NPGCD WATER CONSERVATION CENTER
2024 DEMONSTRATION PROGRAM

Incorporating Forage Sorghum into a Corn / Cotton Rotation

NORTH PLAINS GROUNDWATER Conservation District

Dr David Sloane

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Contents

Table of Figures

About the Author

Dr David Sloane, Chief Agronomist, GroGuru; Owner of Irrigronomy LLC.

Dr David Sloane is the Chief Agronomist with GroGuru Inc. He is an expert irrigation agronomist specializing in irrigation management of a wide range of commodity and specialty crops. David is a graduate of the University of Sydney and did his PhD in Agronomy at the University of Adelaide, where his area of study was plant-water relations. He has been working with soil moisture and environmental sensors for over 30 years and for the last 16 years he has been based in St Louis, MO. His past projects include setting up area-wide environmental monitoring sensor networks to remotely track the water balance both on and off farm. This included measurement of crop water use, drainage, ground water and water movement through supply infrastructure. David has spent the last 15 years working with irrigators in the western corn belt of the USA and has spent the majority of that time focused on the Texas Panhandle. Over that time, he has introduced strategic irrigation management to many local producers and helped them make changes that have brought about large improvements in water use efficiency. David is a founding presenter with the Master Irrigator program and has worked with the North Plains Groundwater Conservation District since 2010.

Executive Summary

Local farmers are under increasing pressure to produce feed for an ever-increasing number of livestock, while similarly facing a decline in irrigation well output. This has put an incredible amount of pressure on the water resources in the region to produce more from less. The 2024 demonstration program at the WCC looked to address this issue by incorporating forage sorghum into the crop rotation, with the aim of producing a greater return per acre-inch whilst still producing much needed animal feed.

The results from the demonstrations at the WCC showed the following:

1. Silage from forage sorghum can produce similar net (variable cost) returns to grain corn but with significantly lower water usage.
    a. Forage sorghum returned $409 on ~13” of irrigation / 24” total water use
    b. Grain corn returned $418 on ~28” of irrigation / 40” total water use
    c. Cotton returned $552 on ~12” of irrigation / 30” total water use (note: yields were significantly higher than in an average season)
2. If forage sorghum was targeted as the main crop grown, it is projected that net returns on variable costs could be superior to grain corn with similar or slightly reduced water use.
    a. Irrigation efficiency of sorghum silage was ~$36 /inch of irrigation
    b. Irrigation efficiency of grain corn was ~$16 /inch of irrigation
    c. Corn silage is projected to give the greatest net return on variable costs ($771/ac) with a projected return ~$30 /inch of irrigation
3. Sorghum silage has a relatively short growing season and provides a range in possible planting dates. This would potentially allow double cropping with a rotation into winter wheat production.
4. Early planting of sorghum silage could allow significant regrowth prior to a winter freeze, negating the need for a cover crop.
5. Drip irrigation provides significant water savings and a massive increase in water use efficiency.
6. No conclusive results proof could be obtained as to the effectiveness of the UpTerra system, however anecdotal evidence suggests that it is changing the way water moves into and is held within the rootzone. The observed effects were related to the changes in the soil rather than changes in the irrigation water, which is intriguing and encourages further observation.

These results have shown that forage sorghum does have a major role to play in maintaining profitability in the face of declining water availability. While it will never generate the return per acre of corn silage, it can generate significant amounts of animal feed with a greatly reduced irrigation footprint.

Introduction

Sorghum Silage Production

Over the last 10 years, the need for silage has massively increased on the Texas North Plains, largely due to the influx of large dairies into the region. This in turn, has put more pressure on farmers to produce more feed and there has been a move towards double cropping (corn / wheat silage) to keep up with this demand. However, this double cropping has also put pressure on groundwater resources, and many well yields have dropped to the point where growing corn (for either grain or silage) is no longer economically feasible. Not only does corn need more water, but yields are highly dependent on the timing of water as well. Corn yields are highly susceptible to maintaining adequate moisture during pollination and the remedy for this problem has been to share water with another, less thirsty crop. This is generally known as split planting, where a higher amount of water is put on a smaller area, to spread out the in-season irrigation demand and maintain high yields. This can either be done by altering planting dates to ensure there is good separation of the critical irrigation period of the same crop (i.e. corn) or it is most commonly done by split-planting with a companion crop such as cotton. A side benefit of split-planting with a less thirsty crop like cotton, is that it will reduce the overall water usage and help producers stay within pumping limits. Indeed, this has been the approach taken at the Water Conservation Center (WCC), where water is shared between corn and cotton for the past 5 years.

While the approach taken at the WCC has been effective at improving irrigation efficiency, cotton does not help produce silage to meet the ever-growing feed demand in the region. Cotton also requires specialist machinery, which might be a problem for some producers, and the long harvest window makes it unsuitable for double cropping. As such, the Ag Committee of the North Plains Groundwater Conservation District (NPGCD) decided that we should investigate other companion crops that fit into the rotation and use less water but still produce the silage needed to meet demand. While corn is still king in the region and continues to be the most profitable crop to grow, it is also a relatively thirsty crop, and the lower well yields make it increasingly harder to grow. It was decided to add forage sorghum into the rotation as a companion crop to share water with grain corn and cotton.

Subsurface Drip Irrigation

As well yields are declining in the region, subsurface drip irrigation (SDI) is increasing being evaluated as a viable alternative to center pivot irrigation as it has the ability to improve irrigation efficiency and hopefully maintain production using less water. However, there is relatively little SDI in the region, and it is new to most people in the area. The relative lack of experience with SDI in the region poses the question of how best to use it and what is the best irrigation strategy. When it comes to pivot irrigation, producers have learned that slow, deep irrigation gives far better results regarding higher yield and improved irrigation efficiency. Yet many of the SDI suppliers promote the benefits of being able to irrigate daily and replace the water used by the crop. The two SDI fields at the WCC presented the perfect opportunity to explore different patterns of irrigation and it was determined that we would change the irrigation frequency, whilst maintaining the total amount of irrigation.

UpTerra

The two hydrogen atoms that bind to an oxygen atom to make up a water molecule can be altered to give it different properties. Most people would agree that rainwater seems to act differently to irrigation water in terms of infiltration and crop response, and this is due to the changes that atmosphere puts on the molecules as they fall from the sky, compared to pumping it out of the ground. Indeed, there have been many devices over the years that claim to change water molecules such as using magnets to polarize water, etc. but with varying degrees of success. Recently UpTerra, a private company, has been promoting a device that uses radio waves of specific frequencies to change the structure of irrigation water to "make it behave more like rainwater". They offered to demonstrate the product at the WCC by fitting it to one of the pivots, so it was agreed to evaluate the product as it might offer benefits to producers in the region. Below is information taken directly from the UpTerra website that describes the system.

UpTerra Electronic Coils

Research studies have shown the positive effect that musical vibrations have on plant growth and development. The Electronic Coils of the UpTerra System create similar beneficial energy for plants and animals.

As the water is organized into a coherent state with the Flow Device, UpTerra's Electronic Coils imprint it with beneficial biochemical signals (harmonics), like playing music for plants.

The result is improved plant, animal, and soil wellness. Plants need less water to achieve adequate hydration and grow more consistently and uniformly, increasing yield. Animals are more well-hydrated, reducing inflammation and disease. Soil is revitalized, reducing reliance on physical inputs over time.

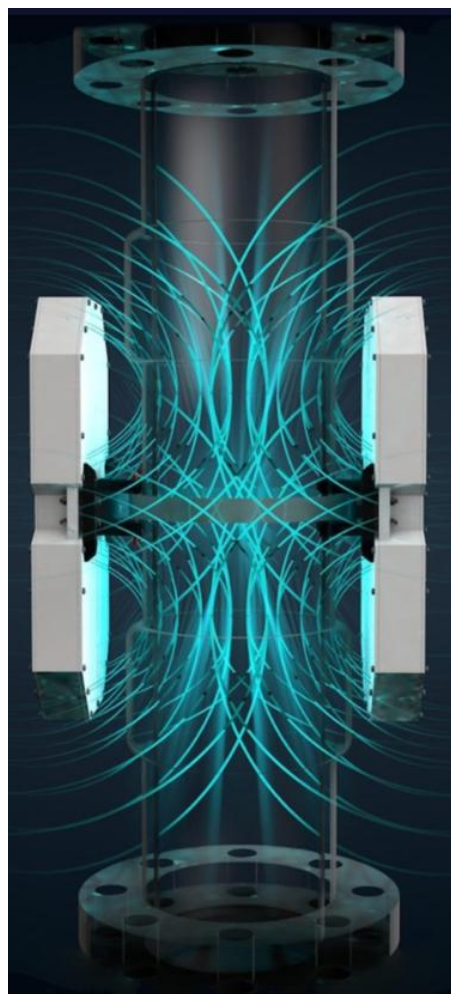

Figure 1 Information supplied by the www.UpTerra.co website

Trial Plan for 2024

History

The Water Conservation Center (WCC) near Etter TX consists of two center pivot fields and two Subsurface Drip Irrigation (SDI) fields (Figure 2). Up until 2015 it was used for small plot research conducted by Texas A&M AgriLife, but since then it has been used as a demonstration facility to promote farming systems that may benefit the producers on the TX north plains. Prior to the 2024 season, there had been a corn / cotton rotation in operation, whereby each full pivot was planted to either corn or cotton and the crops were mirrored the following year. The fields were generally strip-tilled in the spring, however, the 2024 season had no tillage so this represented year 1 of a no-till farming practice.

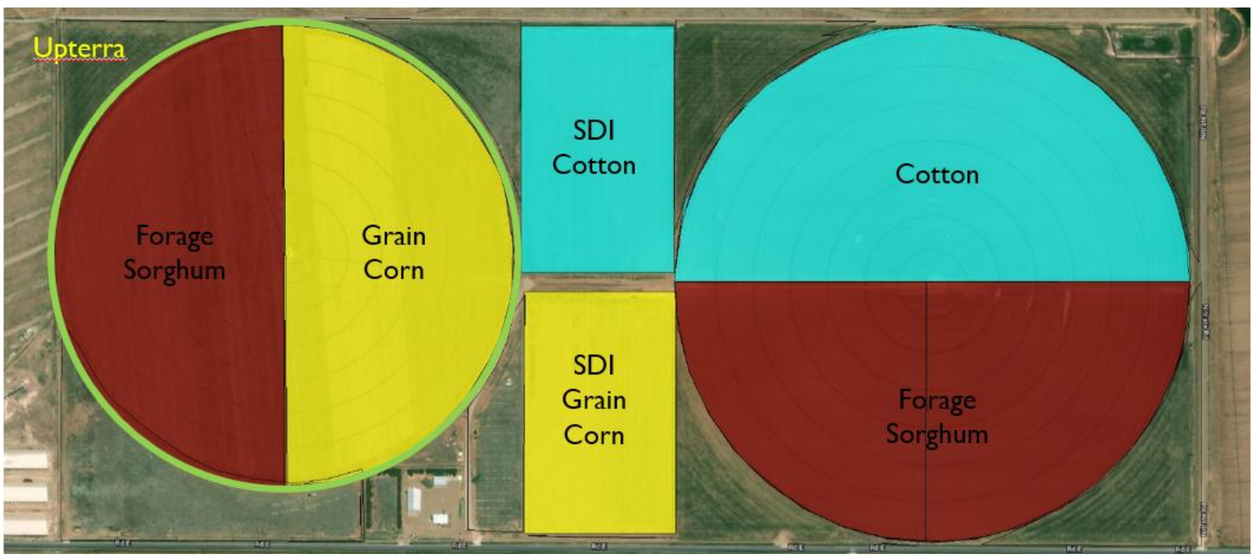

Figure 2 Map of the Water Conservation Center demonstration layout for 2024. The east pivot was split-planted to cotton and forage sorghum, and the west pivot was split-planted to corn and forage sorghum. The SDI fields were planted to cotton and corn respectively. The UpTerra system was installed on the west pivot (circled in green).

In 2019 there were GroGuru soil moisture sensors permanently installed under each pivot and these have produced a continuous, unbroken record of soil moisture since that time. They also highlight the soil moisture conditions leading into the season, during the season and after the season for 5 years leading up to the 2024 crop. This data set also provides valuable insights into the sharing of water between these crops in the corn / cotton rotation over that time. In 2020 GroGuru sensors were permanently installed under each SDI plot, also providing valuable and continuous information over a 4 year time period prior to the 2024 season.

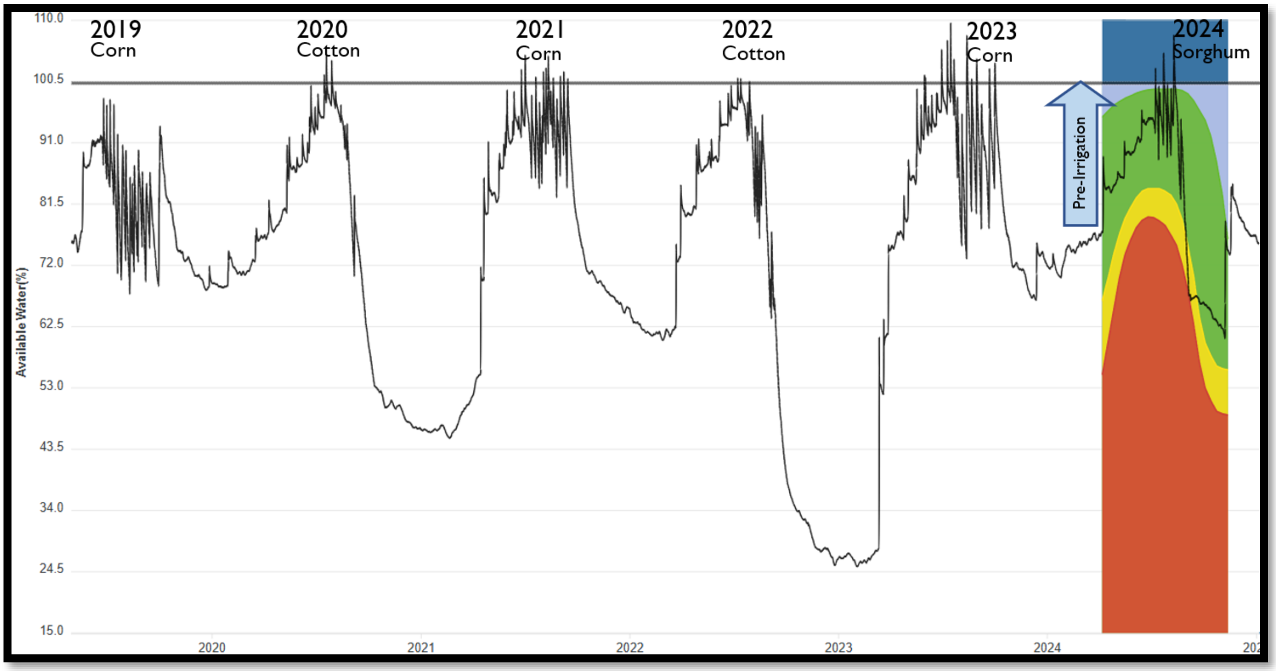

Figure 3 Total soil moisture status for the east pivot over 6 years. Data is from a GroGuru permanently installed soil moisture probe and represents soil moisture in the top 48". The block arrow represents the amount of pre-irrigation that was required to fill the soil profile after the previous crop.

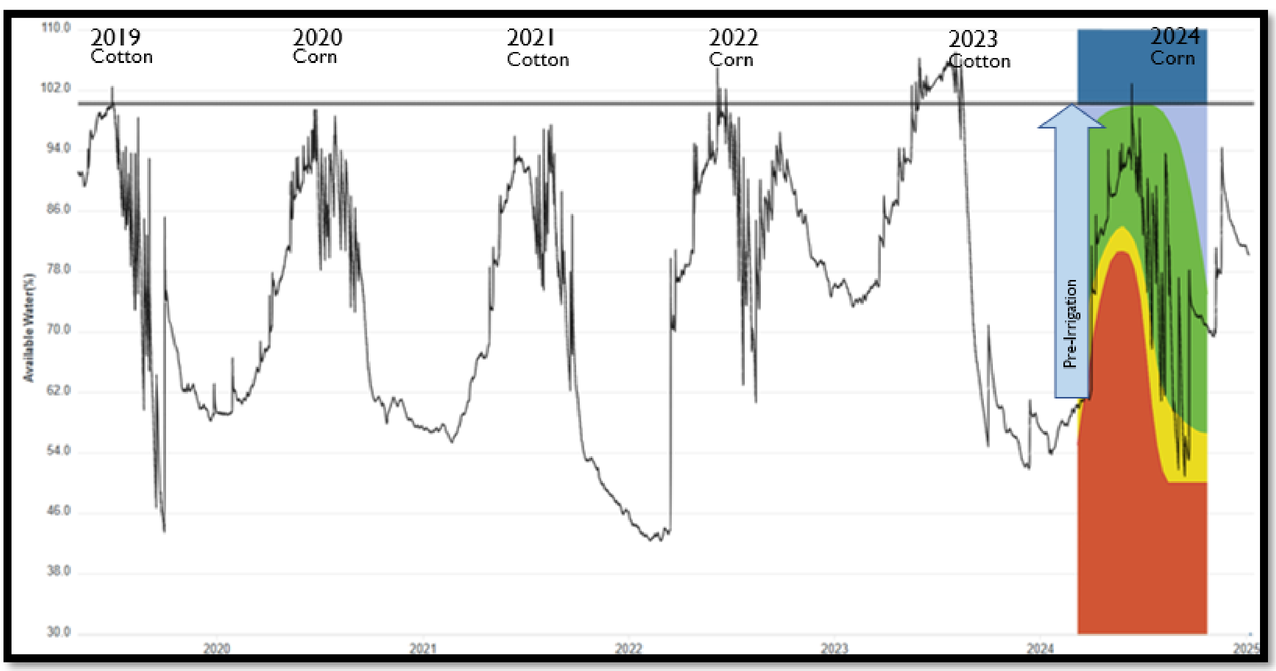

Figure 4 Total soil moisture status for the west pivot over 6 years. Data is from a GroGuru permanently installed soil moisture probe and represents soil moisture in the top 48". The block arrow represents the amount of pre-irrigation that was required to fill the soil profile after the previous cotton crop.

The soil moisture graphs shown in Figure 3 and Figure 4 show the total soil moisture on the east and west pivots respectively. It is evident that the soil was much drier on the west pivot after the 2023 cotton crop, compared to the moisture level on the east pivot after the 2023 corn crop. Due to these differences, it was necessary to apply 2.85" of pre-irrigation on the east pivot and 5.12" of pre-irrigation on the west pivot to fill the soil profile to an equal status on each field. The fact that the west pivot needed 2.27" more is highlighted by the blue arrows on each graph. Figure 3 and Figure 4 show that each soil profile filled to the historical full point prior to the 2024 growing season, allowing for a valid comparison between the two forage sorghum crops, despite the different rotations on each field. This highlights the value of having multiple years of continuous soil moisture data to allow for accurate and confident pre-irrigation, compared to simply trying to guess. This also shows the vast differences in soil moisture left in the ground after each crop. Careful examination of Figure 3 and Figure 4 shows large differences between crops and between seasons, with regards to carryover soil moisture, making it hard to use a rule of thumb for accurate pre-irrigation. Part of the purpose of the WCC is to demonstrate technology and permanently installed probes have proved to be an extremely valuable tool.

Water Supply

There are three production wells on the Water Conservation Center farm and two of them are used for irrigation. The west well is the main production well and supplies approximately 600 gpm. The north well is a newer well that supplies approximately 375 gpm and the third well is much smaller and supplies about 130 gpm. There are flow meters fitted to each pivot point and the actual usage of water was measured over the entire calendar year. The "running wet" hours were measured using Pivotrac monitoring devices fitted to each pivot that measured end pressure and pivot location over the same period. The supply of water was then calculated as shown in Table 1 and it was evident that both pivots were limited to a supply of 3.68 gallons per acre per minute and 3.56 gallons per acre per minute for the east and west pivots respectively. This is generally viewed as a water-limited supply for growing corn in the Texas panhandle, where somewhere greater than 5 gallons per acre per minute is accepted as a lower limit for fully irrigated corn production. It should be noted that the water supply pressure measured at the end of each pivot was maintained in the range of ~16 psi for the entire season. This should have enabled the pressure regulators on each nozzle to function appropriately.

Table 1 Water usage for the 2024 calendar year for each center pivot

	West	East
Acre Ft	158.54	106.02
Gallons	51659766	34546723
Acres	88	110
Gal / ac	587043	314061
Wet Hours	2745.37	1420.49
Minutes	164722.2	85229.4
G/ac PM	3.56	3.68

Incorporating Forage Sorghum into the Rotation

According to the historical rotation, in 2024 the east pivot was due to be planted to cotton and the west pivot was due to be planted to corn. However, in 2024 each circle was split-planted to include forage sorghum under each sprinkler according to the layout in Figure 2. The idea was to lower overall water demand, whilst still producing silage that is in high demand in the area. By split-planting with forage sorghum, we were able to make three separate assessments based on the following:

1. Sharing water between corn and forage sorghum
2. Sharing water between cotton and forage sorghum
3. Examine the effect of forage sorghum grown with and without UpTerra

Detailed pumping records were kept and we were able to demonstrate the effectiveness of using limited water to produce grain, feed and fiber, and draw some conclusions as to the role forage sorghum might have in the Texas Panhandle.

Each half of the pivot effectively formed a single farm-scale plot. Since this was set up as a demonstration, rather than a scientific study, there was no replication or small plots involved. All operations were conducted using regular farm equipment and the demonstration fields were farmed commercially by a neighbor who was renting the ground and farming it as part of a larger farming operation.

Results – East Pivot

The east pivot was slightly larger of the two pivots (110ac) and the north half was planted to cotton and the south half was planted a month later to forage sorghum (see Figure 2). Both sides were planted in a circular pattern that followed the curvature of the pivot tracks. Table 2 shows the planting and water use information for the crops planted on the east pivot. The total irrigation applied to the whole pivot was measured using a flow meter at the center of the pivot, which was read weekly. The amount of water that was applied pre-season vs in-season was calculated by totaling the wet run hours for each period using the Pivotrac monitoring system. The total water applied was then prorated into pre-water and in-season irrigation on that basis.

The east pivot required 2.85” of pre-irrigation to fill the profile adequately for planting. The pre-irrigation was applied evenly to the whole pivot since the previous corn crop was also planted across the whole pivot in 2023. There was no blanket fertilizer applied to the east pivot in 2024 as it received 3 t/ac of manure prior to the corn crop in 2023. As such, the cotton received no additional fertility beyond what was in the soil, and the sorghum had fertilizer applied through the irrigation system.

A good plant stand on both sides of the pivot was established and weed control was conducted in line with other fields that the farmer was also farming. This consisted of a pre-plant herbicide application and a post plant herbicide application. Once established, the forage sorghum grew quickly and covered the ground approximately 3 weeks after planting. This was due to the narrow drill rows and warm soil that allowed it to germinate quickly and grow rapidly.

Table 2 shows the crop type, planting information and water use for the east pivot

East Pivot (110ac)		
Crop Type	Cotton	Forage Sorghum
Planted	7th May	7th June
Fertilizer	None	104 lbs N
Hybrid	FM 765AX	Nutricane II
Seeding Rate	60,000	8 lbs/ac
Row Width	30”	7.5”
Tillage	No Till	No Till
Pre-plant Irrigation	2.85”	2.85”
Pre Plant Rainfall	1.73”	3.12”
In-Season Irrigation	9.11”	10.59”
Total Irrigation	11.96”	13.44”
Soil Extraction	10.0”	6.7”
In-Season Rainfall	10.68”	6.98”
Total In-Season Water Use	29.79”	24.27”
Yield	1612 lbs/ac	18.41 t/ac
Water Use Efficiency	54.1 lbs/in	0.76 t/in

The 2024 season was relatively hot and experienced a warm fall, where the hard freeze was significantly delayed from usual. This allowed for higher-than-expected cotton yields and the cotton produced 1612 lbs/ac. The total in-season irrigation on the cotton was 9.11” and the soil moisture probes showed that there was approximately 10.0” extracted from the soil during the season. When this was combined with 10.7” of in-season rainfall, the total cotton water use was calculated at 29.8” or 54 lbs of lint per inch of water used.

The forage sorghum was windrowed on 5th September and picked up by a forage harvester the following day. The silage was hauled to a nearby feed yard and the yield was corrected to 65% moisture. There was 18.41 tons of silage produced per acre, which consumed 10.59” of in-season irrigation and extracted 6.7” of soil moisture (as measured using the soil moisture probes). This gave a total conversion of 0.76 tons of silage per inch of moisture used.

Results – West Pivot

The west pivot had 3 t/ac of composted manure spread over the entire circle in the spring, which provided approximately 50 lbs/ac of available nitrogen (96 lbs/ac total N) according to lab analysis. The field was not tilled but a spring burn-down herbicide was applied in March, followed by another herbicide application in late April. Corn was planted on the west pivot on 14th May and the sorghum was planted some 3 weeks later. The idea was to provide some separation in the peak water use between the two crops that were sharing water under the same pivot. Separation in peak water demand is necessary to provide the benefits of companion crops in water limited situations, since the well cannot pump enough water to keep up with the peak demand of both crops at the same time.

The west pivot was planted to cotton in 2023 and was left substantially drier than on the east pivot. As such, there was 5.12” of pre-plant irrigation applied, compared to the 2.85” applied to the east pivot. The difference in pre-irrigation required to fill the profile prior to planting has been noted when comparing water use between the two fields. This carryover effect of beginning moisture is an important part of planning any water sharing rotation and must be considered when planning the irrigation strategy. The author has taken this difference in starting moisture into account in the calculations and most comparisons are either done on total crop water use or on in-season irrigation, so as to remove the effect of starting moisture.

The corn was harvested for grain on 30th September and the field achieved 240.0 bu/ac. It should be noted that this was a relatively high yield for the region in 2024 and was the highest yielding field for the farmer that year. Some of this high yield should be credited to the soil moisture probes and the fact that a final irrigation of 1.5” was applied on 3rd September which was subsequently all used fairly rapidly by the crop to finish grain fill (Figure 6). Had we not had the soil moisture probes, the farmer would not have applied this final irrigation and the yield would most likely be 8-10 bu/ac lower – as seen in his other crops with the same hybrid.

Table 3 shows the crop type, planting information and water use for the west pivot

West Pivot (88ac)		
Crop Type	Corn	Forage Sorghum
Planted	14th May	7th June
Fertilizer (pre-plant)	56 lbs N	51 lbs N
Fertilizer (fertigation)	85 lbs N	49 lbs N
Hybrid	P1366 AML	Nutricane II
Seeding Rate	30,000	8 lbs/ac
Row Width	30”	7.5”
Tillage	No Till	No Till
Pre-plant Irrigation	5.12”	5.12”
Pre-plant Rainfall	2.09”	3.12”
In-Season Irrigation	25.91”	12.71”
Total Irrigation	31.03”	17.83”
Soil Extraction	6.6”	6.4”
In-Season Rainfall	8.00”	6.98”
Total In-Season Water Use	40.51”	26.09”
Yield	240 bu/ac	18.93 t/ac
Water Use Efficiency	5.92 bu/in	0.73 t/in

The dry finish to the season saw the crop harvested at an average moisture content of 14.78%, which equates to a corrected yield of 241.7 bu/ac had it been harvested at 15.5% moisture. The reason for the delay was because it was custom harvested and the warm dry fall caused it to dry out quickly. The corn consumed 40.5” of moisture, including 25.9” of irrigation, for a total conversion rate of 5.83 bu per inch of total in-season water.

The forage sorghum on the west side of the pivot was windrowed on 5th September and picked up by the forage harvester the next day. The silage was hauled to a nearby feed yard and the yield was 18.93 t/ha, corrected to 65% moisture. The total in-season water used by the forage sorghum was 26.1", which included 12.71" of in-season irrigation.

Economic Analysis

The partner who commercially farms the WCC also farms a number of other fields in the local area. Since the farmer moves seamlessly between each field, the costs associated with field operations were also merged across the whole enterprise and unfortunately it proved too difficult to extract the exact operating costs for each field at the WCC. Since the records were not able to be adequately separated to generate individual gross margins budgets, the Texas A&M AgriLife Extension Crop Profitability Analyzer for 2024 (Texas AgriLife Extension, 2025) was used to generate realistic gross margins budgets according to the yield and inputs for each field (see appendix 3). While this is obviously not ideal, since the actual yield and relative harvest, shipping costs and irrigation costs were used, it is deemed to be sufficient for comparative analysis. In the absence of actual costs, fertilizer and chemical costs are indicative but should be consistent between the corn, cotton and forage sorghum. Only returns above variable costs have been considered and no attempt has been made to include rents or returns on fixed costs. As such, the gross margins reported are greater than if these costs had been taken into consideration.

Table 4 Water Use and Net Returns for crops grown under the east and west pivot

Crop	East Pivot		West Pivot	
	Cotton	Forage Sorghum	Corn	Forage Sorghum
Pre-season Irrigation	2.85"	2.85"	5.12"	5.12"
In-season Irrigation	9.11"	10.59"	25.91"	12.71"
Rainfall (in-season)	10.68"	6.98"	8.00"	6.98"
Soil Moisture Extracted	10.00"	6.70"	6.60"	6.40"
In-season Water Use	29.79"	24.27"	40.51"	26.09"
Yield	1612 lbs/ac	18.41 t/ac	240 bu/ac	18.93 t/ac
Yield per inch (in-season total usage)	54.1	0.76	5.92	0.73
Yield per inch (in-season irrigation)	127.8*	1.74	9.3	1.49
Net Return $/ac (above variable cost)	$552	$409	$418	$413
Net Return $/inch in-season water use	$18.53	$16.85	$10.32	$15.83
Net Return $/inch in-season irrigation	$43.77*	$38.62	$16.13	$32.49

**Includes 3.5" extra irrigation to replenish additional soil extraction*

Table 4 shows the water use and net returns above variable costs for the crops grown under the east and west pivots. The higher-than-expected cotton yields due to the warm fall, actually gave the best gross margin per acre but had this been closer to the long term average of 1250 lbs/ac, this would have been closer to $316 per acre rather than the $552/ac observed. It is interesting to note that the net return on forage sorghum ($411 avg) was almost equivalent to grain corn ($418). This is largely due to the lower fertilizer, irrigation and insurance costs of forage sorghum. Additionally, the costs of establishing (and potentially irrigating) the cover crop after forage sorghum have not been considered. Had this been taken into account, it would most likely tilt the economics towards grain corn being a better gross margin. Whilst no irrigation was necessary to establish a winter cover crop due to timely rains in 2024, this may be required in any other year. The very late hard freeze experienced in 2024, also saw significant regrowth of the sorghum silage, which also acted like a cover crop.

It is interesting to note that the yield per inch of irrigation applied to the corn field was calculated at 9.3 bu/inch of in-season irrigation or 7.7 bu/inch of total irrigation. The latter number is more representative of year on year corn as it takes into account 5 inches of pre-irrigation and it falls right within the accepted rule of thumb of 7-10 bu/inch of irrigation for the Texas panhandle region.

The cotton crop extracted approximately 10" of moisture out of the soil by the end of the season, compared to the other crops which extracted around 6.5". To correct this imbalance, an extra 3.5" of irrigation was added to the calculations of return per inch of water used for the cotton. In this way, all of the crops were deemed to have left the field with equal moisture by the end of the season. Another way of looking at it was that all the crops started with a full profile and cotton was credited with the extra irrigation required to bring it to parity with the other crops by the end of the crop cycle.

Economic Modeling

In this study, forage sorghum was seen as the poor cousin when sharing water with corn, and the corn was deemed to be the dominant crop. That is, if there was a conflict between which crop would get the water, corn was favored with timely irrigation. However, what might happen if we grew a full circle of forage sorghum instead of sharing water with corn? Table 1 shows that a total of 158 acre feet of water were pumped onto 88 acres at an average of 21.5 inches per acre. If all of that water was used to fully irrigate a forage sorghum crop, what could we expect for a yield?

If we look at the amount of silage produced per inch of total water use for forage sorghum, it sits within the range of 0.73-0.76 tons per inch of total water use (Table 4). If we then added 21.5" of irrigation to the total water use (assuming the same rainfall and soil moisture extraction) then the total water use would be in the range of 35 inches /ac. Using the average conversion rate of 0.745 t/inch, this would equate to 26 ton/ac of silage. If we then use the crop Profitability Analyzer to project the net returns on this 26 ton silage crop, we see a net return of $637 per acre. This is vastly more than the net $418 per acre seen with grain corn.

Alternatively, if we harvested the corn for silage instead of for grain, then the likely equivalent corn silage yield would be in the order of 30 t/ac. Additionally, the price for corn silage is generally 12x the grain price and not 10x the grain price. Once again, using the Crop Profitability Analyzer with this scenario, we see that the net return on variable costs would be in the order of $771 per acre (Appendix 3g) but it would also take >24" of irrigation to grow. This would make corn silage the most profitable crop to grow over either grain corn or sorghum silage ($409-$418/ac). However, when you look at the returns per acre inch of irrigation, sorghum silage gave twice the water use efficiency of grain corn; $32/in compared to $16/in when grown side by side on the west pivot (Table 4). Sorghum silage even stacks up well against a the simulated water use efficiency of $32/in from a corn silage crop, showing just how efficiently it can provide a return on limited water. Sorghum silage produces less dollars per acre than corn silage but it uses far less water and the conversion rate of water into money is projected to be very similar.

When considering any silage crop, it must be reiterated that the profitability of silage compared to grain is a function of the high demand for silage in the local region and the relatively low trucking costs with the distances involved. If the fields were in a more isolated location, with further transport distances and/or a reduced local demand, then it could be expected that grain might be more favorable. Silage contracts also vary between feed yards and care must be taken to look at the local deals each farmer can negotiate.

Sharing Water

The historical reason that the farm has undergone a corn / cotton rotation was because there was not enough water to grow all corn every year. By growing half the farm to corn and half to cotton, it not only reduced the total water requirement, it also reduced the peak demand for water during the critical pollination period of corn. Table 5 shows that during 2024, the total water pumped on the corn was over 31”, compared to cotton at just under 12”. This is somewhat misleading as it doesn’t take into account the deficit left by the previous crop, however it all counts towards the annual allocation. Clearly 31” per acre per year is not permissible, however by sharing water between crops, the overall average water pumped on the west pivot was reduced to around 24”. This is further reduced when you consider total farm usage, which was at 17.9” for the entire 198 wet acres across both pivots.

Table 5 Total amount of water pumped on each pivot

East Pivot	**Cotton**	**Forage Sorghum**	**Average**
Total Irrigation	11.96”	13.44”	12.70”
In-season Irrigation	9.11”	10.59”	9.85”
West Pivot	**Corn**	**Forage Sorghum**	**Average**
Total Irrigation	31.03”	17.83”	24.43”
In-Season Irrigation	25.91”	12.71”	19.31”

Sharing Water Between Forage Sorghum & Cotton

The reason that cotton is such a good crop to partner with when sharing water is because, while the overall water consumption might not be that much lower, the greatest demand is usually later that that for corn and sorghum. When cotton is planted into good moisture, it can rely on stored soil moisture to meet its requirements for the early part of the growing season. The two red circles shown in Figure 5, illustrate that when the cotton on the north side of the pivot is using stored soil moisture, irrigation can be directed to the sorghum on the south side of the circle, better meeting the crop demand.

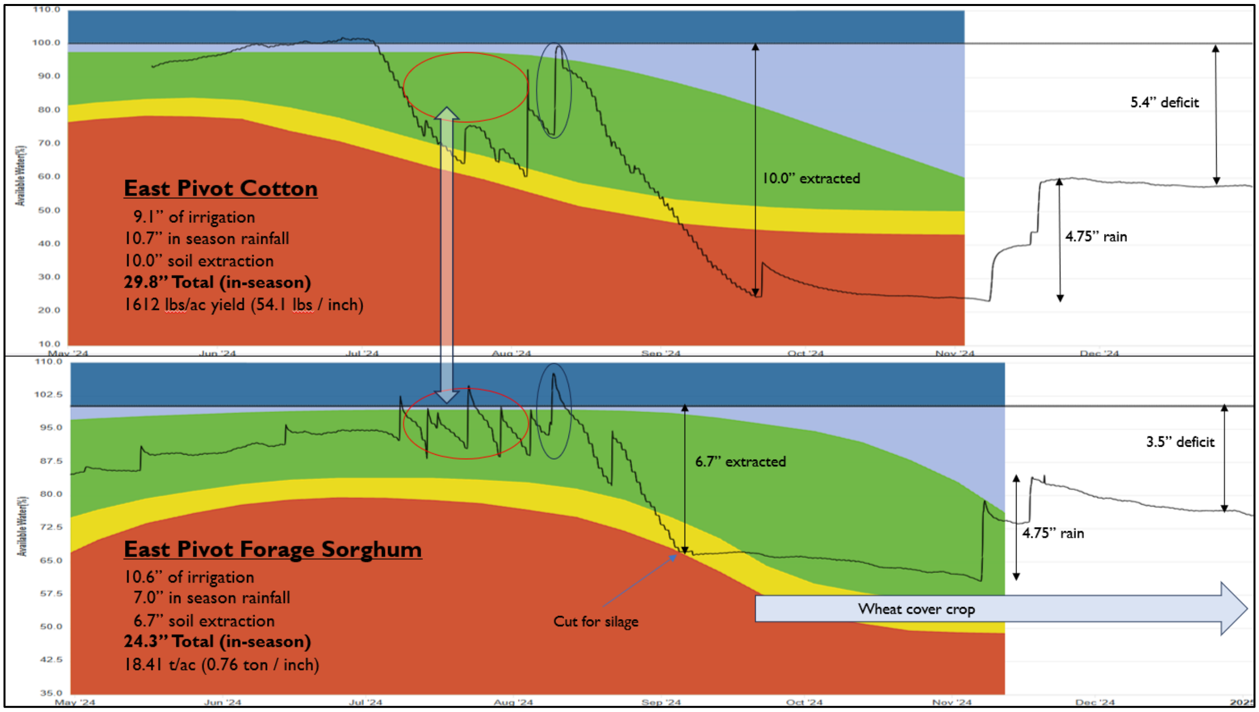

Figure 5 GroGuru soil moisture summary graphs showing total water use for cotton (above) and forage sorghum (below) grown under the east pivot

The two blue circles shown in Figure 5 indicate a large rainfall event that dropped around 3.6" over a 4-day period. It was evident that this was extremely helpful in filling the soil profile on the cotton field since it had not received as much irrigation as the sorghum on the south side of the field. The fact that the sorghum had been relatively well watered, meant that the soil could not hold all of the rainfall and the soil moisture probe graph showed a significant amount of drainage below 48".

Sharing Water Between Forage Sorghum and Corn

Corn and forage sorghum have similar water use patterns, meaning that they both need irrigation at the same time. In order to separate the peak water demand in this water sharing scenario, they were planted 24 days apart. However, the red circles in Figure 6 show that both crops tended to dry the soil somewhat, as irrigation was not able to keep up with crop demand. In both crops, the 3.6" of rain that fell over 4 days in early August (circled in blue in Figure 6) had a large positive impact, since the soil was relatively dry and could catch all of the rain that fell. The soil moisture probe data showed that all of the rainfall was captured and none drained below the root zone. Anecdotal observation did not show any observable run-off from the field or prolonged ponding on the soil surface after the rain had stopped.

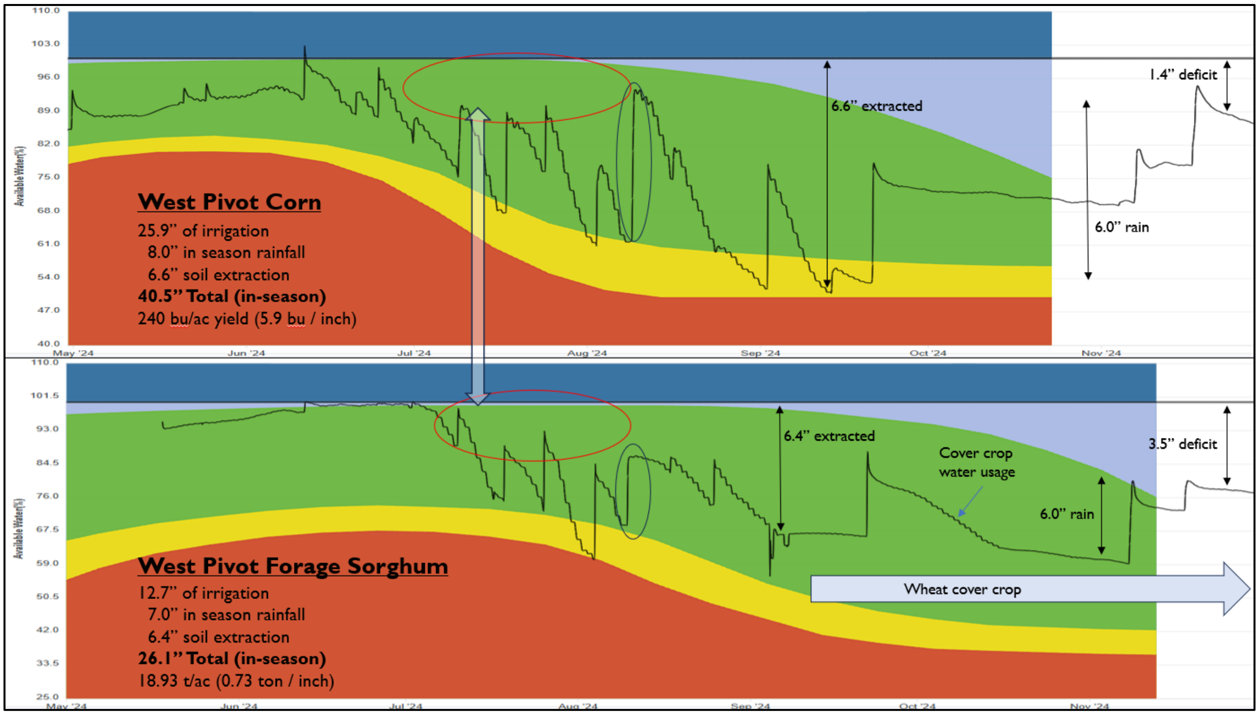

Figure 6 GroGuru soil moisture summary graphs showing total water use for corn (above) and forage sorghum (below) grown under the west pivot

Comparison of Two Forage Sorghum Irrigation Strategies

Any forage crop, where maximizing biomass is the critical factor, enjoys access to adequate moisture, especially during the early season. This is to maximize cell expansion and leaf production, to generate vigorous and explosive growth to maximize forage yield over a short growing season. However, access to early season moisture really depends on the partner crop that is sharing water with the forage crop to determine the compatibility with the water sharing arrangement. It was evident that cotton and forage sorghum, especially when the sorghum is planted later, should be more compatible than when forage sorghum is partnered with corn. This was due to the relatively lower water requirements of cotton compared to corn during the early season.

The forage sorghum was planted on the same day, using the same equipment, with the same variety. Anecdotally, it was noticed that the sorghum on the west pivot, which was planted after cotton, emerged more quickly and was more vigorous in the first 10 days after planting (Figure 7). It was assumed that this was most likely due to higher soil temperatures in early June following cotton, compared to corn, where there was more stubble and trash present. Whilst no direct temperature measurements were taken, the soil moisture probes at 12" depth did show a 3.5° F difference in soil temperature between the two fields, supporting this theory. This difference, however was only short lived and the growth differences between the two fields quickly evened out (Figure 8).

Figure 7 The forage sorghum plant stand 20 days after planting for the east pivot after corn (right) and the west pivot after cotton (left). It was noticed that the sorghum after cotton experienced a quicker emergence and stand establishment.

Figure 8 The forage sorghum plant stand 28 days after planting, showing growth and ground cover had largely evened out between the two fields

Figure 9 shows the soil moisture summary graphs for the two forage sorghum crops and highlights the difference between sharing water with cotton (top) versus corn (bottom). It was evident that the irrigation of the forage sorghum on the east pivot that shared water with the cotton crop was better able to keep up with plant demand than for the irrigation on the west pivot. The block arrows show that when forage sorghum was sharing water with corn, the soil was drying out due to the crop demand being greater than the irrigation supply. It should be noted that the large 3.6" rainfall event on 10th August (circled in blue in Figure 9) was extremely timely and probably had a large effect in ensuring that the silage yield on the west pivot was greater than the silage yield on the east pivot. Indeed, it is hypothesized that this single event played a large role in "levelling the playing field" between the two water sharing arrangements. Table 5 shows that there was 1.1" more water pumped on the forage sorghum grown on the west pivot, but had that large rain not fallen, it is likely that this difference would have been larger, due to the fact the crop had depleted the soil moisture store much earlier that on the east pivot. Figure 9 shows that, when sharing water with cotton, the irrigation was better able to keep up with demand (horizontal block arrow) before it was depleted later in the season, leading up to harvest (as seen by the downward trend in the block arrow). Clearly, the timing of rainfall, especially significant rain, can make a massive difference to yield. It is also true that chances of rainfall in August are actually elevated, however the sharing of water with corn does increase the risk of an adverse outcome if the rain does not come. This must be considered in the context of this study.

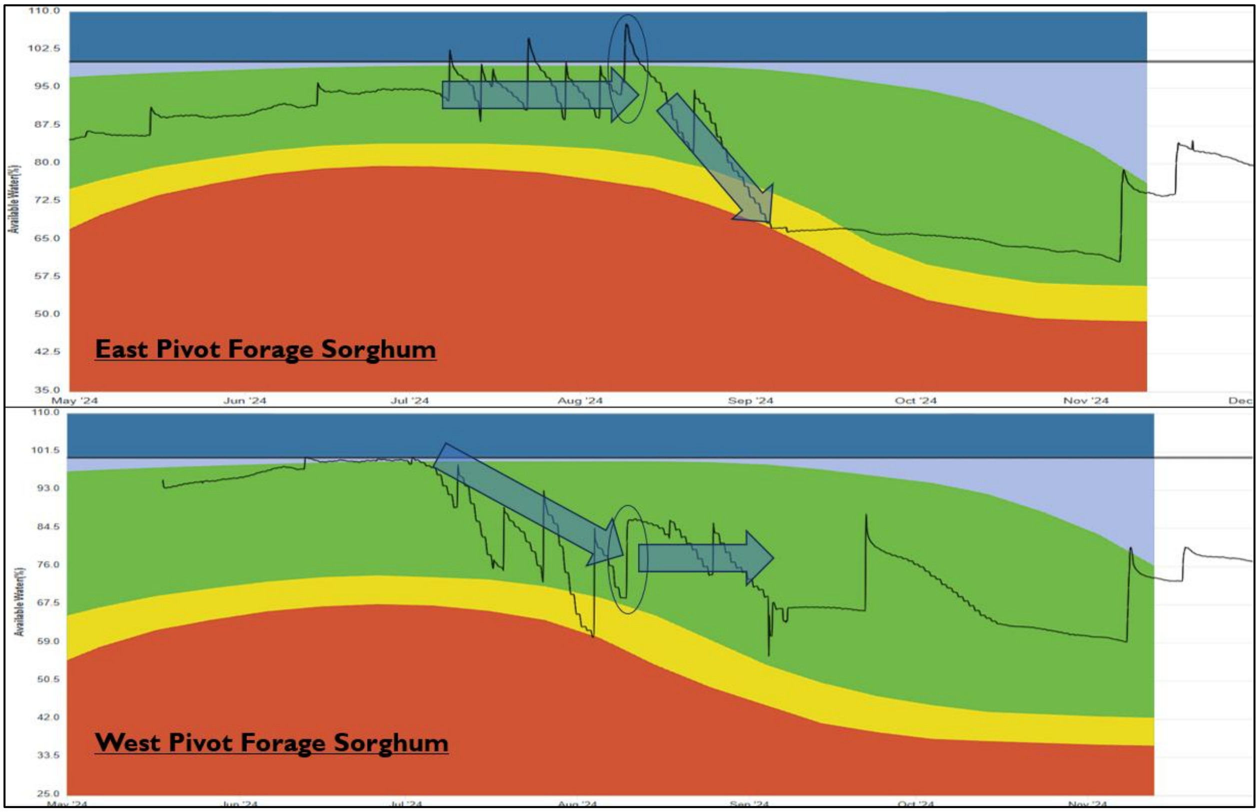

Figure 9 Comparison of forage sorghum water use when sharing water with cotton (above) or corn (below).

Figure 10 Forage sorghum plant height. West pivot 69" tall (left). East pivot 75" tall (right)

It was interesting to note that where the forage sorghum enjoyed greater access to irrigation (i.e. on the east pivot), the final plant height just before cutting was approximately 75" tall (Figure 10). Whereas the west pivot, which was sharing water with corn and underwent a more deficit-style irrigation pattern had a final plant height of 69". This difference in vigor was expected based on the irrigation patterns involved. What was more interesting was that the shorter crop was actually heavier and enjoyed a 0.5 t/ac greater final silage yield. It just shows that, despite the different patterns of growth, the conversion of water into biomass was very similar.

Pivot vs Subsurface Drip Irrigation

The two 19ac subsurface drip irrigation (SDI) field were planted to cotton (north) and corn (south) (see Figure 2). Each field was further divided into 8 irrigation zones and two neighboring zones were treated as one zone to give 4 different treatment plots in each field. The manual legacy irrigation controller that had been used for many years was replaced during 2024 to provide an automated irrigation system, but unfortunately not in time for the start of the season. As such, the initial irrigation regime ended up being the same for all treatments and there were no irrigation differences established for the first half of the season. Once the automated controller was fitted and programed, the same volume of total irrigation was applied in 4 different ways.

1. Irrigation every day
2. Twice the run time every 2nd day
3. Three times the run time every 3rd day
4. Four times the run time every 4th day

Corn

Table 6 Comparison between center pivot irrigated and subsurface drip irrigated corn

East Pivot (110ac)	Pivot	SDI
Crop Type	Corn	Corn
Planted	14th May	14th May
Fertilizer (pre-plant)	56 lbs N	56 lbs N
Fertilizer (fertigation)	85 lbs N	85 lbs N
Hybrid	P1366 AML	P1366 AML
Seeding Rate	30,000	30,000
Row Width	30”	30”
Tillage	No Till	No Till
Pre-plant Irrigation	5.12”	1.91”
Pre-plant Rainfall	2.09”	2.09”
In-Season Irrigation	25.91”	18.55”
Total Irrigation	31.03”	24.46
Soil Extraction	6.6”	6.6”
In-Season Rainfall	8.00”	8.00”
Total In-Season Water Use	40.51”	33.15”
Yield	240 bu/ac	177 bu/ac
Yield/inch (in-season water use)	5.92	5.34
Yield/inch (in-season irrigation)	9.26	9.54

The corn planted on the west pivot and the south SDI plots was planted on the same day, at the same rate, using the same equipment, etc. As such, they were essentially set up to be exactly the same. Both fields were pre-irrigated and both established very similar plant stands, since they had the same historical crop rotation.

Table 6 shows that the SDI field has over 7.3" less irrigation applied compared to the pivot irrigation. This is expected due to the greater efficiency of subsurface drip irrigation, however the SDI field also experienced a significantly lower yield. Figure 11 shows that the soil moisture was maintained through the pivot system, whereas the SDI system under-irrigated the field and allowed the corn to dry out during the peak demand in late July (see block arrow on right graph). The large rain around 10th August significantly helped to raise soil moisture in the profile but by then a lot of the yield potential had been lost.

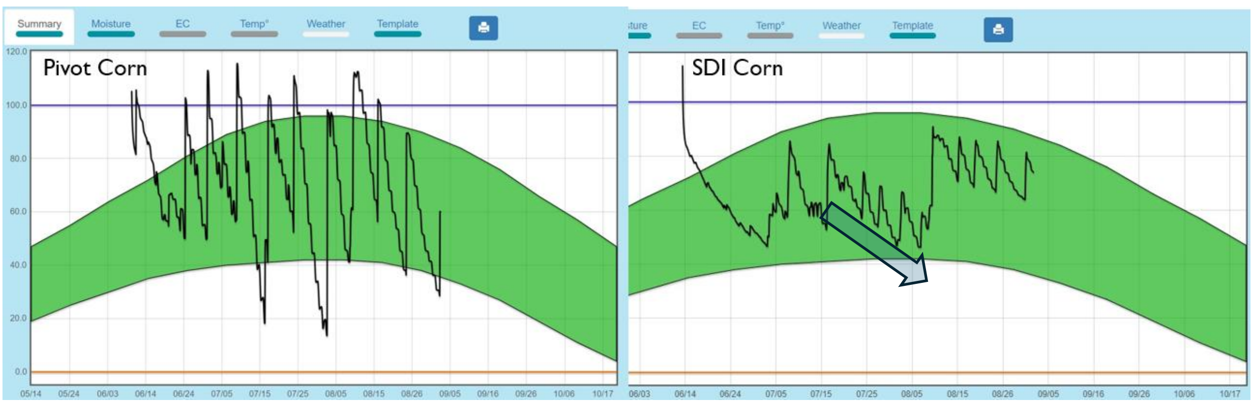

Figure 11 Comparison of sprinkler irrigated (left) and subsurface drip irrigated (right) summary soil moisture

Figure 12 shows the differences in total soil moisture from the AquaSpy summary graphs for each treatment, where the same total volume of water was applied, it was just applied using different irrigation run times.

Since the irrigation was not consistent from the start, no attempt was made to harvest each of the SDI plots individually. As such, only a total SDI yield was calculated and compared to the sprinkler irrigated corn in Table 6. It should also be noted that, the soil moisture probes were not closely followed either and it was evident that this field was under-irrigated. While the yield was 63 bu/ac lower on the SDI plots compared to the west pivot, it was interesting to note that the actual yield per inch of water was almost the same (5.92 bu/in compared to 5.34 bu/in) and the yield per inch of irrigation was actually higher (9.26 bu/in vs 9.54 bu/in). This highlights the great efficiency of delivering water straight to the rootzone.

On 3rd September, 10 randomly selected ears were taken and measured for ear length. This was done because it was noticed that significant kernel loss from "tipping-back" had occurred in many of the SDI pots. Figure 13 shows that the ear loss seemed to be correlated with the irrigation regime experienced by the SDI plots. All of the ears in the sprinkler irrigated corn were 7" or greater, whereas most of the ears in the SDI plot that was watered every 4th day were 6" or less. While this is only anecdotal evidence, it was an interesting observation.

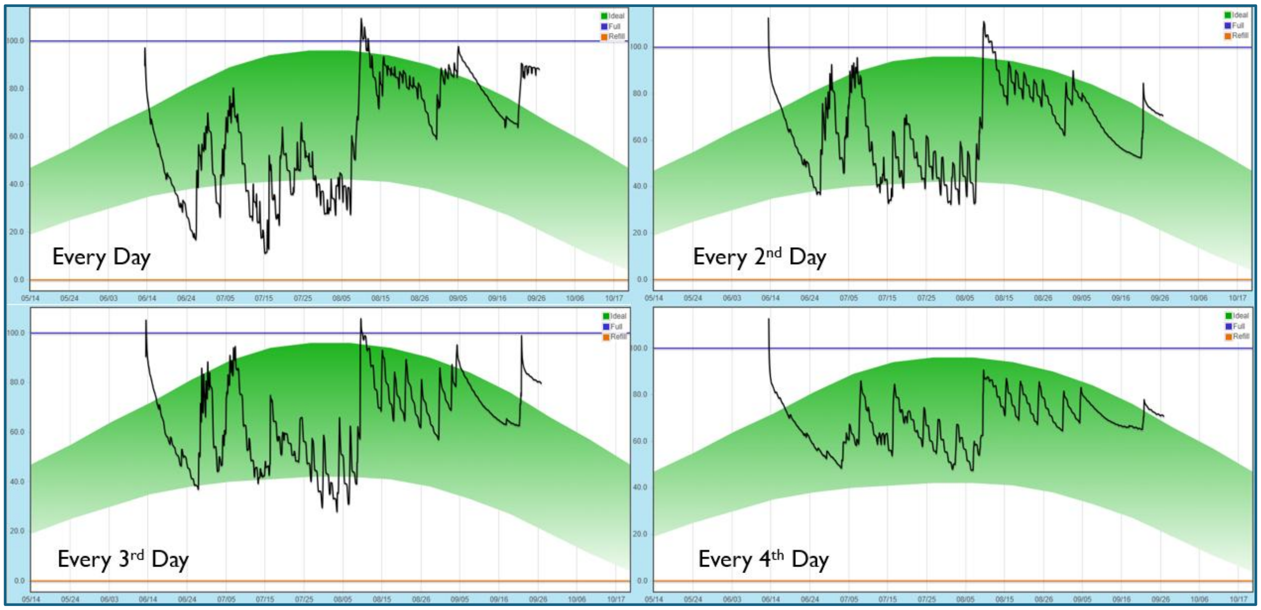

Figure 12 The four graphs show the summary soil moisture for SDI corn that was irrigated every day, every 2nd day, every 3rd day and every 4th day, with the same total volume of water applied to each plot

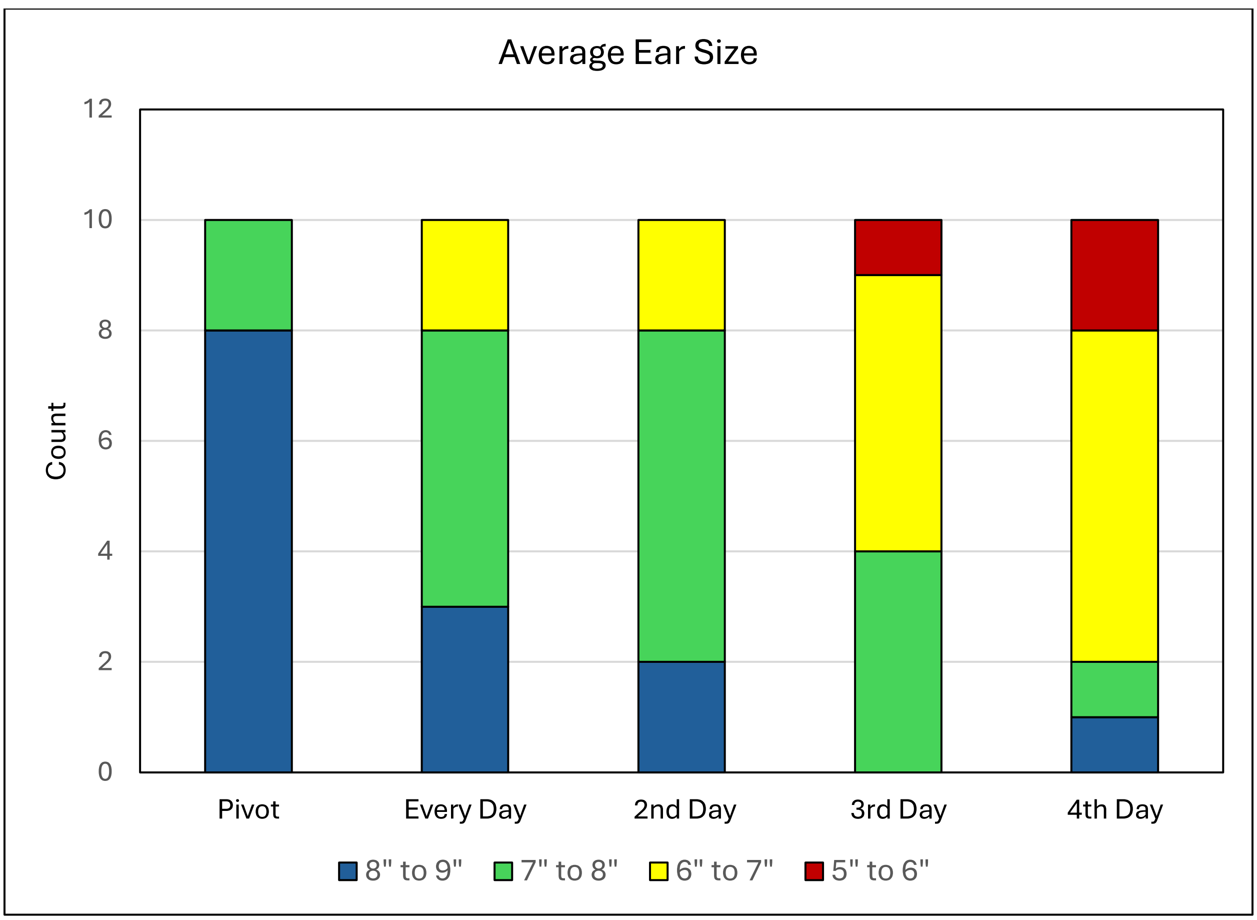

Figure 13 Corn ear size from 10 randomly selected ears in each plot

Cotton

Since the SDI cotton was irrigated using the same controller as the corn, the different irrigation regimes were similarly not imposed until the later part of the season. For this reason, the cotton plots were also harvested in bulk and not separated. As such, only anecdotal observations can be made. The final yield of the SDI field was 1261 lbs/ac, which was 351 lbs/ac lower than the sprinkler irrigated cotton (Table 7) but was well in line with historical averages and was achieved using less than half the irrigation under the pivot. There was however, reasonably high in-season rainfall and a large amount of extraction of stored soil moisture. Since the desired irrigation regime was not successfully implemented, not too much weight was placed on these results. Another mitigating factor in the yield difference was the greater number of skips and misses in the cotton plant stand achieved with on the SDI field. Cotton germination is much easier to achieve using a sprinkler than with SDI since the drip tape was buried some 12-14" deep. Experience has shown that it can be hard to achieve an even germination without rainfall and for that reason, the farmer is reluctant to grow cotton again on the SDI system.

Table 7 Differences in irrigation, yield and water use efficiency between pivot and SDI irrigated cotton

	Pivot Cotton	SDI Cotton
In-season Irrigation	9.11"	4.23
Rainfall (in-season)	10.68"	10.68"
Soil Moisture Extracted	10.00"	10.00"
In-season Water Use	29.79"	24.91
Yield	1612 lbs/ac	1261 lbs/ac
Yield per inch (in-season total usage)	54.1	50.62
Yield per inch (in-season irrigation)	127.8	298.1

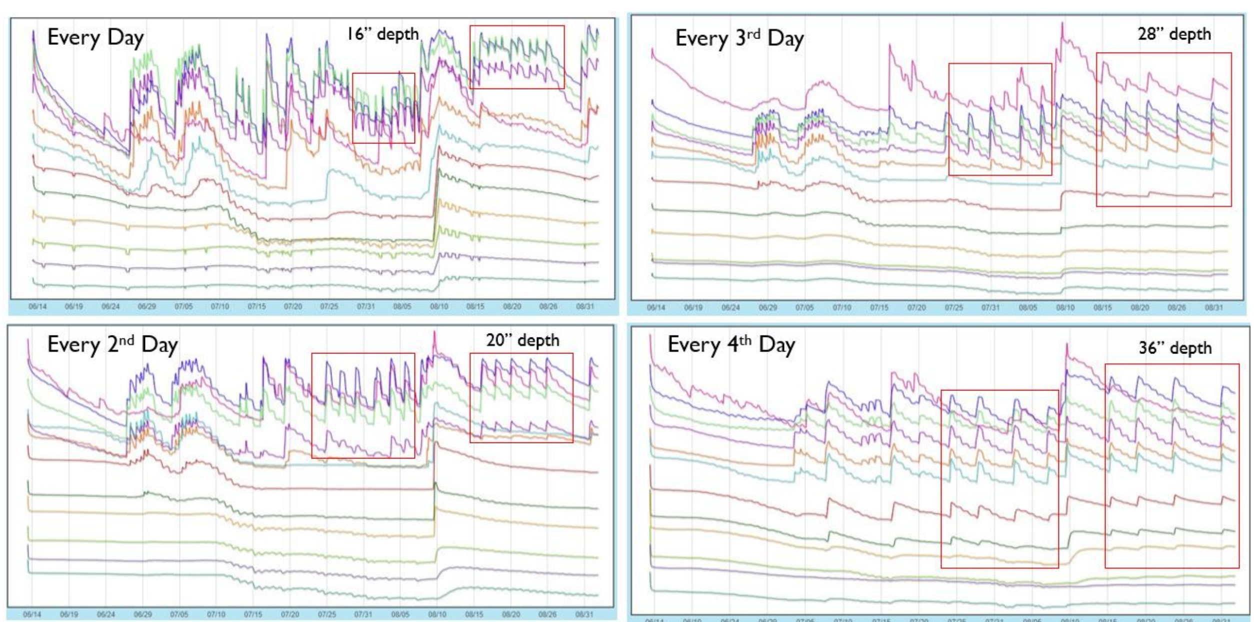

Figure 14 Soil moisture graphs showing the differences in irrigation wetting fronts due to different SDI run times

One interesting observation in Figure 14 is that the different run times did produce differences in the wetted volume of soil. The highlighted boxes contained within the graphs show that the longer the run time (i.e. irrigation every 4th day) the deeper the irrigation penetrated, as viewed by the stepping upwards by a greater number of colored lines, even as deep as 36". Whereas, irrigation every day (with a much shorter run time) was only able to wet the sensors in the top foot of soil. It is presumed that if the irrigation regimes were implemented earlier, we might have observed differences in root depth, caused by differences in the wetted volume. That is to say that the roots might have been "trained" to grow deeper using a longer run time, if it was implemented from the beginning, during the period of rapid root growth. The fact that there was no differences in irrigation run times for the first half of the season, the root systems would have developed similarly between plots, greatly reducing any effect of different irrigation patterns later in the season.

UpTerra

Installation

The UpTerra system was fitted to the irrigation supply pipe at the center of the west pivot approximately one week prior to corn planting. Figure 15 shows how the pipe was cut and a flange inserted in order to bolt the UpTerra system in place. Electronics were later fitted to supply the electromagnetic frequency to the water that passes through the unit. All of the pre-irrigation was not treated by the system, only the irrigation from planting onwards was subjected to the system.

Figure 15 The UpTerra system was fitted to the supply pipe at the center of the west pivot.

Sorghum Comparison (A-B Test)

The graphs shown in Figure 16 show the total soil moisture for the forage sorghum grown on the east (untreated) and west (treated) pivots respectively. The main differences in irrigation strategy were pointed out earlier in comments relating to Figure 9. There were no anecdotal differences in the way irrigation and more importantly, infiltration was observed between the two systems. Indeed, they had very similar rates of supply (see Table 1) and were treated similarly when scheduling irrigation. However, large differences were noted when a large 3.6” rainfall event began on 8th August. The block arrow in Figure 16 highlights when this occurred and it is clear that the soil moisture significantly increased on both graphs. However, what is more curious is the fact that on the UpTerra treated field, the water was held entirely in the top 24” (Figure 17). It can be observed that the red line at 24” increased but the orange line at 32” did not (Figure 17, bottom graph), indicating that no moisture infiltrated to the 32” level. Whereas on the east pivot (Figure 17, top graph) the moisture penetrated to the lowest (pink) sensor at 48”. What is more, the signature after this wetting event indicates that moisture drained below this depth, which would be entirely expected for such a large rainfall event. While no further measurements were made, it is highly unusual behavior for a soil to be able to store this amount of rainfall without significant drainage or runoff. It should be noted that no runoff was observed.

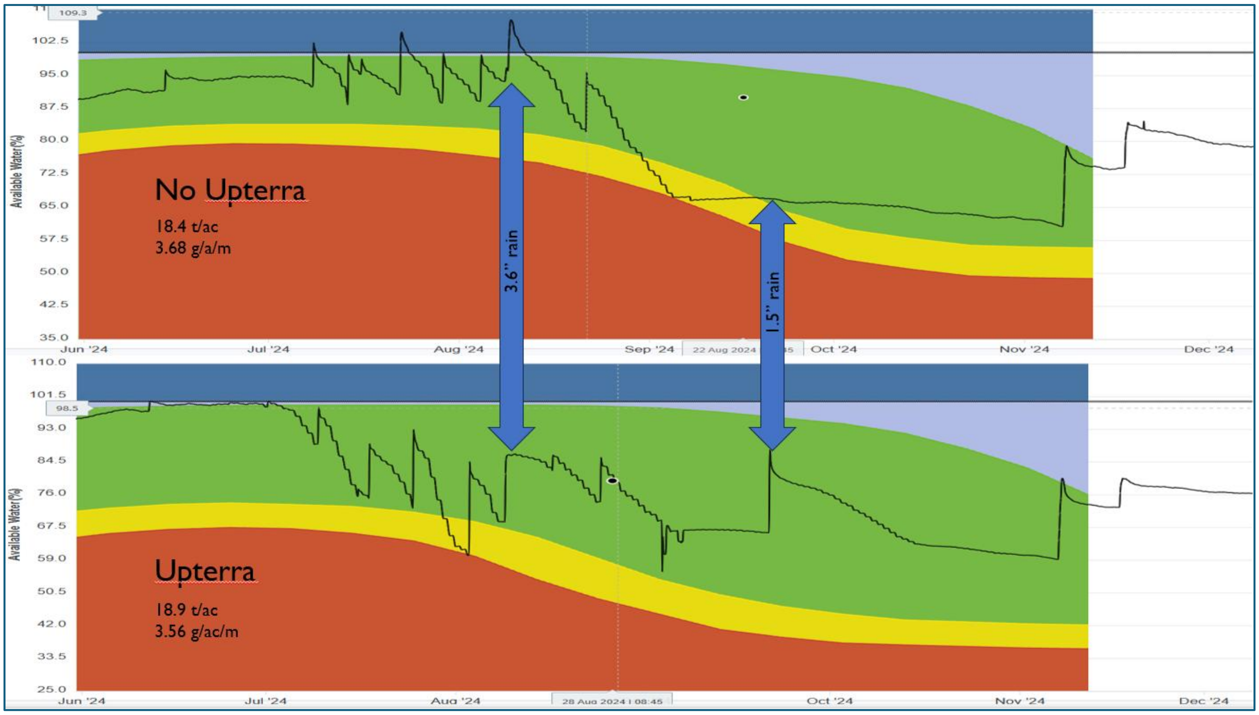

Figure 16 Soil moisture summary graphs from the east pivot (above) and the west pivot (below) showing a comparison of the soil moisture conditions with and without the UpTerra unit.

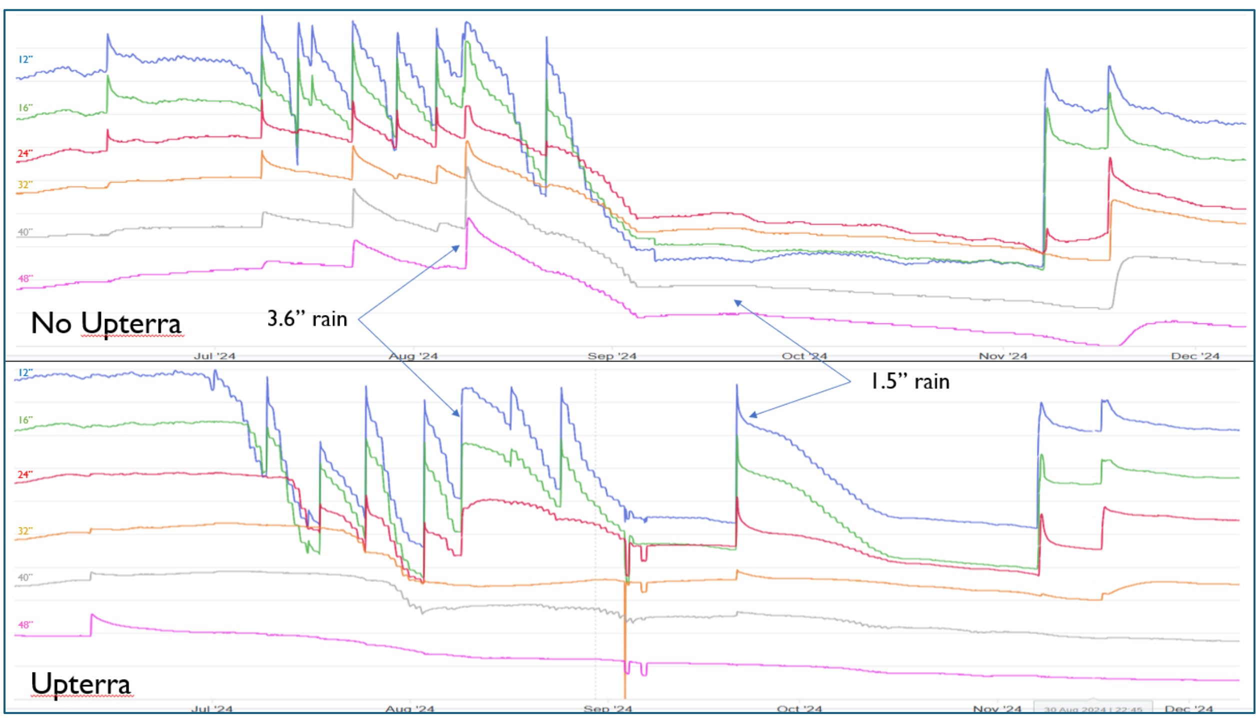

Figure 17 Soil moisture probe data showing the moisture conditions at each individual depth in the forage sorghum grown on the east pivot (top) and the west pivot (bottom), highlighting differences in soil moisture dynamics between the UpTerra and non UpTerra treatments.

The second interesting point to note was that there was 1.5” of rain that fell on 20th September, after the forage sorghum was cut for silage. It is obvious in Figure 16 that this rainfall can be observed as an increase in soil moisture on the west pivot (bottom graph) but not on the east pivot (top graph). While it is entirely possible that 1.5” of rainfall could be held entirely within the top foot when the soil is dry, it is interesting to note the difference between two fields that were otherwise treated the same, having had the same crop, planted on the same day at the same rate. They also experienced approximately the same soil moisture deficit at the time the rain fell. The main difference between the two probe sites was the treated irrigation water versus the untreated irrigation water. Upon further examination (Figure 17), we can see that the rainfall was able to penetrate to 32” and even 40” (seen as a small blip at those sensor depths). This is somewhat perplexing given the lack of penetration with a much larger rainfall event earlier in the season. It should also be noted that these infiltration effects were observed from rainfall which was the same for both fields, so any differences imparted by the UpTerra system, must have been imposed on the soil itself and not the water.

Current Season vs Historical Comparison

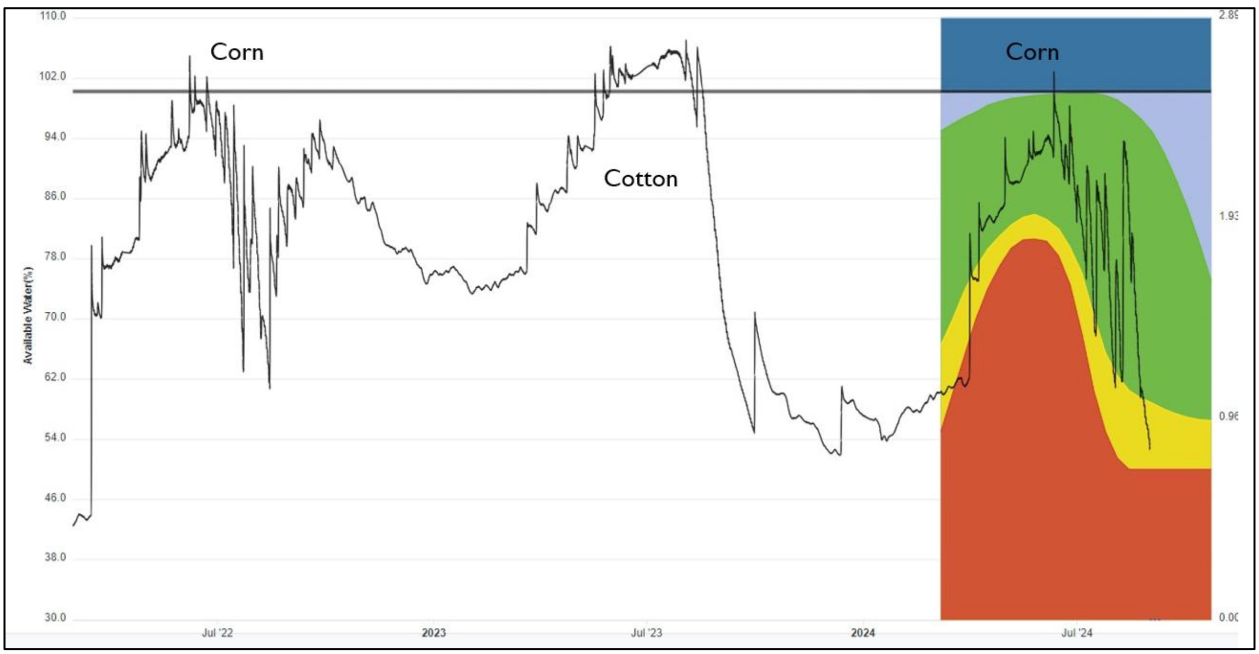

Figure 18 Historical soil moisture summary data showing the last 3 seasons of crop water use. This enables a comparison of the 2024 corn crop with the previous corn crop grown on the same field in 2022.

The fact that a soil moisture probe has been installed in the same location for 6 years, enables a valid comparison over time. Figure 18 shows the soil moisture usage from the current corn crop grown on the west pivot in 2024, along with the water usage from the previous 2023 cotton crop and the 2022 corn crop. While the 2024 growing season shows very good root activity and irrigation penetration, it is hard to say (even anecdotally) that there is any observable difference since the UpTerra system was installed, compared to the corn grown in 2022. As such, it is inconclusive to see any major difference on the same monitoring site over period before and after the UpTerra system was installed.

Conclusions

The Role of Forage Sorghum

The results have shown that silage produced from forage sorghum can significantly reduce the irrigation footprint and improve the conversion of water into feed for producers in the Texas panhandle. Partnering forage sorghum with cotton production produced far greater returns per acre inch than partnering it with grain corn. This was partly due to the exceptional cotton growing conditions in 2024 and the high yields that resulted, but it was also due to the highly compatible water sharing arrangements between the two crops. The peak demand for corn and forage sorghum did overlap considerably and if it weren't for a significant and timely rainfall, the yields on both crops might have been much lower for the west pivot. Given the highly variable nature of rain in the Texas panhandle, it is recommended that the demonstration be repeated in 2025 to see how the water sharing arrangement fares under different seasonal growing conditions.

Silage production can be tough on soil health due to the removal of all biomass on the soil surface. The bare soil is prone to wind erosion and the lack of ground cover gives a greater heating and cooling effect and higher soil evaporation – both detrimental to soil biology. As such, any silage crop should be immediately followed by establishment of ground cover through either a cover crop or a following rotational silage crop (i.e. double cropping). The unseasonably warm fall temperatures and very late hard freeze contributed to significant regrowth of the forage sorghum. If double cropping is not desired, one possible option would be to plant forage sorghum somewhat earlier, so that regrowth after harvest could be better assured, even with an earlier freeze. In this way, the effects of a cover crop could be obtained, without the need to plant one. Regrowth from an already established root system would also be more vigorous and potentially offer greater ground cover heading into the winter. This would also eliminate the need to terminate the cover crop and not risk using any stored soil moisture in the spring. The greater water use efficiency of forage sorghum could also allow some additional irrigation to be invested in establishing a cover crop, especially due to regrowth of the forage sorghum after cutting.

The short growing season of forage sorghum provides good flexibility with a wide range of possible planting dates. It could be planted both early and late on the same pivot to allow split watering between two forage sorghum crops. Or if could be partnered with early or late planted rotational crops to spread out peak irrigation demand rather than needing to reduce acreage under the pivot. Sorghum has a role in replant situations where it could be planted after an earlier crop failure but still produce a highly profitable silage crop.

It should be noted that this demonstration only used one hybrid of male sterile brown midrib forage sorghum. Variety trials have shown that, while corn silage yields are generally fairly consistent across hybrids, sorghum silage yields are far more variable between hybrids. The opportunity exists to possibly find a better, more productive hybrid to further enhance the results. However, there needs to be a balance between feed value and yield and further exploration of alternative hybrids would be prudent.

Productivity in the Face of Declining Water Supply

Results showed that the wells at the WCC were able to supply just over 3.5 gallons per acre per minute. While this was slightly greater that first though, it is firmly in the range of “low” water supply for traditional irrigation in the Texas panhandle. While we were able to supply enough water to deficit irrigate corn and forage sorghum combined, the small pivots and 88 ac field size had a lot to do with it. We were able to apply 1.75” per pass, conducting an 8-day loop. However, if this was a standard 120ac pivot, it would have taken significantly longer to apply the same amount of water. This would almost certainly reduce the yield potential from what we experienced at the WCC and must be considered when viewing these results. One solution many farmers have found is to split-plant a standard quarter mile pivot into two 60ac fields. The solution then would be to plant one side very early and the other side very late, to spread out the peak demand. If forage sorghum were planted on both sides, this would be a good use of water but may present harvest issues with harvesting silage on a half field. While it is not the normal practice in the local area due to the extra management involved, it could produce other side benefits. One major issue with silage production is the potential compaction from running heavy machinery and trucks over wet soil. If a full circle is grown, then at harvest time, one side of the pivot will inevitably be wetter than the other. But if only half a field is ready at any one time, greater control over drying the field could be obtained and there is a much greater chance of avoiding compaction. This is something for consideration when viewing not only how best to manage water, but also how to maintain and even enhance the soil resource.

Double Cropping

Rotating from a summer silage to a winter silage and back again (i.e. double cropping) has proven to be very popular in the Texas panhandle region. This is almost solely due to the large numbers of animals on feed in the area and the massive recent expansion in silage demand. The typical rotation is for corn silage, into wheat silage and back to corn again the following summer. This exerts a very high irrigation demand on the aquifer and it is probably not sustainable in the long run. This demonstration has shown that a profitable silage yield can be obtained using forage sorghum, but with only half the water use. While double cropping is not encouraged due to the stress on the aquifer, forage sorghum should have a large role to play in reducing the irrigation footprint, or getting it more in line with the current decline in water supply. Forage sorghum should produce a greater conversion of water into silage than corn, enabling greater tonnage to be produced for the water available. While it may not be as palatable or desirable as corn, it has a role in producing greater raw tonnage of silage for the water that is available.

Further Thoughts

While the demonstration program for 2024 set out to achieve three main objectives, the core focus was always to examine the role that forage sorghum could play in the crop rotation for irrigators on the Texas north plains. Use of the subsurface drip fields and the addition of the UpTerra system were really included in the program simply because they were available. The need to understand how best to utilize low output wells has become the overwhelming issue for irrigators in the region. The fact that it is even possible to grow 240 bu/ac corn on 3.5 g/a/m irrigation supply is testament to the many changes that have occurred over the past 10 years. We have learned to run sprinklers in bubble mode for the majority of the season, and to use 30" nozzle spacing. We have learned to irrigate very slowly, so water penetrates deeply. We have learned to get the agronomy right to not over fertilize and use the correct seeding rates, with the correct hybrids. Yet even that might not be enough to keep up with the dwindling water supplies as well yields continue to drop. We need to continue to innovate and look for new crops and ways to grow them, so that we may continue to live profitably in such an arid landscape.

Appendix

1. Rainfall Data

Date	North Gauge	South Gauge	East Gauge	West Gauge	WS Site Gauge	HOBO New	Pivotrac West	Pivotrac East	HOBO Old	Weekly Average	Monthly Average
1/1/24	0	0	0	0	0	0	0	0	0	0	
1/8/24	0.46	0.49	0.39	0.43	0.46	0.41	0.19	0.35	0.48	0.41	
1/15/24	0	0	0	0	0	0	0	0	0	0	
1/22/24	0	0	0	0	0	0	0	0	0	0	
1/29/24	0.03	0.04	0.03	0.04	0.04	0.03	0.04	0.06	0.03	0.037	0.444
2/5/24	0.26	0.27	0.29	0.25	0.23	0.21	0.2	0.29	0.25	0.246	
2/12/24	0.25	0.25	0.25	0.25	0.25	0.05	0	0	0.06	0.25	
2/19/24	0	0	0	0	0	0	0	0	0	0	
2/26/24	0	0	0	0	0	0	0	0	0	0	0.496
3/4/24	0	0	0	0	0	0	0	0	0	0	
3/11/24	0	0	0	0	0	0	0	0	0	0	
3/18/24	0.14	0.15	0.15	0.16	0.15	0.12	0.14	0.14	0.15	0.144	
3/25/24	0.1	0.18	0.11	0.15	0.11	0.09	0.1	0.23	0.13	0.133	
4/1/24	0.04	0.03	0.03	0.03	0.04	0.05	0.06	0.07	0.06	0.045	0.322
4/8/24	0.45	0.45	0.38	0.43	0.43	0.47	0.38	0.44	0.58	0.445	
4/15/24	0	0	0	0	0	0	0	0	0	0	
4/22/24	0	0	0	0	0	0	0	0	0	0	
4/29/24	0	0	0	0	0	0	0	0	0	0	0.445
5/6/24	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.015	
5/13/24	0.4	0.36	0.37	0.36	0.39	0.36	0.36	0.29	0.43	0.368	
5/20/24	0.79	0.49	0.57	0.42	0.67	0.8	0.58	1.49	1.01	0.76	
5/27/24	0.08	0.08	0.07	0.08	0.08	0.07	0.07	0.11	0.08	0.08	
6/3/24	0.12	0.16	0.13	0.17	0.14	0.14	0.27	0.34	0.19	0.19	1.413
6/10/24	0.58	0.51	0.47	0.53	0.54	0.52	0.34	0.49	0.58	0.506	
6/17/24	0.12	0.12	0.13	0.11	0.13	0.13	0.15	0.21	0.15	0.138	
6/24/24	0.38	0.4	0.32	0.39	0.42	0.4	0.32	0.38	0.46	0.385	
7/1/24	0.09	0.17	0.12	0.19	0.15	0.14	0.26	0.22	0.16	0.166	1.195
7/8/24	0.57	0.44	0.46	0.41	0.53	0.51	0.34	0.54	0.59	0.487	
7/15/24	0	0	0	0	0	0	0	0	0	0	
7/22/24	1.04	1	1.07	0.96	1.08	1.12	0.93	1.1	1.31	1.067	
7/29/24	0.07	0.08	0.07	0.06	0.09	0.13	0.15	0.14	0.15	0.104	
8/5/24	0.45	0.46	0.4	0.44	0.5	0.51	0.55	N/A	0.61	0.49	1.661
8/12/24	3.68	3.92	3.67	3.83	3.42	3.4	3.27	N/A	3.9	3.636	
8/19/24	0	0	0	0	0	0	0	0	0	0	
8/26/24	0	0	0	0	0.01	0	0	0	0	0	
9/2/24	0	0	0	0	0	0	0	0	0	0	3.636
9/9/24	0	0	0	0	0	0	0	0	0	0	
9/16/24	0	0	0	0	0	0	0	0	0	0	
9/23/24	1.53	1.58	1.43	1.49	1.58	1.55	1.58	1.63	1.83	1.577	
9/30/24	0	0	0	0	0	0	0	0	0	0	1.577
10/7/24	0	0	0	0	0	0	0	0	0	0	
10/14/24	0	0	0	0	0	0	0	0	0	0	
10/21/24	0.69	0.76	0.73	0.75	0.67	0.65	0.78	0.71	0.75	0.721	
10/28/24	0	0	0	0	0	0	0	0	0	0	
11/4/24	0.41	0.41	0.38	0.41	0.4	0.36	0.37	0.41	0.43	0.397	1.118
11/11/24	1.8	1.8	1.44	1.79	1.75	1.96	1.66	2.14	2.29	1.847	
11/18/24	1.74	1.88	1.65	1.85	1.75	1.73	1.55	1.85	2.04	1.785	
11/25/24	0	0	0	0	0	0	0	0	0	0	
12/2/24	0	0	0	0	0	0	0	0	0	0	3.632
12/9/24	0	0	0	0	0	0	0	0	0	0	
12/16/24	0	0	0	0	0	0	0	0	0	0	
12/23/24	0	0	0	0	0	0	0	0	0	0	
12/30/24	0	0	0	0	0	0	0	0	0	0	0
Total	**16.28**	**16.5**	**15.13**	**16**	**16.03**	**15.92**	**14.66**	**13.64**	**18.71**	**16.429**	**15.939**

2. Pivotrac Data

a) East Pivot

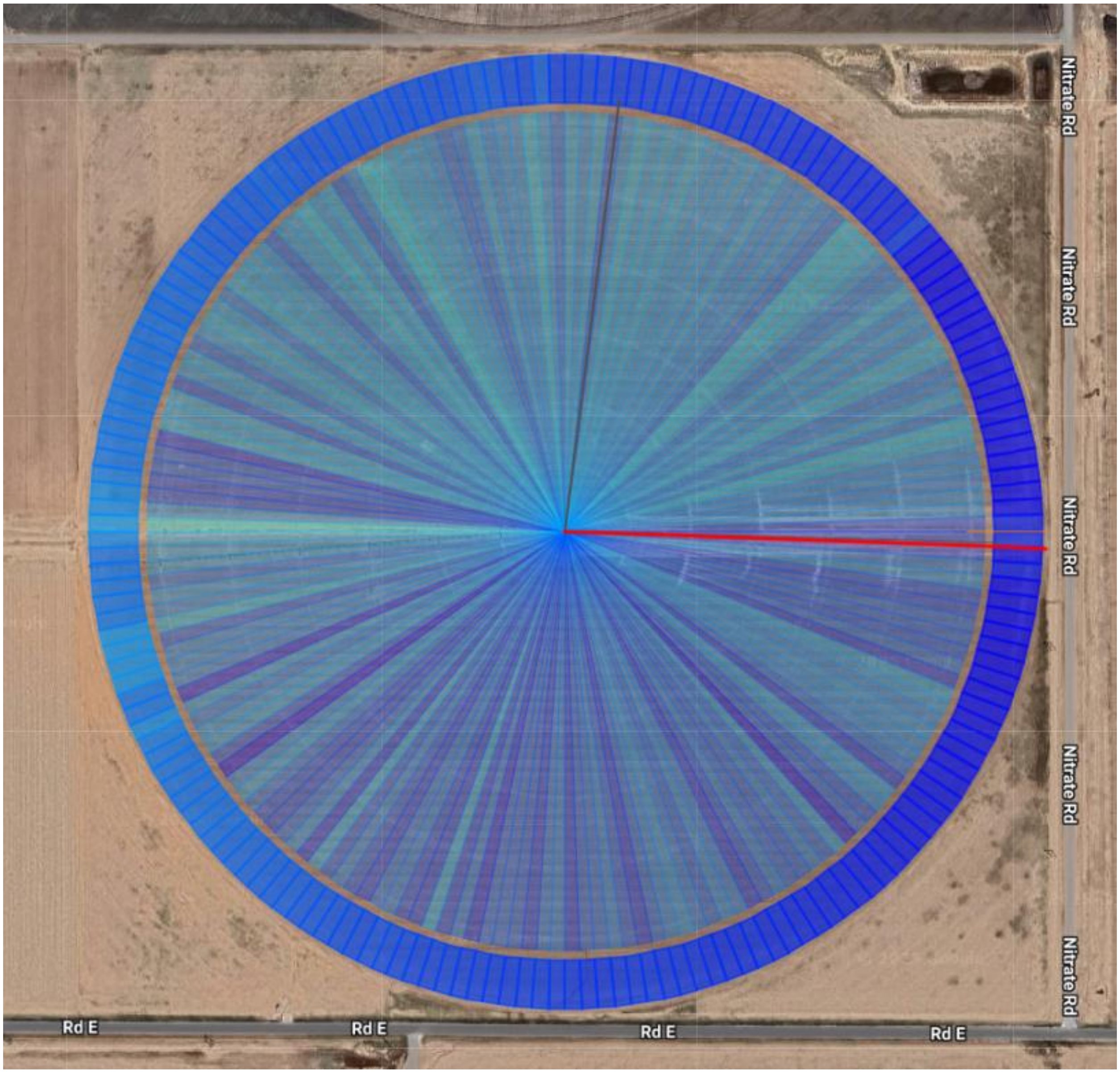

Figure 19 Pivotrac data showing the total water applied on the east pivot in 2024, where the north side is cotton and the south side is forage sorghum. The outside ring shows average end-pressure for the sprinkler.

b) West Pivot

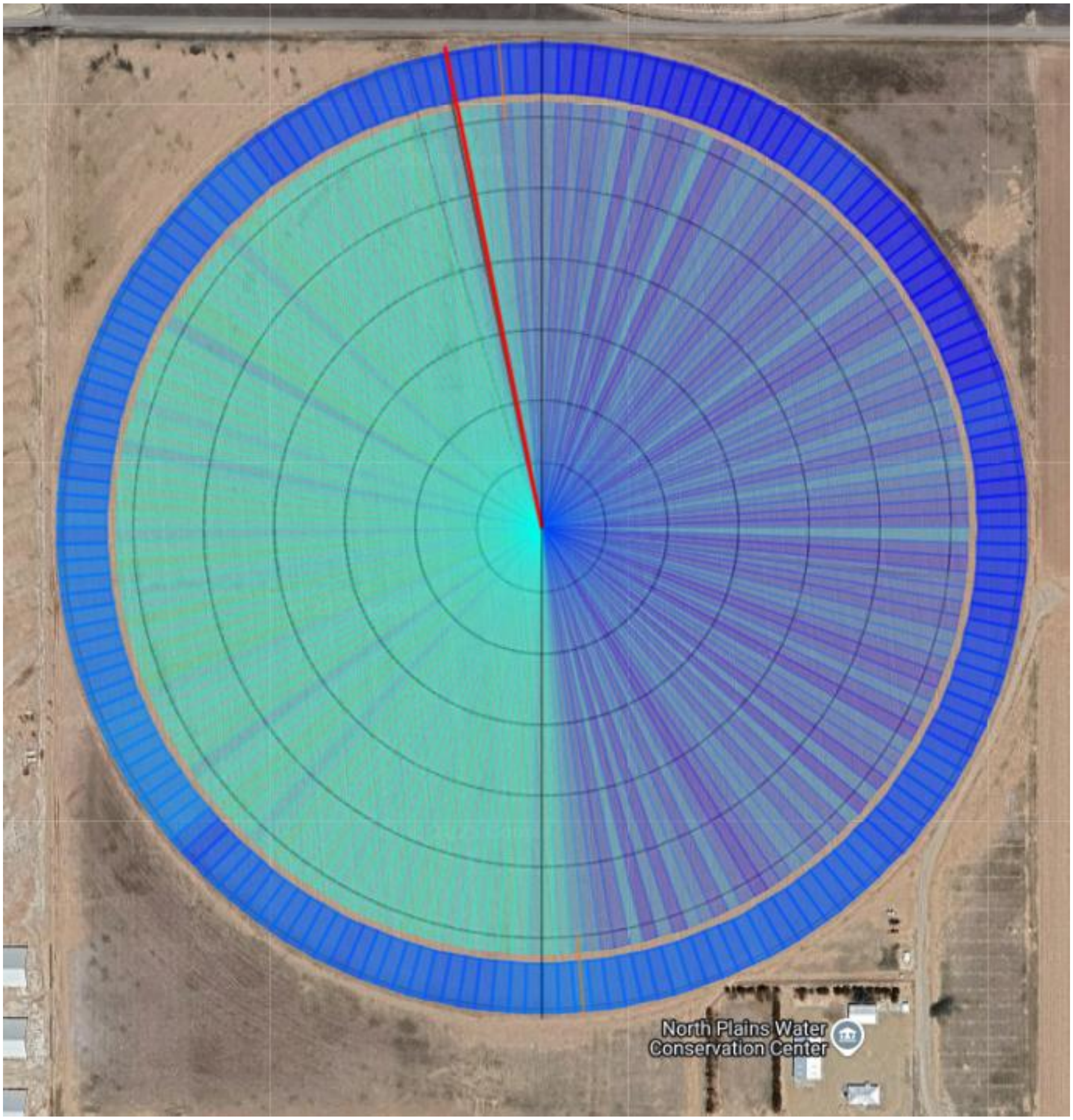

Figure 20 Pivotrac data showing the total water applied on the west pivot in 2024, where the east side is corn and the west side is forage sorghum. The outside ring shows average end-pressure for the sprinkler.

3. Gross Margin Analysis

a) Irrigated Cotton – East Pivot

Estimated Costs and Returns per Acre
Irrigated Cotton
Projected for 2024

Item	Quantity	Unit	Price	Total
Income				
cotton lint	1612	lb	$0.70	$1,128.40
cotton seed	1.209	tons	$225.00	$272.03
Expected Turnout	0.327			
other income	1	unit	$0.00	$0.00
other income	1	unit	$0.00	$0.00
Total Income				**$1,400.43**
Variable Costs				
Seed				
cotton seed	0.27	bags	$375.00	$101.25
Boll Weevil Assess.-Irr	1	acre	$1.00	$1.00
Fertilizer				
fert (P) - dry	0	lb	$0.80	$0.00
fert (N) - dry	0	lb	$0.52	$0.00
Field Operations				
preplant herbicide & application	1	acre	$60.15	$60.15
post emergence herbicide & application	1	acre	$49.00	$49.00
fertilizer application	0	acre	$7.50	$0.00
insecticide & application	0	acre	$15.73	$0.00
harvest aids	1	acre	$36.25	$36.25
strip & module	16.12	cwt.	$12.00	$193.44
ginning	49.29664	cwt.	$3.25	$160.21
hoeing	1	acre	$30.00	$30.00
scouting	1	acre	$9.50	$9.50
other	1.00	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
Crop Insurance	1.00	acre	$58.00	$58.00
Operator Labor & Hand Labor	0.77	hours	$17.65	$13.59
Irrigation Labor	0.774	hours	$17.65	$13.66
Diesel Fuel - Tractors	1.97	gallons	$3.10	$6.11
Gasoline - Pickup	3.482	gallons	$2.40	$8.36
Irrigation Fuel	12	acin	$3.80	$45.60
Repair & Maintenance				
Implements	1	acre	$0.00	$0.00
Tractors	1	acre	$0.00	$0.00
Irrigation-Above Ground	12	acin	$3.22	$38.64
Self Propelled Equipment	1	acre	$0.00	$0.00
Pickup	1	acre	$4.26	$4.26
Interest-operating capital	9.0%			$19.76
Total Variable Costs				**$848.78**
Returns Above Variable Costs				**$551.65**

b) Irrigated Sorghum Silage – East Pivot

Estimated Costs and Returns per Acre
Irrigated Sorghum Silage – East Pivot
Projected for 2024

Item	Quantity	Unit	Price	Total
Income				
sorghum silage	18.41	ton	$51.10	$940.75
other income	1	unit	$0.00	$0.00
other income	1	unit	$0.00	$0.00
Total Income				**$940.75**
Variable Costs				
Seed	8	lb	$2.50	$20.00
Fertilizer				
fert (P) - dry	0	lb	$0.80	$0.00
fert (N) - NH3	0	lb	$0.43	$0.00
fert (N) - liquid	49	lb	$0.58	$28.33
Field Operations				
herbicide & application	1	acre	$57.75	$57.75
fertilizer application - NH3	0	acre	$18.00	$0.00
insecticide & application - headwrm	0	acre	$27.50	$0.00
custom harvest & haul	18.41	ton	$12.50	$230.13
crop consultant	1	acre	$9.50	$9.50
insecticide sugar cane aphid	0	acre	$21.00	$0.00
fertilizer application	1	acre	$7.50	$7.50
other	1	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
Crop Insurance	1	acre	$26.00	$26.00
Operator Labor & Hand Labor	0.5	hour	$17.65	$8.83
Irrigation Labor	0.84	hours	$17.65	$14.83
Diesel Fuel - Tractors	1.41	gallons	$3.10	$4.37
Gasoline - Pickup	3.07	gallons	$2.40	$7.37
Irrigation Fuel	13.44	acin	$3.80	$51.07
Repair & Maintenance				
Implements	1	acre	$0.00	$0.00
Tractors	1	acre	$0.00	$0.00
Irrigation-Above Ground	13.44	acin	$3.75	$50.40
Self Propelled Equipment	1	acre	$0.00	$0.00
Pickup	1	acre	$3.76	$3.76
Interest-operating capital	9.0%			$12.07
Total Variable Costs				**$531.90**
Returns Above Variable Costs				**$408.86**

c) Irrigated Sorghum Silage – West Pivot (Pre-irrigation adjusted)

Estimated Costs and Returns per Acre
Irrigated Sorghum Silage – West Pivot
Pre-irrigation adjusted to remove additional water needed after previous cotton crop
Projected for 2024

Item	Quantity	Unit	Price	Total
Income				
sorghum silage	18.93	ton	$51.10	$967.32
other income	1	unit	$0.00	$0.00
other income	1	unit	$0.00	$0.00
Total Income				**$967.32**
Variable Costs				
Seed	8	lb	$2.50	$20.00
Fertilizer				
fert (P) - dry	0	lb	$0.80	$0.00
fert (N) - NH3	0	lb	$0.43	$0.00
fert (N) - liquid	49	lb	$0.58	$28.33
Field Operations				
herbicide & application	1	acre	$57.75	$57.75
fertilizer application - NH3	0	acre	$18.00	$0.00
insecticide & application - headwrm	0	acre	$27.50	$0.00
custom harvest & haul	18.93	ton	$12.50	$236.63
crop consultant	1	acre	$9.50	$9.50
insecticide sugar cane aphid	0	acre	$21.00	$0.00
fertilizer application	1	acre	$7.50	$7.50
other	1	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
Crop Insurance	1	acre	$26.00	$26.00
Operator Labor & Hand Labor	0.5	hour	$17.65	$8.83
Irrigation Labor	0.84	hours	$17.65	$14.83
Diesel Fuel - Tractors	1.41	gallons	$3.10	$4.37
Gasoline - Pickup	3.07	gallons	$2.40	$7.37
Irrigation Fuel	15.56	acin	$3.80	$59.13
Repair & Maintenance				
Implements	1	acre	$0.00	$0.00
Tractors	1	acre	$0.00	$0.00
Irrigation-Above Ground	15.56	acin	$3.75	$58.35
Self Propelled Equipment	1	acre	$0.00	$0.00
Pickup	1	acre	$3.76	$3.76
Interest-operating capital	9.0%			$12.36
Total Variable Costs				**$554.69**
Returns Above Variable Costs				**$412.63**

d) Irrigated Sorghum Silage – West Pivot (Actual pre-irrigation after cotton)

Estimated Costs and Returns per Acre
Irrigated Sorghum Silage – West Pivot
Actual total irrigation (includes extra pre-irrigation required after cotton)
Projected for 2024

Item	Quantity	Unit	Price	Total
Income				
sorghum silage	18.93	ton	$51.10	$967.32
other income	1	unit	$0.00	$0.00
other income	1	unit	$0.00	$0.00
Total Income				**$967.32**
Variable Costs				
Seed	8	lb	$2.50	$20.00
Fertilizer				
fert (P) - dry	0	lb	$0.80	$0.00
fert (N) - NH3	0	lb	$0.43	$0.00
fert (N) - liquid	49	lb	$0.58	$28.33
Field Operations				
herbicide & application	1	acre	$57.75	$57.75
fertilizer application - NH3	0	acre	$18.00	$0.00
insecticide & application - headwrm	0	acre	$27.50	$0.00
custom harvest & haul	18.93	ton	$12.50	$236.63
crop consultant	1	acre	$9.50	$9.50
insecticide sugar cane aphid	0	acre	$21.00	$0.00
fertilizer application	1	acre	$7.50	$7.50
other	1	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
Crop Insurance	1	acre	$26.00	$26.00
Operator Labor & Hand Labor	0.5	hour	$17.65	$8.83
Irrigation Labor	0.84	hours	$17.65	$14.83
Diesel Fuel - Tractors	1.41	gallons	$3.10	$4.37
Gasoline - Pickup	3.07	gallons	$2.40	$7.37
Irrigation Fuel	17.83	acin	$3.80	$67.75
Repair & Maintenance				
Implements	1	acre	$0.00	$0.00
Tractors	1	acre	$0.00	$0.00
Irrigation-Above Ground	17.83	acin	$3.75	$66.86
Self Propelled Equipment	1	acre	$0.00	$0.00
Pickup	1	acre	$3.76	$3.76
Interest-operating capital	9.0%			$12.36
Total Variable Costs				**$571.83**
Returns Above Variable Costs				**$395.50**

e) Irrigated Corn – West Pivot (Pre-irrigation adjusted)

Estimated Costs and Returns per Acre
Irrigated Corn
Pre-irrigation adjusted to remove additional water needed after previous cotton crop
Projected for 2024

Item	Quantity	Unit	Price	Total
Income				
corn grain	240	bu	$5.11	$1,226.40
other income	1	unit	$0.00	$0.00
other income	1	unit	$0.00	$0.00
Total Income				**$1,226.40**
Variable Costs				
Seed				
corn seed	0.38	bags	$320.00	$121.60
Fertilizer				
fert (N) - NH3	20	lb	$0.43	$8.54
fert (P) - liquid	0	lb	$0.88	$0.00
fert (N) - liquid	85	lb	$0.58	$49.14
Field Operations				
herbicide preplant	1	acre	$46.25	$46.25
fertilizer application	1	acre	$18.00	$18.00
insecticide & application	1	acre	$45.00	$45.00
custom harvest & haul	240	bu	$0.48	$115.20
crop consultant	1	acre	$9.50	$9.50
scouting	1	acre	$0.00	$0.00
herbicide postplant	1	acre	$51.00	$51.00
other	1	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
Crop Insurance	1	acre	$50.00	$50.00
Operator Labor & Hand Labor	0.7	hour	$17.65	$12.36
Irrigation Labor	1.344	hours	$17.65	$23.72
Diesel Fuel - Tractors	2.03	gallons	$3.10	$6.29
Gasoline - Pickup	3.07	gallons	$2.40	$7.37
Irrigation Fuel	28.76	acin	$3.80	$109.29
Repair & Maintenance				
Implements	1	acre	$0.00	$0.00
Tractors	1	acre	$0.00	$0.00
Irrigation-Above Ground	28.76	acin	$3.75	$107.85
Self Propelled Equipment	1	acre	$0.00	$0.00
Pickup	100.0%	acre	$3.76	$3.76
Interest-operating capital	9.0%			$23.33
Total Variable Costs				**$808.19**
Returns Above Variable Costs				**$418.21**

f) Irrigated Corn – West Pivot (Actual pre-irrigation after cotton)

Estimated Costs and Returns per Acre
Irrigated Corn
Actual total irrigation (includes extra pre-irrigation required after cotton)
Projected for 2024

Item	Quantity	Unit	Price	Total
Income				
corn grain	240	bu	$5.11	$1,226.40
other income	1	unit	$0.00	$0.00
other income	1	unit	$0.00	$0.00
Total Income				$1,226.40
Variable Costs				
Seed				
corn seed	0.38	bags	$320.00	$121.60
Fertilizer				
fert (N) - NH3	20	lb	$0.43	$8.54
fert (P) - liquid	0	lb	$0.88	$0.00
fert (N) - liquid	85	lb	$0.58	$49.14
Field Operations				
herbicide preplant	1	acre	$46.25	$46.25
fertilizer application	1	acre	$18.00	$18.00
insecticide & application	1	acre	$45.00	$45.00
custom harvest & haul	240	bu	$0.48	$115.20
crop consultant	1	acre	$9.50	$9.50
scouting	1	acre	$0.00	$0.00
herbicide postplant	1	acre	$51.00	$51.00
other	1	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
Crop Insurance	1	acre	$50.00	$50.00
Operator Labor & Hand Labor	0.7	hour	$17.65	$12.36
Irrigation Labor	1.344	hours	$17.65	$23.72
Diesel Fuel - Tractors	2.03	gallons	$3.10	$6.29
Gasoline - Pickup	3.07	gallons	$2.40	$7.37
Irrigation Fuel	31.03	acin	$3.80	$117.91
Repair & Maintenance				
Implements	1	acre	$0.00	$0.00
Tractors	1	acre	$0.00	$0.00
Irrigation-Above Ground	31.03	acin	$3.75	$116.36
Self Propelled Equipment	1	acre	$0.00	$0.00
Pickup	100.0%	acre	$3.76	$3.76
Interest-operating capital	9.0%			$23.33
Total Variable Costs				**$825.33**
Returns Above Variable Costs				**$401.07**

g) Irrigated Corn Silage - Estimated

Estimated Costs and Returns per Acre
Irrigated Corn Silage
Projected for 2024

Item	Quantity	Unit	Price	Total
Income				
corn silage	30	ton	$61.32	$1,839.60
other income	1	unit	$0.00	$0.00
other income	1	unit	$0.00	$0.00
Total Income				$1,839.60
Variable Costs				
Seed				
corn seed	0.4	bags	$300.00	$120.00
Fertilizer				
fert (N) - NH3	20	lb	$0.43	$8.54
fert (P) - liquid	0	lb	$0.88	$0.00
fert (N) - liquid	85	lb	$0.58	$49.14
Field Operations				
herbicide preplant	1	acre	$46.25	$46.25
fertilizer application	1	acre	$18.00	$18.00
insecticide & application	1	appl	$45.00	$45.00
custom harvest & haul	30	ton	$12.50	$375.00
crop consultant	1	acre	$9.50	$9.50
scouting	1	acre	$0.00	$0.00
herbicide postplant	1	acre	$51.00	$51.00
other	1	acre	$0.00	$0.00
other	1	acre	$0.00	$0.00
Crop Insurance	1	acre	$45.00	$45.00
Operator Labor & Hand Labor	0.77	hour	$17.65	$13.59
Irrigation Labor	1.284	hours	$17.65	$22.66
Diesel Fuel - Tractors	2.21	gallons	$3.10	$6.85
Gasoline - Pickup	3.07	gallons	$2.40	$7.37
Irrigation Fuel	28.76	acin	$3.80	$109.29
Repair & Maintenance				
Implements	1	acre	$0.00	$0.00
Tractors	1	acre	$0.00	$0.00
Irrigation-Above Ground	28.76	acin	$3.75	$107.85
Self Propelled Equipment	100.0%	acre	$0.00	$0.00
Pickup	1	acre	$3.76	$3.76
Interest-operating capital	9.0%			$29.87
Total Variable Costs				**$1,068.67**
Returns Above Variable Costs				**$770.93**