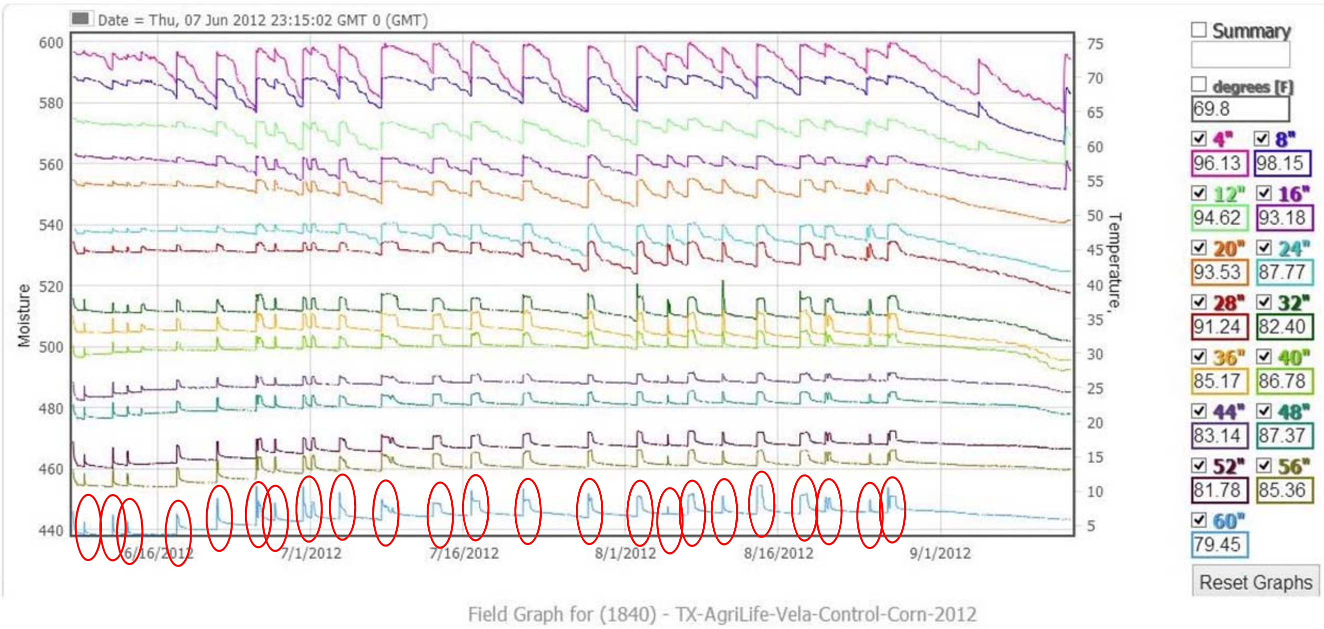
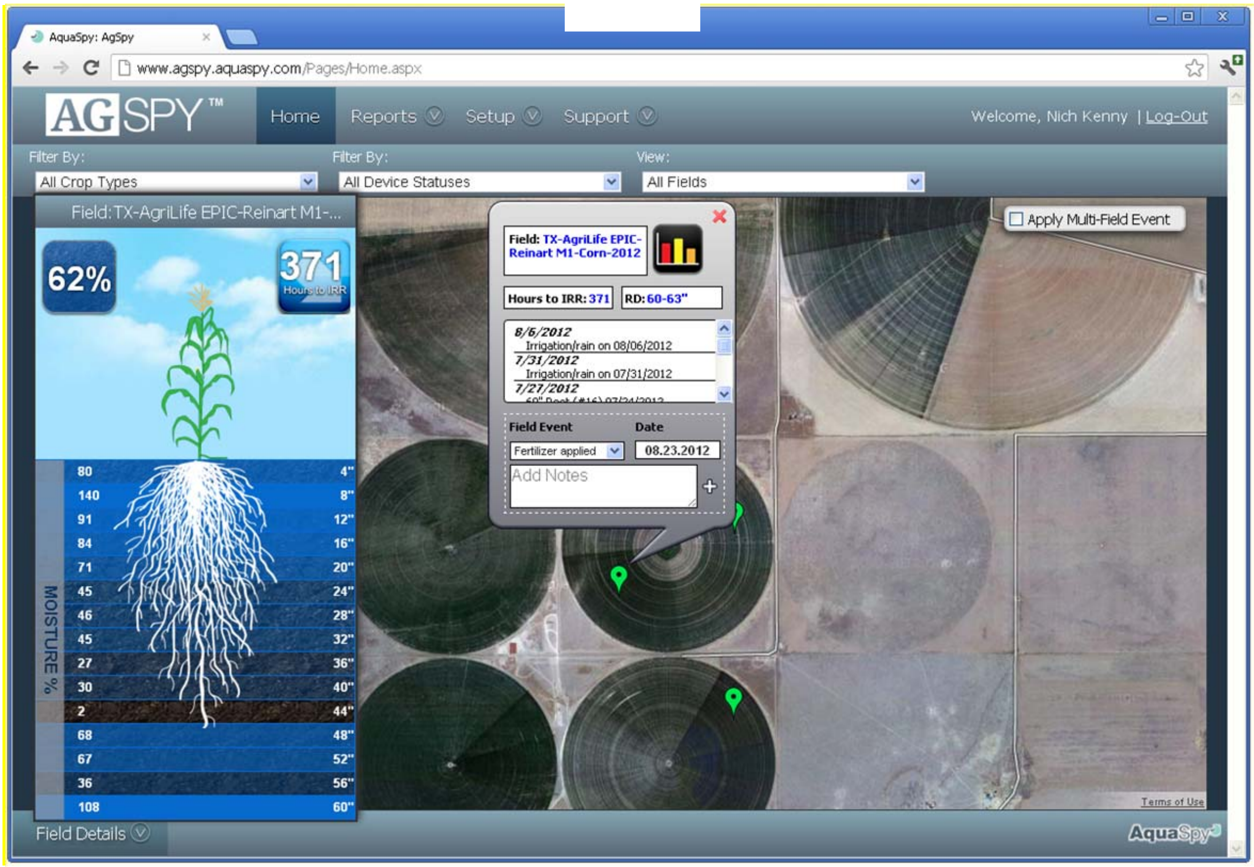


Figure 13: AquaSpy individual chart of the Ochiltree County Legacy Plot. Each line represents the relative soil moisture content at a given depth in the soil, beginning at 4 inches and continuing in 4 inch increments to a 60 inch depth. The red circles at the bottom indicate leaching events, typically related to irrigation events (circles added by author).



In 2012, AquaSpy released an updated web portal to access probe data. Two added features on the web site are a Google Maps based background interface with colored indicators at probe locations to provide a quick visual cue for fields with AquaSpy probes and a graphic estimating plant rooting depths and development. Both of these features are in preparation for the development of permanently installed probes that will allow for off-season soil water accumulation monitoring and improved probe calibration to the local soils. This feature is expected to be very well received as the permanent probes will also provide the much needed early season information so vital in setting-up the crop and early season water savings.

Figure 14: AquaSpy probe status page for a Sherman County plot demonstrating estimates of water uptake at depths in the root zone and providing an irrigation status report.



AquaSpy probes measure soil water movement at depth and basically identify areas of root activity. In 2011 and 2012, probes in the EPIC plots where water was withheld showed active corn root activity as deep as five feet. In an effort to determine if corn roots were actually rooting that deeply or whether water was moving through capillary action, a soil pit was dug in the Lipscomb County field. Visible roots were measured to 80 inches below the surface, suggesting that corn root water activity is occurring even deeper than the 60 inch measuring limit.

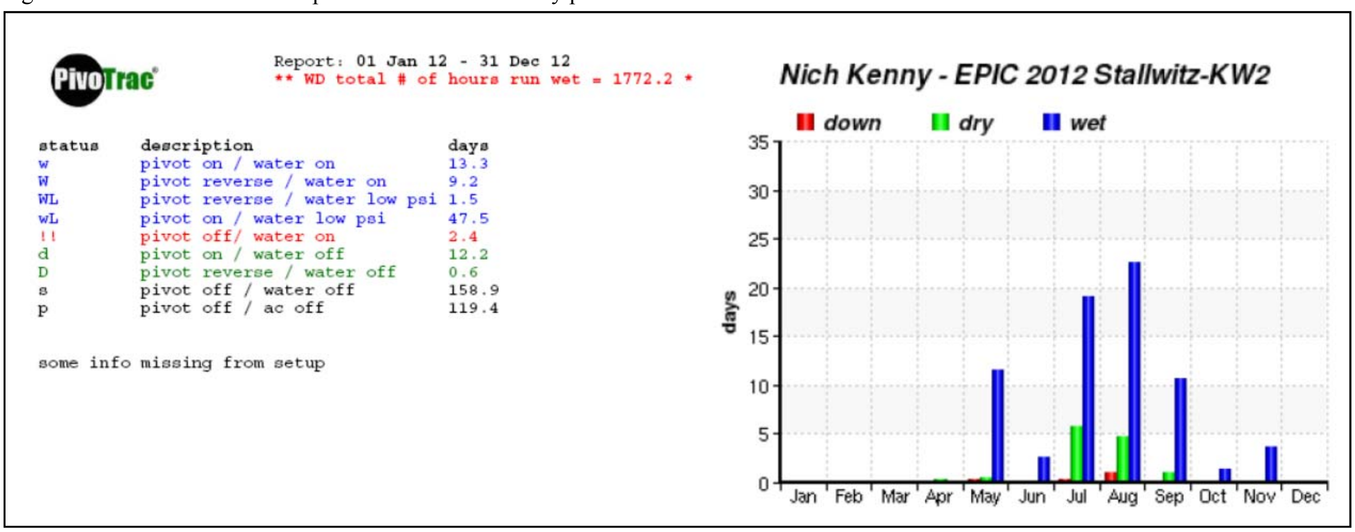
Figure 15: Lipscomb County Texas A&M AgriLife Extension agent JR Sprague measuring corn roots in the Lipscomb County field. In the image on the right, notice the roots circled and the 72 inch mark on the 2x4. Roots were identified to 80 inches below the soil surface.

PivoTrac Monitoring

Each center pivot sprinkler was fitted with PivoTrac monitoring with a pressure transducer and GPS to allow for real-time location and irrigation monitoring, control, and record-keeping. PivoTrac was considered vital for the full effect of the EPIC project because it allowed for internet accessible, off-site monitoring of pivot activities, application rates, and ground speeds. Further, records of irrigation application are automatically compiled throughout the season, allowing for simple status evaluations during the season and rapid compilation of records in the post season. AquaPlanner reports seamlessly extract information from PivoTrac to populate irrigation event graphics and compile operational records. All pivots in the project were set-up with control options to allow for the producers to operate the machines remotely using a computer, smartphone, or tablet interface. As a new feature in 2012 PivoTrac was optimized for a smart phone allowing for very convenient mobile controls.

The operating cost of PivoTrac Monitoring is a first year investment of approximately $855 with an annual expense of $325 for each subsequent year. At a first year cost of $7.13 per acre and an annual cost of $2.71 per acre for each subsequent year on a 120 acre pivot, this cost is very well justified in all of the plots in this project.

Figure 16: PivoTrac seasonal report on the Moore County plot.



CropMetrics

The next step in maximizing irrigation water use efficiency is the implementation of Variable Rate Irrigation (VRI), a tool that identifies soil variability through electro-conductivity (Veris), electro-magnetic, and elevation mapping, uses algorithms to partition water across the variable soils, and outputs control commands to adjust pivot speed to apply the variable rate irrigations. CropMetrics has developed a very robust software package that makes VRI a feasible option for many producers. Due to the defined scope of the EPIC project, VRI was not implemented as it would create challenges in deciphering results and may compromise the premise. However, one snap-shot of the Dallam field demonstrated a valid correlation between CropMetrics prescriptions and real world observations as a bare spot became evident in an area of the field the CropMeterics identified as a trouble spot. This technology can be especially valuable in fields with significant soil and slope variability.

Figure 17: CropMetrics VRI prescription for the Dallam County field. Notice the blue sectors in the five to six o'clock positions, indicating that this portion of the field should receive additional water.

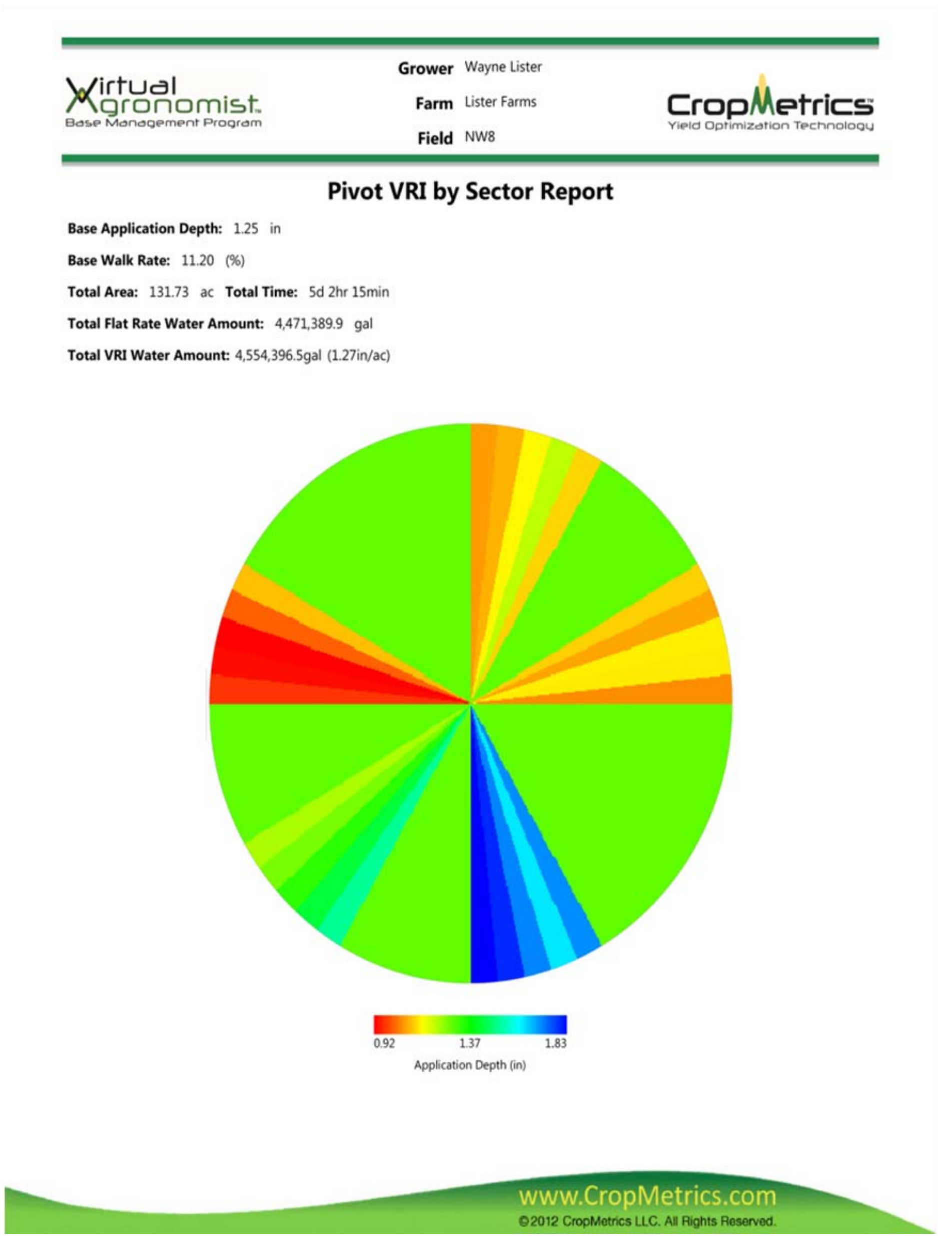


Figure 18: A picture of the Dallam County field prior to pollination. Notice the barren spots in the five to six o'clock position.

Task 2: Regional Dissimilation of Applied Research Findings and Results

The underlying objective of the EPIC results demonstration is to demonstrate sufficient evidence for an irrigated corn producer to adopt more intense, efficient irrigation practices to improve production economics and conserve water resources, simultaneously. A significant portion of reaching this objective is achieved by delivering this information at the farm and producer level where practices can literally be instituted and real impacts created. Intermediate results and project premises were delivered during August 2012 across the Texas North Plains during a series of corn irrigation field days held as part of the EPIC project in further cooperation with the North Plains Groundwater Conservation District and multiple industry sponsors. The location and dates of the meetings were:

Morse Community Center; Morse, Texas	21 August
Ochiltree County Expo Center; Perryton, Texas	22 August
North Plains Research Field; Etter, Texas	23 August
Sherman County Barn; Stratford, Texas	24 August

This series of corn irrigation meetings delivered approximately 5 official hours of corn irrigation educational material to a registered audience of approximately 200 people. Tours to EPIC cooperator fields were included as part of the Morse and Stratford meeting. The meeting at the North Plains Research Field included a field tour of Texas AgriLife Research experimental plots, including stops at the 12-200 Limited Irrigation Corn Study, Pioneer Hi-Bred Optimum Aquamax and Syngenta Artesian stress plots, and germplasm and stay-green research plots. North Plains Groundwater Conservation District 200-12 plots were toured as part of the Morse, Perryton, North Plains Research Field, and Stratford programs.

Texas Blue Legacy in Agriculture Award

In late 2012, the Texas A&M AgriLife Extension Service, Panhandle District was awarded the Blue Legacy in Agriculture award for the EPIC project. The award was presented at the IdeAg Amarillo Farm and Ranch Show Commodity Symposium on 28 November.

Conclusions

The North Plains Efficient Profitable Irrigation in Corn (EPIC) project results have indicated over a two year study period that it is very likely that yield and production profitability can be increased in association with timely reductions in applied irrigation water. The primary results demonstration goal of EPIC was to demonstrate a methodology that decreases applied irrigation water while maintaining or improving grain corn yield, ultimately increasing the profit potential of high-yielding grain corn while simultaneously conserving pumped irrigation water. In four of the six cooperator producer locations, applied irrigations were reduced and yields were subsequently maintained or improved. Improved profitability from the four respondent locations ranged from $120.23 to $261.35 per acre.

A large portion of the success of this project is the viability of the application of multiple irrigation management tools, namely AquaPlanner, AquaSpy, and PivoTrac monitoring. These products deliver real-time useful information that can be practically implemented into any farming operation and inform irrigation managers on the insights necessary to duplicate the results of this project.

The EPIC results demonstration has very significant economic and conservation implications for the Texas North Plains and all grain corn growing demographics, demonstrating for two consecutive years that substantial increases in yield can be realized by improving irrigation management. This effort is expected to continue, funding permitting, for two additional years (through 2014) to further confirm the methodology and to expand the knowledge base of this method and management practice throughout the Texas North Plains. The primary funding source of the EPIC project is the North Plains Groundwater Conservation District with in-kind funding from the Texas A&M AgriLife Extension Service and educational funding being provided by the USDA Ogallala Aquifer Program.

Recommendations

Based on the results from two years of the EPIC project, the implication is that grain corn yields can generally be maintained or increased with a reduction in applied irrigation water. To further mature this concept and verify the 2011 and 2012 results, it is recommended that EPIC is continued for two additional seasons (through 2014). The operational recommendation is that producers who have participated in one season of blind technology utilization are advanced to full exposure of the management tools with appropriate training. New cooperators would still be expected to participate in one season of blind participation to ensure a control. This component of EPIC has proven essential from a human nature standpoint as multiple cooperators admitted desire to alter the management of their Legacy plot to match the EPIC strategy in 2011 and multiple producers did match the EPIC strategy on the EPIC plots in2012. In the future iterations of EPIC, it would be desirable to include one producer from each of the eight North Plains Groundwater Conservation District counties. Adoption of the EPIC pattern should be considered by other Texas grain corn production regions to demonstrate an additional method of economic, water conservation.

Acknowledgements

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James Born – Ochiltree County Cooperator
Mark Howard and Braums Farms– Lipscomb County Cooperator
James and John Lieb – Hutchinson County Cooperators
Darren Stallwitz – Moore County Coopeator
Charles and Chandler Bowers – Gray County Cooperators
Lewis, Dave, and Ryan Davis – Gray County Cooperators
Randy Coon – NPGCD Field Technician
David Reinart – Wilbur –Ellis, Dumas
David Graf – Texas AgriLife Extension Service, Swisher County
Pat Scarth – AquaPlanner
David Sloane – AquaSpy
Karlyle Haaland – PivoTrac Monitoring.

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Appendix A: 2012 EPIC Project Proposal and Scope of Work (March 2012)

AgriLIFE EXTENSION
Texas A&M System

2012 North Plains Corn Irrigation Demonstration Project: Proposal

Efficient Profitable Irrigation in Corn

Nicholas Kenny, Scott Strawn, J.R. Sprague, Marcel Fischbacher,
Mike Bragg, Kristy Synatschk, Brad Easterling

Background:

Efficient Profitable Irrigation in Corn (EPIC) is a results demonstration effort conducted by the Texas AgriLife Extension Service and funded primarily by the North Plains Groundwater Conservation District in its inaugural year, 2011. The foundation of EPIC is the principle of managing irrigation water for maximized profitability as a means for making optimal economic and agronomic use of the water resource, namely the Ogallala Aquifer EPIC targets grain corn producers who historically employ efficient irrigation systems and solid agricultural practices in a production strategy focusing on maximized yields (revenue). EPIC is designed to be a multi-year, staged project that helps high-yield grain corn producers maximize their on-farm production potential and reduce applied irrigation water. Potential regional water savings under partial adoption of this practice is estimated to exceed 37,500 acre-feet or 12 Billion gallons annually.

In 2011 EPIC's in-field, scientific approach utilized two side-by-side field plots (separate fields or split fields), maintaining one plot as a control and management of irrigation on the experimental plot to meet two objectives; 1) maintain or improve yield as compared to the control and 2) reduce pumped irrigation water by one to four inches. In the inaugural 2011 season, five (5) irrigated producers in the Texas North Plains became EPIC cooperators, contributing field-scale control and experimental plots, all farm operations, and all production costs with no monetary compensation from EPIC. The EPIC project provided Pivotrac monitoring (where applicable) with producer access and AquaSpy soil probes and AquaPlanner crop modeling without producer access in order to maintain the validity of the control plot. The control plot was titled the "Legacy" plot and was managed according to the specific producer's standard practice and the "EPIC" plot was managed with Texas AgriLife inputs based on best management practices and information from management tools.

The preliminary 2011 EPIC results are tabulated below (Figure 1). In four of the five cooperator plots grain corn yields were maintained and increased with a corresponding reduction in irrigation water applied. It is important to note that the design and scope of this project did not include on-site replication and the results were obtained primarily for the purpose of demonstrating a scientifically sound approach to managing water. Although very compelling, the results should be viewed anecdotally as local examples rather than conclusive scientific evidence. Economic impacts between the EPIC and Legacy plots varied from no change to $200 per acre profit improvement.

Figure 1 - 2011 North Plains EPIC field results. Control plots are labeled “Legacy” and experimental plots are labeled “EPIC”.

		Water (Inches)					
Location	Plot	Irrigation	Soil[3]	Precipitation	Total	Yield (Bu/ Acre)	WUE[4]
Dallam Co.[1]	Legacy	29.1	2.71	0.97	*32.8*	*207.5*	6.3
Hartley Co.	Legacy	34.6	0.12	1.97	*36.7*	*241.0*	6.6
	EPIC	31.4	(0.35)	1.97	*33.1*	*241.0*	7.3
Hutchinson Co.[2]	Legacy	20.0	4.32	2.57	*26.9*	*180.1*	6.7
	EPIC	17.4	3.10	2.57	*23.1*	*190.2*	8.2
Ochiltree Co.	Legacy	31.2	(0.66)	2.30	*32.8*	*168.0*	5.1
	EPIC	30.0	0.39	2.30	*32.6*	*188.0*	5.8
Sherman Co.	Legacy	28.6	4.40	2.11	*35.1*	*140.8*	4.0
	EPIC	25.6	2.12	1.67	*29.4*	*171.0*	5.8

[1] Irrigation application was not able to be reduced on the Dallam County field due to the severe 2011 weather conditions.
[2] The Hutchinson County plots utilized subsurface drip irrigation (SDI). The Legacy plot (10.25-acres) reached physiologically maturity earlier than the EPIC plot (11.6-acres) and the remainder of the field (total of approximately 65-acres). The field average yield was 184-bushels, including the two test plots.
[3] Soil water content was measured early and late in the season using gravimetric sampling, except the Dallam field which is modeled by AquaPlanner. Negative values indicate seasonal soil moisture accumulation and were evidenced in multiple fields due to dry residual early soil conditions.
[4] WUE refers to water use efficiency defined as bushels of corn per inch of TOTAL water (bu/ inch)

In 2011, project concept promotion was accomplished through conducting four specified corn irrigation field days during August, conducted in Morse, Perryton, Etter, and Dalhart, Texas on August 19, 24, 25, and 26, respectively. The total recorded audience during these meetings was *166 people*. Up to five continuing education units were offered at each venue. Additionally, the results of the EPIC project were promoted at the High Plains Irrigation Conference on 19 January 2012 in Amarillo, Texas to an audience of 148, at the Perryton Sorghum Production Meeting on 5 March to an audience of 35, at the Oklahoma Panhandle Crop Production Clinic on 8 March to an audience of approximately 60, and at the High Plains Association of Crop Consultants to an audience of 35. The final report was delivered to the North Plains Groundwater Conservation District Board of Directors on 14 February 2012 in Dumas.

This project is designed to be repeated for three additional seasons, through 2014, funding pending. The EPIC protocol is expected to be expanded to other irrigated grain corn production areas through the Southern High Plains.

Scope of Work

Task 1: Applied Research Demonstration Project

<u>Work to be Performed</u>

The corn irrigation demonstration project will identify and select up to eight producers from eight counties within the North Plains Groundwater Conservation District (Dallam/Hartley, Hansford, Hutchinson, Lipscomb, Moore, Ochiltreee, and Sherman Counties) and be facilitated locally by the county extension agents in each respective county. One high-yielding producer will be identified and selected per participating area. Project continuity will be coordinated by appropriate administrators and specialists from the Panhandle Regional Headquarters in Amarillo. <u>The primary focus of this project is irrigation management with respect to high-end yields and maximized profits.</u> In recognition of different management practices associated with capacity limited irrigation and strategic or regulatory limitations, this project will target operating systems with sufficient irrigation system capacity for full corn irrigation to highlight effects of irrigation management inputs.

The corn irrigation demonstration project will consist of a blind, side-by-side comparison of two grain corn fields; one irrigated following the producer's standard practice (control) and one irrigated under the direction of Texas AgriLife Extension Service personnel based on solid management practices and tools. The tools will include capacitance probes, computer models, and gravimetric / volumetric soil sampling and the related consultation services provided by the tool vendors. The cooperating producer will not be exposed to the management tools throughout the season to reduce the potential of mid-season irrigation strategy adoption on the control field.

Corn varieties, planting populations, fertility, pest control, and tillage practices will be identical for both fields and will be agreed upon with each cooperator based on each producer's operating system and best management practices. Records of total water applied, irrigation events, precipitation events, beginning and ending soil moisture levels, grain yields, and differences in production costs will be accumulated for comparative analysis on a site-by-site basis and for compiled evidences across the entire project area. Multiple indices will be used to evaluate and display potential benefits and feasibility of intensive irrigation management.

A cooperating producer workshop will be conducted in the early spring prior to planting to formalize project parameters amongst all entities. Each cooperator will be asked to sign a project agreement with basic terms. Regular communication will be upheld throughout the season between extension personnel, producers, and service providers to maintain project continuity.

Field Requirements:

- Two very similar, adjacent production fields planted to grain corn
- Highly efficient irrigation system such as LEPA, LESA, or SDI.
- Irrigation system capacity of 5.5 gallons per minute per acre or greater for each field
- Each field to be fitted with accurate, functioning flow meter and pressure gauges (may be provided by NPGCD).
- Each demonstration and control field will be fitted with a capacitance probe, modeled by a computer model, and fitted with a remote irrigation system monitoring device.

Alternate Experiments:

1. In the case a two field project area is not found in a particular county, a pivot may be split into two management zones. This method is not preferred due to the isolation limitations between the two management zones.
2. In Eastern Counties within the North Plains Groundwater Conservation District jurisdiction, high yielding sorghum producers may be identified and included. This is in response to significant requests for this option, especially considering the representative volumes of sorghum producers in relation to grain corn producers in Ochiltree and Lipscomb counties.
3. Producers continuing with the project will be encouraged to adopt additional technologies and techniques such as CropMetrics variable rate irrigation, converting to more efficient irrigation methods, improving fertilizer application, and altering planting dates

Task 1 Timeline: *March 2012 – November 2012*

Task 2: Regional Dissemination of Applied Research Findings and Results

Work to be Performed

Three late season public field days will be conducted in August or September as irrigation workshops and field days to introduce area producers to the demonstration management strategies. A final producer workshop will be conducted following harvest to summarize results and evaluate the anticipated adoption potential. A formal results presentation will be delivered at the annual High Plains Irrigation Conference in Amarillo in January 2013. A demonstration project report will be constructed and delivered to the North Plains Groundwater Conservation District at the January or February Board of Directors meeting or to the Agricultural Committee as requested.

Task 2 Timeline: *August 2012 – February 2013*

Proposed Budget

1-Year: 2012 Total Project Cost (Seven sites)

Item	Unit Cost	Units	Extended Cost
AquaSpy C-Probe Service	$ 2,000	14	$ 28,000
PivoTrac w/GPS Monitoring	$ 395	11	$ 4,345
One-time Set-up Cost	$ 500	5	$ 2,500
CropMetrics Field Set-up and VRI Prescriptions	$ 11	375	$ 4,125
Aqua Planner Computer Modelling w/CMP	$ 4	1375	$ 5,500
High Plains Consulting, Inc. - Aerial Imagery	$ 25	33	$ 825
Field Day (meal, facilities, advertisement, cost recovery)	$ 1,050	3	$ 3,150
County Agent / Technician Expenses			
Travel	$ 250	7	$ 1,750
Supplies	$ 250	7	$ 1,750
Project Coordinator Expenses			
Travel	$ 1,500	1	$ 1,500
Supplies	$ 1,000	1	$ 1,000
AgriLife Indirect Costs*			$ -

Comprehensive Project Cost (seven sites)	$ 54,445
Costs Paid directly by NPGCD (AquaSpy, PivoTrac, CropMetrics)	$ 38,970
Total Contract to Texas AgriLife	***$ 15,475***

*Indirect costs are being waved to comply with the policies of the primary funding organization (North Plains Groundwater Conservation District) of not paying indirect on grants.

Budget Justification

AquaSpy Capacitance Probes, AquaPlanner Computer Modelling, and PivoTrac Monitoring are all production services billed annually and are written into this contract as an annual service expense. The Field Day expenses will include costs incurred in conducting three late season field days. These expenses may include meal and refreshments, advertising, publications, venue costs, miscellaneous production expenses, and Texas AgriLife Cost Recovery Initiative Cost of $10 per attendee. County Agent, Technician, and Project Coordinator expenses are split to include travel expenses and supply expenses for apparatus used as part of the project (ie, soil probes, soil testing apparatus, marking flags, etc.) and publication expenses related to end of project responsibilities.

Communications

Cooperator names will be shared with the North Plains Groundwater Conservation District in confidentiality at the beginning of the project and will be reported anonymously for the entirety of the project. Example cooperator agreement documents will be shared with the North Plains Groundwater Conservation District, but actual cooperator documents will be retained exclusively by Texas AgriLife. Project communication between Texas AgriLife and the North Plains Groundwater Conservation district is to be open throughout the duration of the project through verbal and /or informal correspondence. Project updates will be provided upon request. No formal communications or reports are to be required prior to the final project report.

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