Water Conservation using Cover Crops, Crop Rotations, and Irrigation Technology to Improve Soil Health

Final Report

to the

Texas Water Development Board

TWDB Contract No. *2213582650*

TAWC

TEXAS ALLIANCE FOR WATER CONSERVATION

April 15, 2023

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Overview of TAWC operations

Mission: To conserve water for future generations by collaborating to identify and transfer those agricultural production practices and technologies which, when integrated across farms and landscapes, will reduce the depletion of ground water while maintaining or improving soil health, agricultural production and provide enhanced economic opportunities.

Approach: Conduct outreach activities to provide information to producers, industry, and communities to accomplish water conservation through demonstration and education.

- Engage in partnerships with public, private, and government entities dedicated to sustaining economic viability of Texas agriculture for all agricultural commodity groups and organizations.
- Explore conservation and sustainability from both a field level as well as systems level approach.
- Generate inter-disciplinary collaborations and provide education and outreach to assist producers in water conservation, crop, and irrigation management.

TAWC Focus: Our focus addresses improving irrigation efficiency, crop resilience to weather extremes, and the enhancement of soil health parameters that include:

- Demonstrate new and innovative sensor-based irrigation management technologies to enhance water use efficiency, capture and store more rainfall, thereby reducing irrigation needs.
- Demonstrate and disseminate important information on water conservation to local producers through different outreach activities and promoting peer to peer learning.

Long term TAWC objectives:

- Monitor soil water balance and soil parameters under different management practices and regions.
- Ascertain the relevance of using different soil moisture sensing technologies to enhance water conservation and water use efficiency.
- Analyze economic profitability of the innovative management practices at the demonstration sites by working with cooperator producers in collecting data on all crop inputs including irrigation and cropping costs and amount and value of crop yield.
- Demonstrate and disseminate results to area crop producers, crop consultants, industry reps through on-farm demonstrations, field days, presentations, and on-line information guides, and instructional videos.

Through years of working directly with producers and building their trust, the TAWC is recognized by area producers as a reputable source striving to help educate them on the best practices and technologies to achieve more with less water. This has taken many years of building trust and recognition through partnerships with industry, government agencies, universities, communities, and producers.

Final Report by Tasks

Task 1: Field Demonstration and Data Collection

The project aims to demonstrate economically viable methods of soil and crop management that conserve irrigation water and improve rainwater capture and storage. Understanding the inter-twined complex soil-water relationships is a vital aspect of sustainable agriculture production systems. We monitored soil water balance, compared benefits related to water conservation and soil health, and demonstrated new irrigation sensor technologies.

Location and Map

The TAWC project is implemented in the Southern Texas High Plains on the area overlaying the Ogallala Aquifer. In the past, TAWC has worked with 36 growers covering over 6,000 project acres on farms constituting over 136,000 total acres. Field sites were initially located in Hale and Floyd counties but have expanded over time. Producers field sites used for this project are in the counties of Martin, Moore, Crosby, Castro, Floyd, Swisher, Hale, Dawson and Lubbock counties. Producers and stakeholders in the High Plains, including the Panhandle, are targeted for information dissemination.

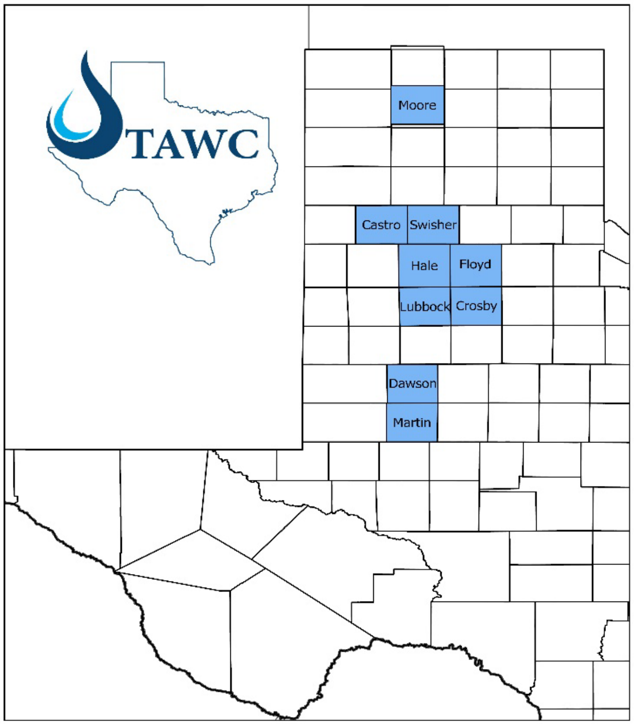


Figure 1: Counties with TAWC demonstration sites

Due to extremely dry summers, low rainfall and declining well capacities producers are forced to abandon large number of acres during the growing season. Further, even more acres could be destroyed prior to harvest because of very low yields that do not meet the return on investment. The region is largely dependent on applied irrigation for achieving economic sustainability which is under threat because of declining Ogallala aquifer.

Sensor Based Irrigation Management

Producers have relied on their instincts and experience to make irrigation decisions for a long time, but this often leads to inappropriate use of precious water resources. Cutting-edge sensor technologies provide ways to make those irrigation management decisions based on real time field inputs. We installed four different sensors technologies Autonomous Pivot, AquaSpy, Goanna Ag and Grow Guru at cooperative producers' fields across the West Texas region. A GIS map indicating the geographic location of the different new sensor's technologies installed in the producer plots in different counties of West Texas is presented in Figure 2. Producers have used some of these technologies for the first time in the 2023 growing season. They explored the integration of different soil moisture sensing technologies for their irrigation scheduling and management. At the end of season, we talked to the producers and received their feedback and experiences with these technologies through in-person meetings and phone calls.

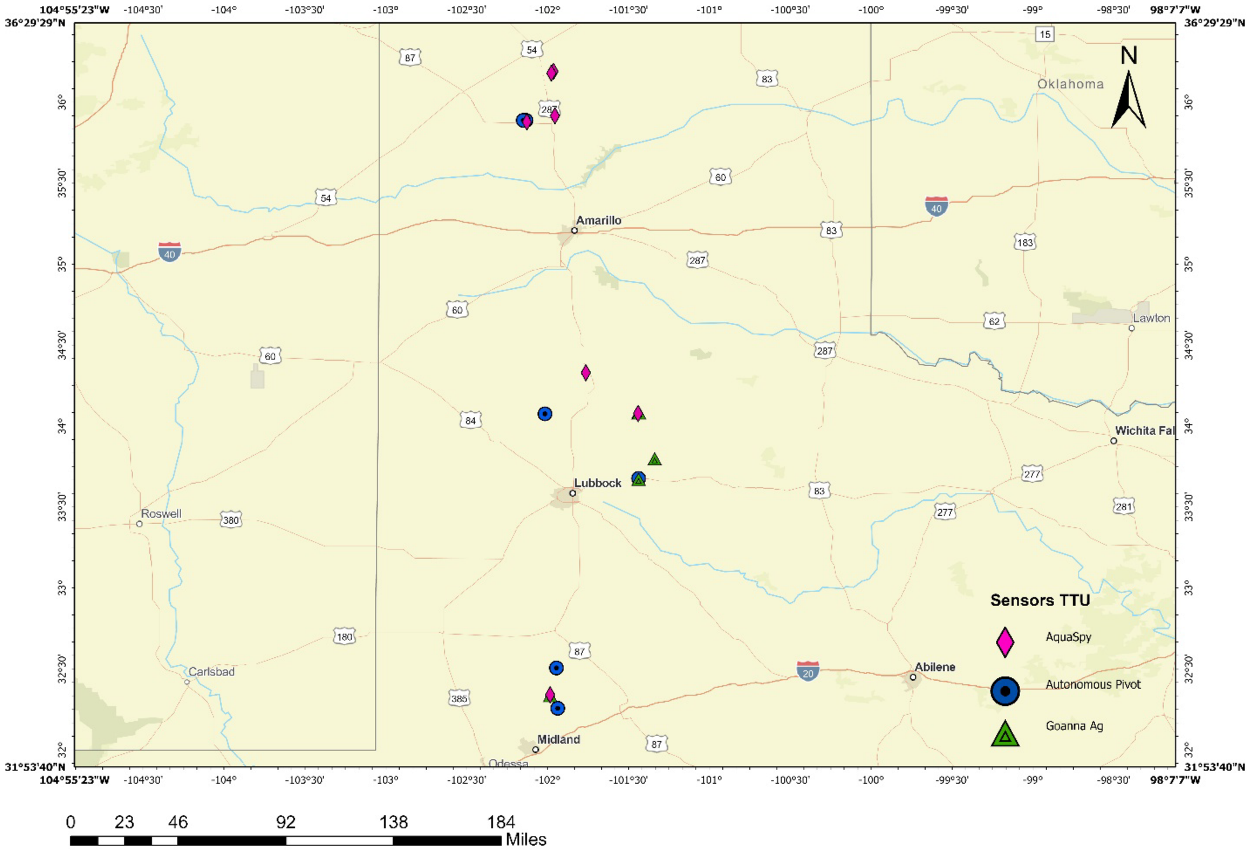
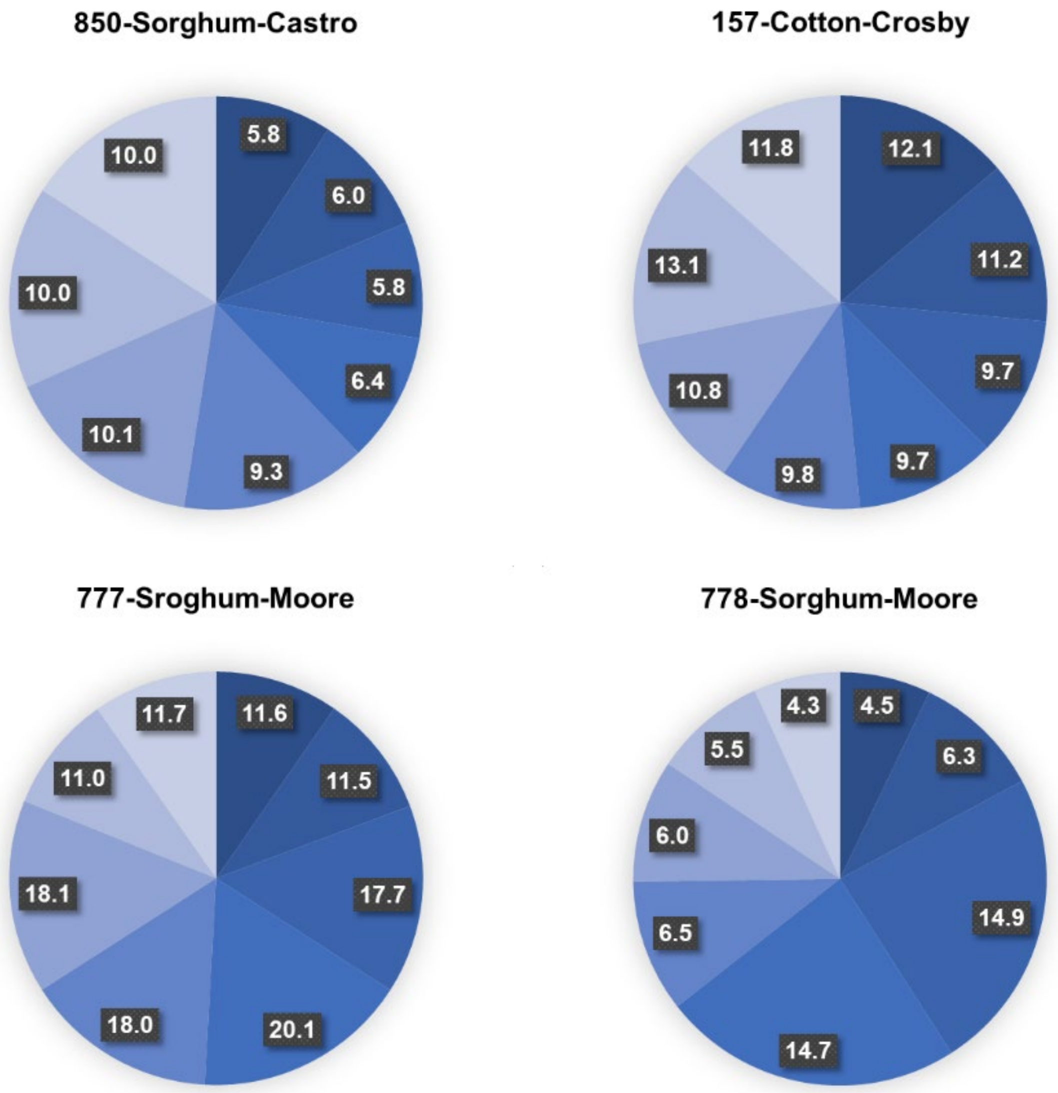


Figure 2: Location of different field sites and sensor technologies funded through the TWDB grant.

Autonomous Pivot is equipped with ground-penetrating radar to detect soil moisture and rain bucket to capture local precipitation that helps in accounting for in field heterogeneity and help in coming up with localized irrigation scheduling recommendation. Goanna sensor showcases several technologies including soil moisture at 32" and aboveground thermal signatures to aid producers in their water management efforts. As a part of the project, we also have several producers with AquaSpy soil moisture technology that the producers in the region are more familiar with. Some primary findings from this are presented below to indicate the relevance of the data collected to help understand the uncertainty involved in irrigation management across different producer operations. Figure 3 shows variability in applied irrigation depth in the different slices of the field which can be attributed to the differences in irrigation pressure, elevation, and pivot speed captured by a GPR on the autonomous pivot.


850-Sorghum-Castro

157-Cotton-Crosby

777-Sroghum-Moore

778-Sorghum-Moore

Figure 3: Variability in applied irrigation depth (inches) in different field slices.

The Figure 4 provides a snapshot of the 2023 growing season, where Autonomous Pivot technology was used to track the well pumping pressure on different producer farms (Crosby, Hale, Moore and Castro counties) in West Texas. The differential water availability at the start and the varying rates of decline in water pumping capacity creates a wide range of scenarios in the producers' fields requiring farm-specific solutions to make appropriate decisions on the extent of transition required for their operations. Over this season we saw a decline of 0.02 to 0.1 psi/day in different producer pivots. This decline over the season indicates that producers are facing difficulties in applying the required amount of water to crops in later season because of declining well pumping capacities. In West Texas, where water shortage is a constant worry, the agricultural landscape is continuously being threatened by such problems making producers abandon or take drastic in-season decisions. The rising demand of water supplies, essential for maintaining crops, is indicated by the pressure decreasing over the season. This decrease in water pressure makes it more difficult for farmers to keep their fields at the ideal moisture levels in an area already struggling with arid conditions. The situation plays out into delicate decision-making scenarios, with decreasing water pressure increasing the probability of jeopardized crop health, yield, and overall economic viability for west Texas producers.

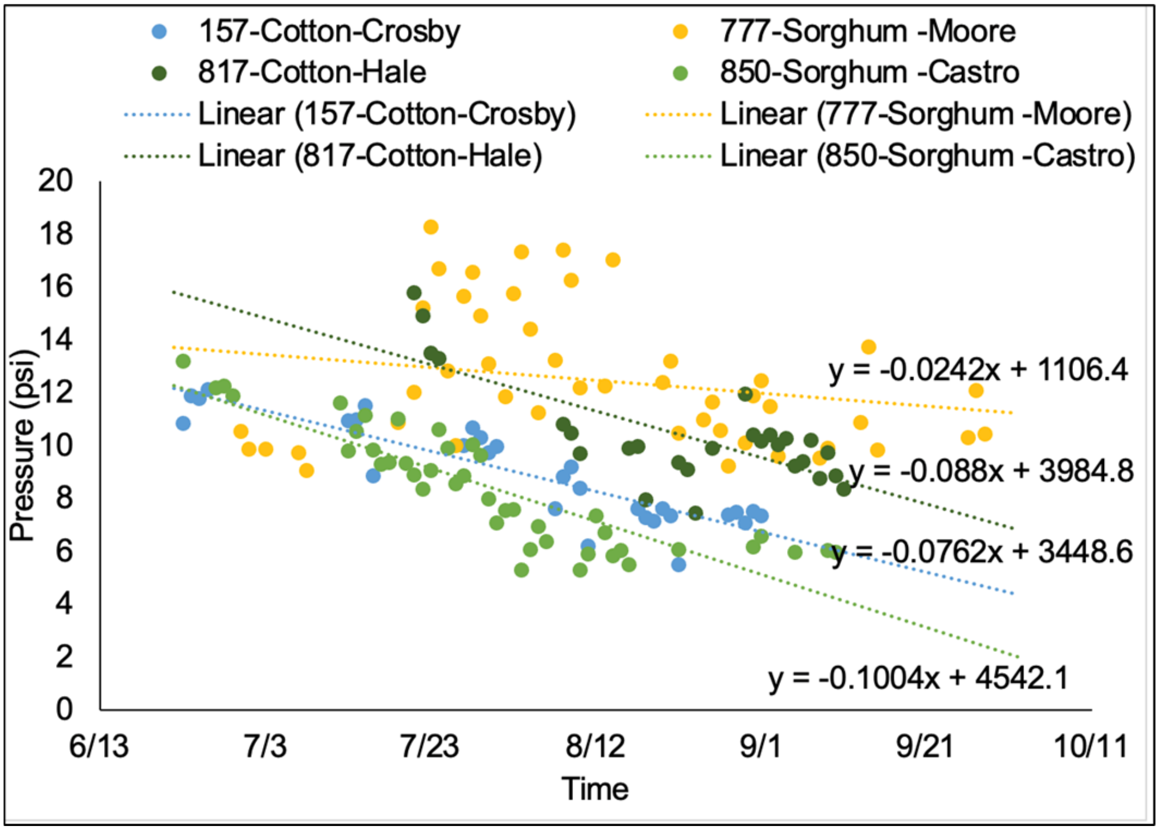


Figure 4: Decline in water pressure (0.02 to 0.1 psi/day) in pivots in different counties.

The agricultural landscape is complex, with irrigation playing a crucial role in crop growth and yield. Variations in irrigation application across farms are largely due to irregular rainfall patterns, which highlight the challenges of managing irrigation in unpredictable weather conditions. Farm-specific irrigation scheduling solutions are needed to address the unique needs of individual farms, taking into account factors like soil type, crop variety, and local climate conditions. This approach can optimize water usage, enhance crop productivity, and mitigate risks associated with excess and insufficient irrigation. The increasing unpredictability of weather patterns due to climate change necessitates a proactive approach that incorporates technological advancements and data-driven insights. Modern technologies, such as soil moisture sensors and weather forecasting tools, can help farmers make real-time decisions about irrigation, promoting sustainable farming practices. We have observed large variations in irrigation application depth which is principally influenced by the amount of rainfall they receive during the season as shown in Figure 5.

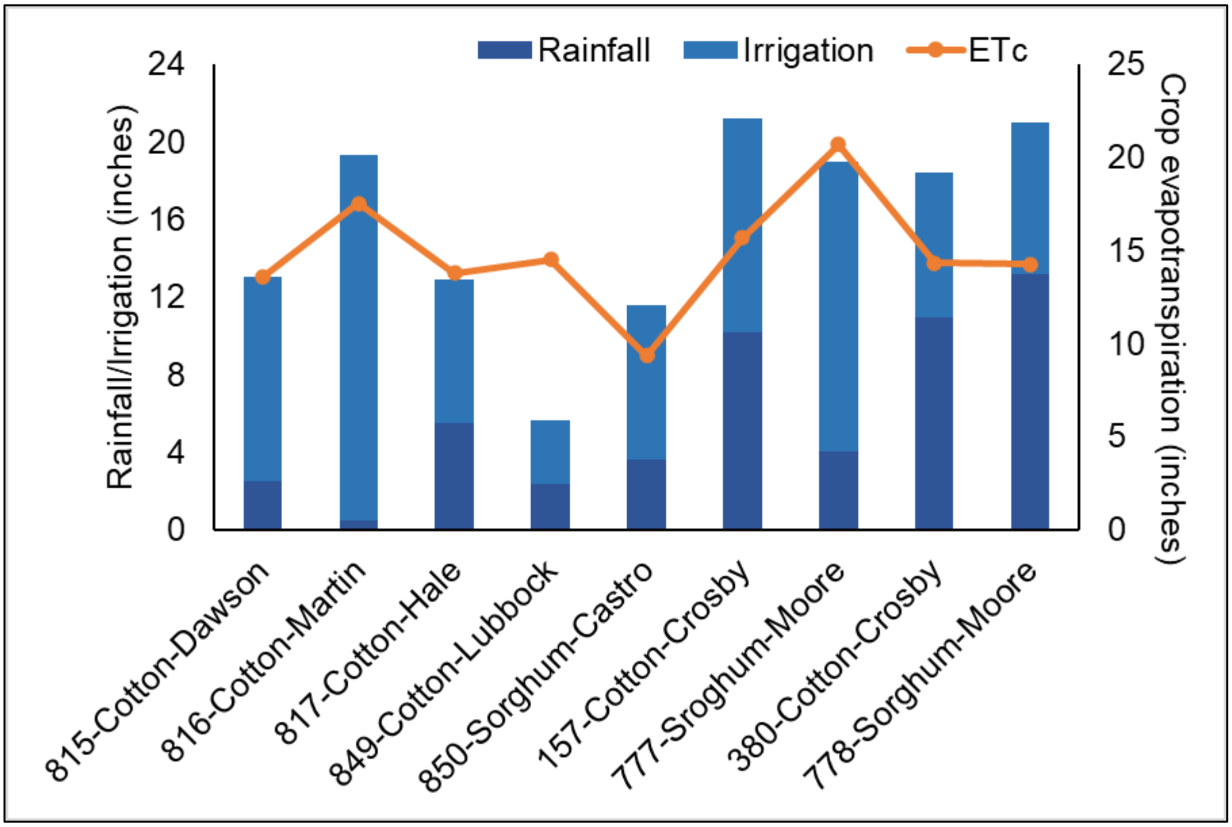


Figure 5: Irrigation and rainfall during this growing season at different producer fields with Autonomous pivot technology.

Goanna are point sensors that provide data for specific locations within a field, which includes soil moisture and temperature data at every 4" till 32" depth and aboveground crop temperature to aid producers in making their irrigation scheduling decisions. Application provides weekly forecast of soil moisture regime and irrigation schedule by calculating crop water use and crop stress. Figure 6 provides a comparison of data collected by Goanna probes for cotton crops under drip and center pivot irrigation systems. The top of the figure shows the total soil moisture in profile and rainfall events along with irrigation thresholds. Bottom figure shows development of stress over the period which light red colored peaks signifying development stress above critical limits denoted by dark red line. Drip irrigated cotton had a greater number of stress events of lower intensity in comparison to pivot where stress event lasted longer and were more intense. This can be attributed to the ability of drip systems to irrigate crops with precise amount at frequent intervals, thus having lower overall plant stress duration.

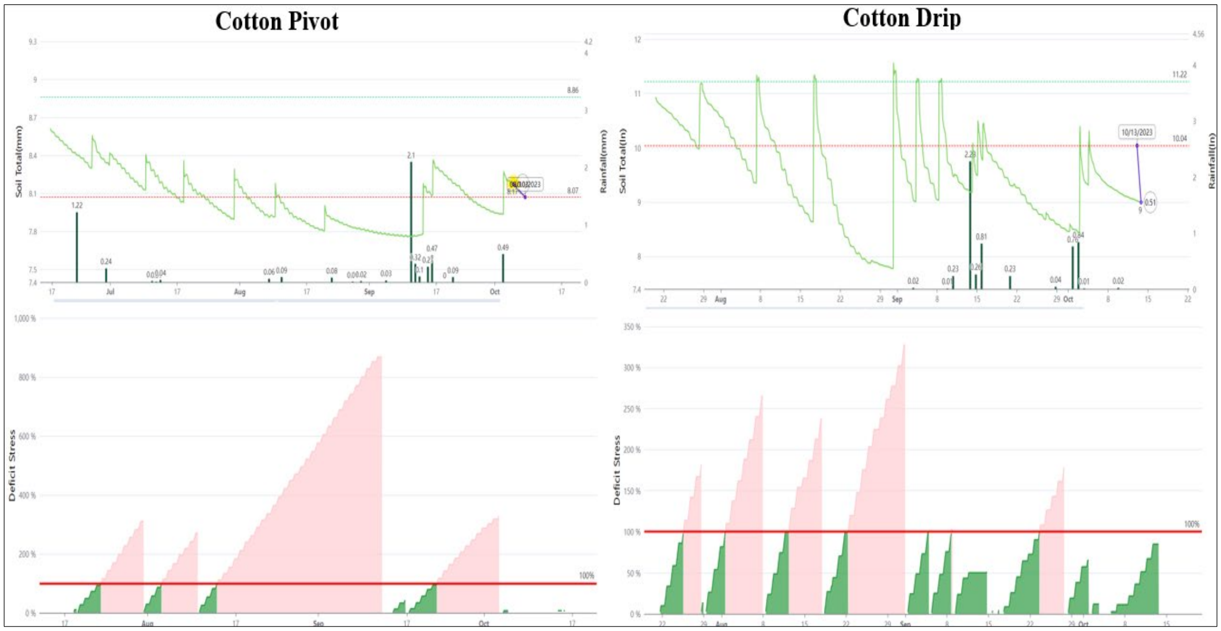


Figure 6:Soil water in soil profile and instances of stress episodes in cotton crop during 2023 growing season.

Figure 7 provides a comparison of available soil moisture data collected by goanna probes for cotton and sorghum crops under different management practices and irrigation systems. Drip irrigated crops had more consistent volumetric water content over the season while pivots saw fluctuations in volumetric water content especially in top of the profile depending on frequency of irrigation in pivots. Rainfed fields saw constant decline over the period with some addition of moisture from rainfall events.

AquaSpy soil moisture sensors have emerged as valuable tools in irrigation scheduling producers have been using them for a long time and have greater level of familiarity because of easy interface. Through the use of AquaSpy sensors, farmers can obtain valuable insights about the moisture at different soil depths, allowing them to customize irrigation strategies to meet the unique requirements of their crops. Figure 8 shows the variation of soil water content over the season in different crops at various sites. Soil moisture declines as summer progresses and crop water demand rises. Sensor-based irrigation methods not only support sustainable agriculture but also advance water conservation efforts in the region by providing a way to make precise application of irrigation water at right time.

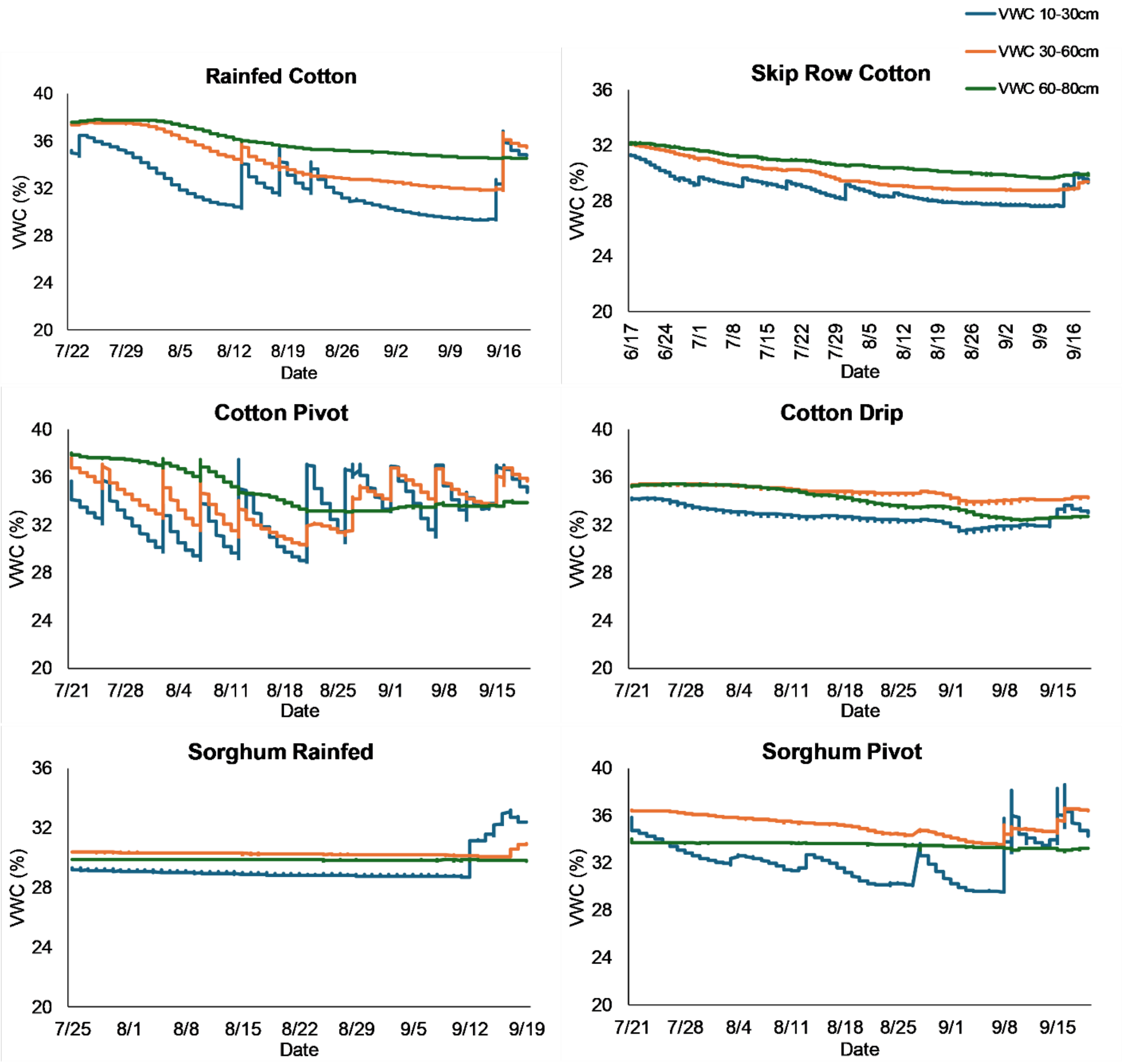


Figure 7: Variation in available soil moisture during 2023 growing season captured by Goanna Ag Sensors.

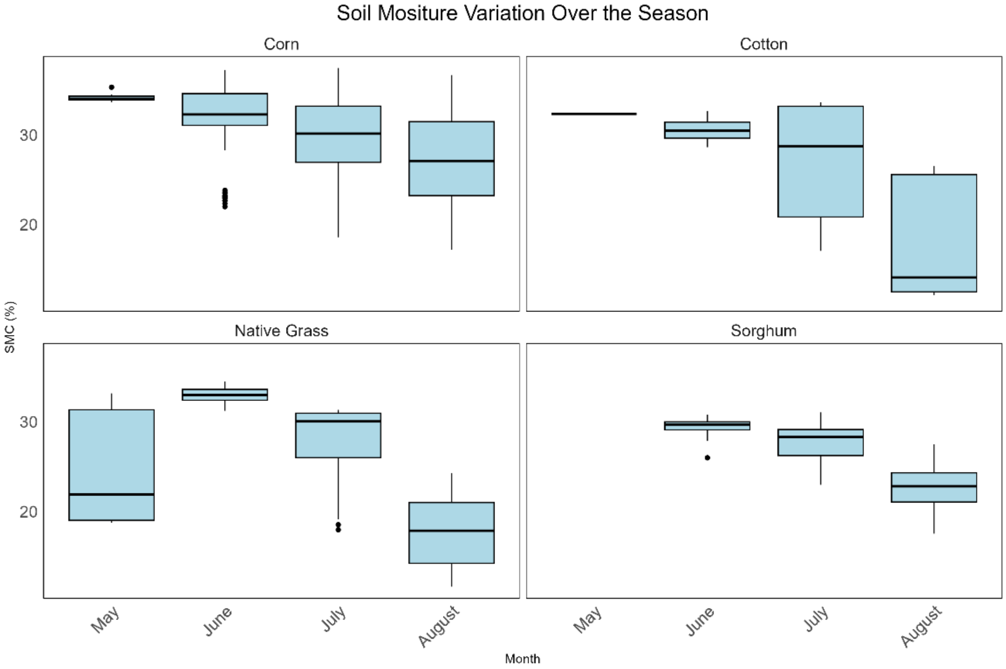


Figure 8: Variation in soil moisture content (%) over the season at different TAWC demonstration sites with AquaSpy sensors.

Yield, Water use and Water use efficiency

On average yield for cotton was 726±359 lbs/acre, for corn it was 10920±3046 lbs/acre and 3815±1812 lbs/acre for sorghum. Similarly, average WUE of irrigation was found to be 126±93 (Cotton), 846±200 (Corn) and 596±137 lbs/acre-inches (Sorghum). Average yield and water use efficiency (WUE) from different sites is presented in Figure 9 & 10. Region experienced lower than expected rainfall in the last growing season with substantial variations amongst the different counties. These conditions prompted varied responses among the producers in various counties based on amount of rainfall they received (Figure 5). Scant rainfall and low water availability led to crop failures at some of the producer sites. The yield of the corn ranged from 6,272 to 13,720 lbs/acre. Similarly, yields for sorghum ranged from 1,064 to 6,720 lbs/acre, while yields for cotton lint ranged from 112 to 1,462 lbs/acre. Likewise, corn had water use efficiency ranging from 452 to 1,043 lbs/acre-inches, for sorghum it varied from 373 to 784 lbs/acre-inches, whereas cotton showed a range of 14 to 322 lbs/acre-inches. Irrigation water applied by producers in different crops was around 7.7±3.6 inches for cotton, 12.9±1.6 inches for corn and 6.1±2.9 inches for sorghum. Amongst the reported producer sites total irrigation water use was determined to be 19487 acre-inches (6213 in Cotton, 9274 in Corn and 4000 acre-inches in Sorghum, respectively). Variation in yield and WUE in different counties is presented in Figure 11 & 12. Soil analysis from different sites in terms of important soil nutrient and quality factors is given in Table 1.

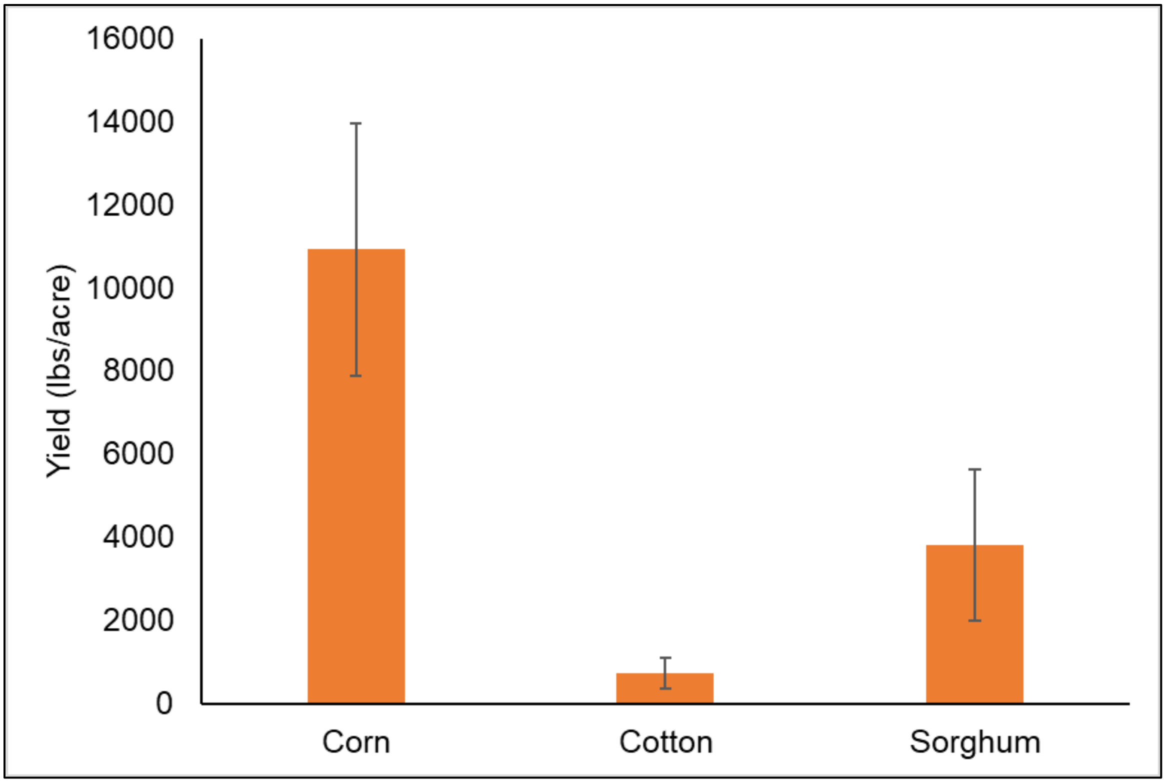


Figure 9: Yield for major crops in different counties.

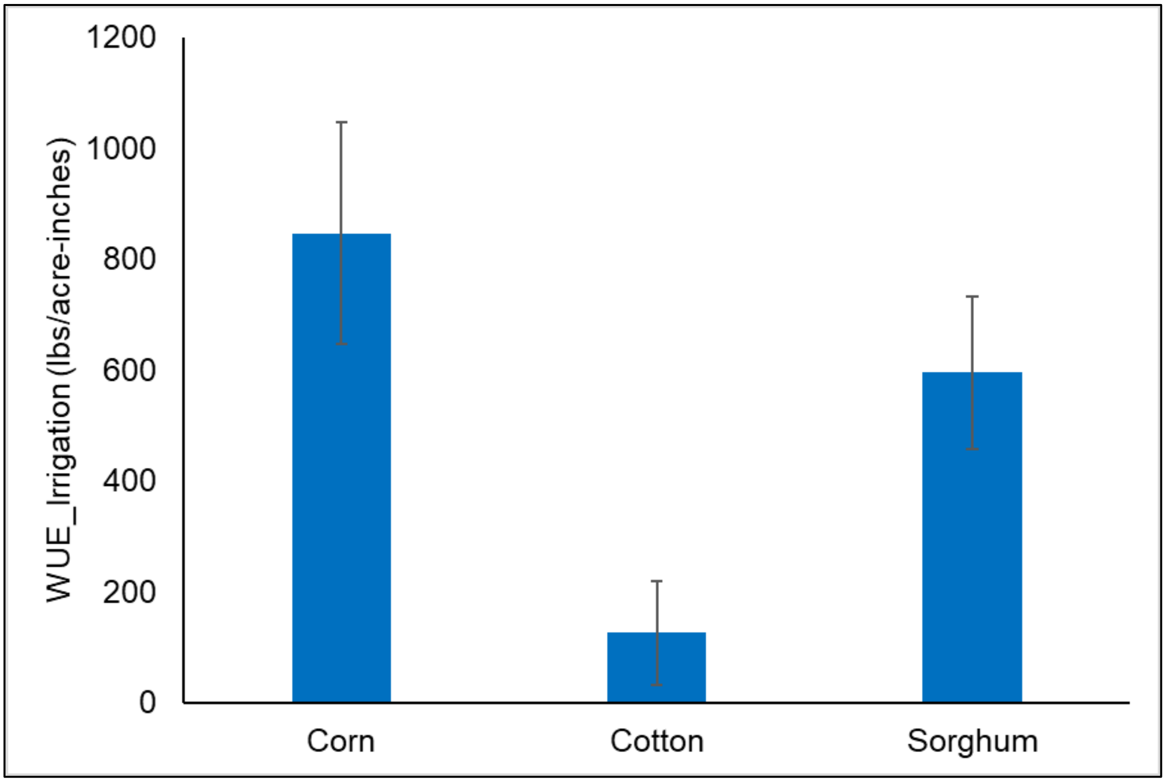


Figure 10: Water use efficiency for major crops in different counties.

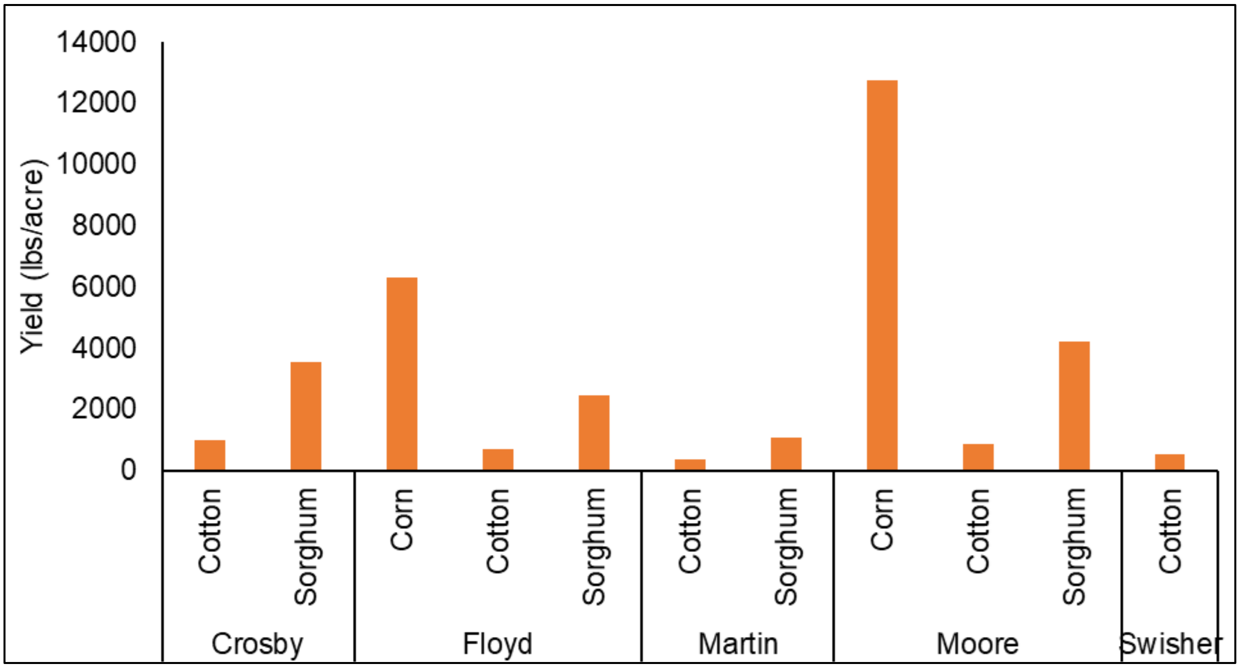


Figure 11:Yield for major crops in different counties.

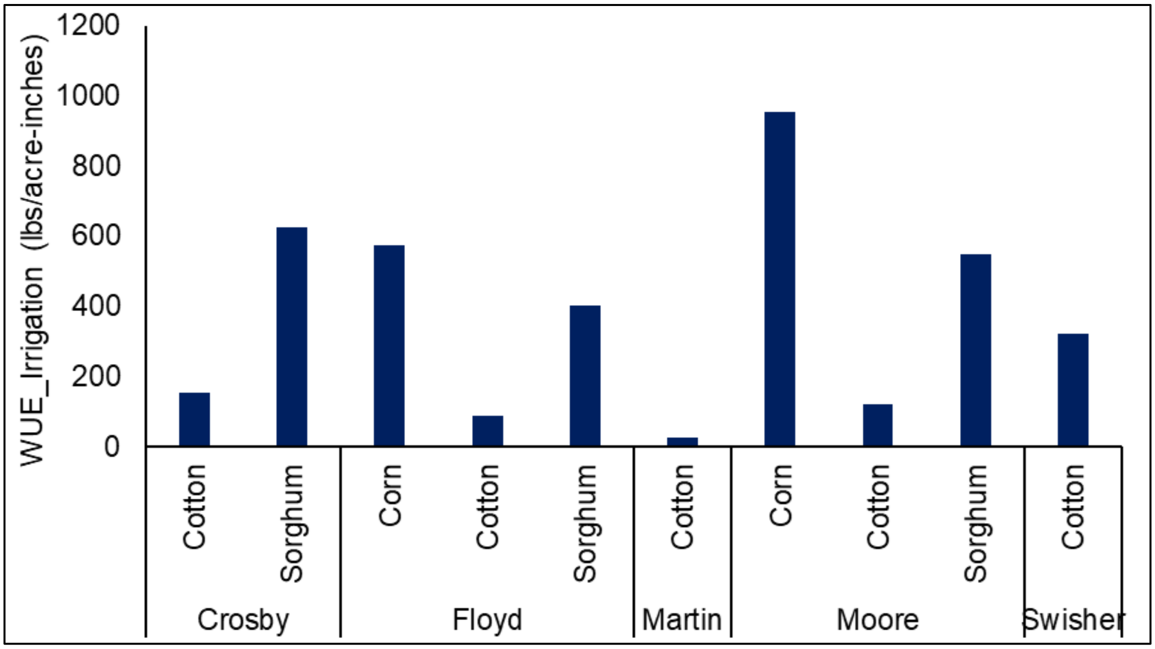


Figure 12:Water use efficiency for major crops in different counties.

Table 1 - Provides details on the soil nutrient and quality parameters that are shared with the producers at the start of the season for appropriate nutrient management.

Table 1: Soil Nutrient and Quality Factors

Site	County	N lbs a^{-1}	P2O5 lbs a^{-1}	K2O lbs a^{-1}	HT3 mg CO2-C/kg	VAST g water cm^{-3} soil	WEOC lbs a^{-1}	C:N ratio	P Sat %	WEON lbs a^{-1}	SLAN lbs a^{-1}
72	Martin	17.8	15.18	477.9	10.59	1	152.48	4.57	49.86	100.1	17.5
71	Martin	28.9	11.73	432.34	13.57	1	94.63	2.94	62.12	96.68	22.5
77	Moore	34.2	22.89	625.82	32.67	5	110.79	5.31	68.15	62.65	31.25
78	Moore	26.3	8.37	1041.19	50.7	19	154.53	4.99	27.65	92.87	51.25
79	Moore	27	9.89	662.35	32.3	9	114.68	3.27	21.97	105.12	26.25
76	Moore	37.6	16.82	521.14	29.37	4	104.26	4.7	39.32	66.6	32.5
74	Moore	23.3	16.13	471.06	33.29	2	93.38	2.65	17.43	105.74	27.5
75	Moore	14.2	8.09	380.42	33.48	1	96.39	2.07	5.41	139.79	21.25
21	Floyd	15.6	3.87	561.35	16.35	1	60.34	3.08	28.88	58.76	22.5
35A	Floyd	21.3	5.27	602.55	22.95	3	62.56	2.1	30.32	89.19	18.75
35B	Floyd	24.9	11.12	780.24	23.32	1	67.35	1.76	24.58	114.96	16.25

Note: Macronutrients nitrogen, phosphate, and muriate of potash as lbs a-1 as fertilizer credit.

HT3, measurement of CO_2 respiration used as an indicator of soil microbial population, mg CO_2-C per kg soil.

VAST- measurement of soil aggregate stability, relating to soil porosity and water infiltration, g water per cm^3 soil.

WEOC- water exractable organic carbon, measurement of C source for soil microbial population, lbs organic C per acre.

C:N ratio- estimates tendency for nitrogen immobilization or mineralization, affects N availability to crop.

P Saturation- measurement of available phosphorous as related to P held by soil.

WEON- water extractable organic nitrogen, measurement of N source available to microbial population, lbs organic N per acre.

SLAN- Solvita Labile Available Nitrogen, measure of organic N held as amino sugars.

Task 2: Economics

Economic Analysis

Record books were distributed to all growers prior to the 2023 crop season and were collected Feb – April of 2024. An undergraduate researcher named Urzula Carrillo has been hired to assist the economics team with data entry. She has worked on updating crop, fertilizer, chemical, and tillage price lists for the economic analysis. The economic analysis of all 2023 field sites was conducted in April 2023. All crop prices were standardized with a $0.75/ lb for cotton lint, $250/ton for cottonseed, $5.53/bu for corn, and $5.60/bu for grain sorghum. Table 1 shows the per acre economic results for each site and each field. Table 1 below shows the draft results from the economic budget analysis. Gross revenue, expenses and profit are shown for each crop and each field for our TAWC sites. While these numbers are subject to change, on average cotton yielded a loss in net returns of -$155.13/acre, corn and grain sorghum had positive net returns of $468.09 and $82.82/acre respectively. Once economic budgets are finalized, an additional analysis will be presented with profit/acre inch of water applied and an analysis of profit across sites. Total costs, gross margin and net returns on different crops at different sites are depicted in Figure 13.

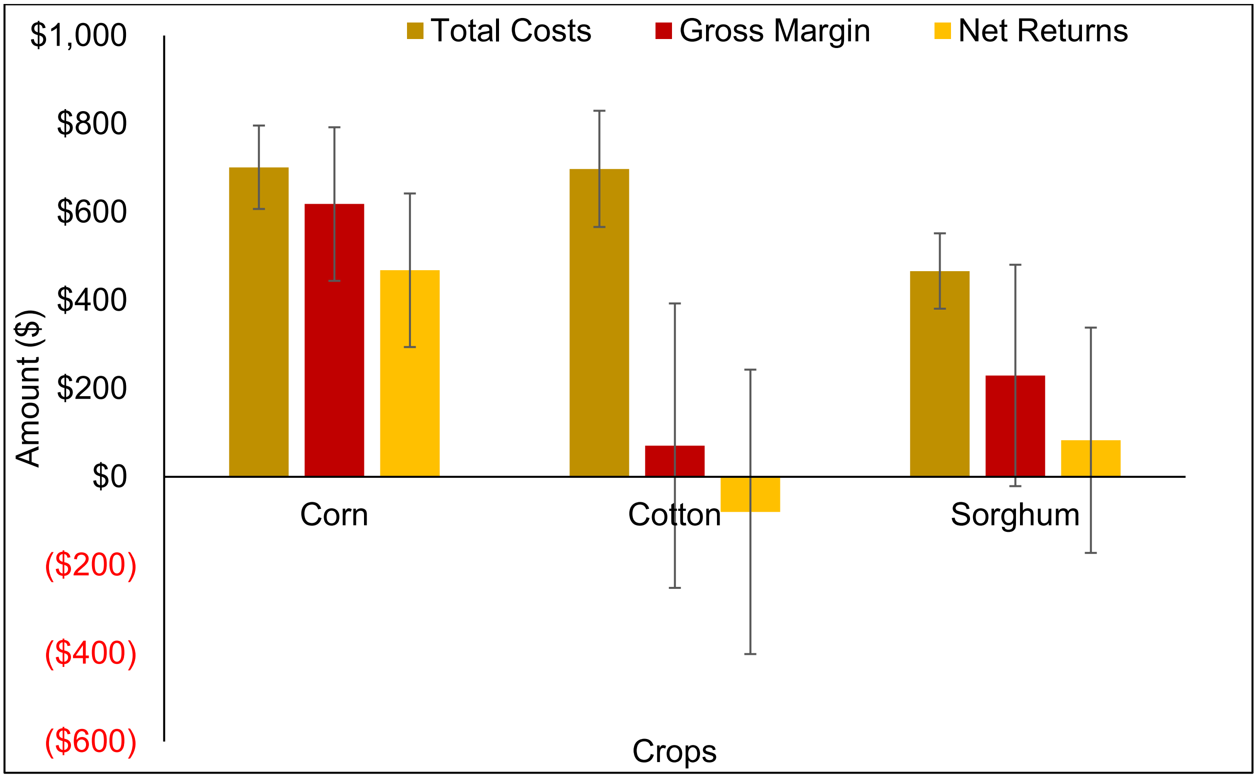


Figure 13: Cost economics of different crops on various sites

Table 2:Economic Analysis of Field Sites in 2023 by Crop ($/acre)

Site	Gross income	Pre-Harvest VC	Total Harvest Cost	Total Variable Cost	Gross Margin	Fixed Costs	Total Costs	Net Returns
Site 21 Field 1-Cotton	$735.49	$308.11	$55.86	$363.97	$371.52	$150.00	$513.97	$221.52
Site 21 Field 2-GS	$258.80	$248.52	$32.33	$280.85	-$22.05	$150.00	$430.85	-$172.05
Site 35 Field 1-Corn	$619.36	$313.13	$47.04	$360.17	$259.19	$150.00	$510.17	$109.19
Site 35 Field 2-Cotton	$651.00	$397.68	$151.61	$549.28	$101.72	$150.00	$699.28	-$48.28
Site 35 Field 3-GS	$218.40	$253.22	$29.46	$282.68	-$64.28	$175.00	$457.68	-$239.28
Site 50 -Cotton	$490.75	$401.43	$117.53	$518.96	-$28.21	$150.00	$668.96	-$178.21
Site 60-Cotton	$547.50	$267.75	$118.18	$385.93	$161.57	$150.00	$535.93	$11.57
Site 71 Field 1-Cotton	$552.50	$552.10	$133.71	$685.81	-$133.31	$150.00	$835.81	-$283.31
Site 71 Field 2-Cotton	$99.00	$560.08	$24.15	$584.23	-$485.23	$150.00	$734.23	-$635.23
Site 72 – GS/Wheat	$492.56	$220.43	$40.00	$260.43	$232.13	$100.00	$360.4265	$132.13
Site 73 -Cotton	$1354.00	$286.78	$315.29	$602.07	$751.93	$150.00	$752.07	$601.93
Site 74 Field 1 - Cotton	$669.38	$421.04	$169.83	$590.87	$78.51	$150.00	$740.87	-$71.49
Site 74 Field 2 – Sorghum Silage	$1041.40	$258.79	$40.00	$298.79	$742.61	$150.00	$448.79	$592.61
Site 74 Field 3-Corn	$1277.43	$530.00	$97.02	$627.02	$650.41	$150.00	$777.02	$500.41

Site 75 Field 1-Cotton	542.30	395.94	0.00	395.94	146.36	$150.00	545.94	-3.64
Site 75 Field 2-Corn	1354.85	511.73	102.90	614.63	740.22	$150.00	764.63	590.22
Site 75 Field3-GS	611.52	311.45	40.00	351.45	260.07	$150.00	501.45	110.07
Site 76 Field 1 - Corn	1338.26	515.84	101.64	617.48	720.78	$150.00	767.48	570.78
Site 76 Field 2 - GS	990.00	470.05	50.40	520.45	469.55	$150.00	670.45	319.55
Site 77 Field 1-Cotton	542.30	533.43	267.96	801.39	-259.09	$150.00	951.39	-409.09
Site 77 Field 2-Corn	1354.85	479.93	102.90	582.83	772.02	$150.00	732.83	622.02
Site 78 Field 1-Corn	1072.82	425.44	81.48	506.92	565.90	$150.00	656.92	415.90
Site 78 Field 2-GS	425.88	242.33	32.76	275.09	150.79	$150.00	425.09	0.79
Site 78 Field 3-GS	354.90	258.89	27.30	286.19	68.71	$150.00	436.19	-81.29

Task 3: Communication and Outreach

Field Day

The 18th Annual TAWC Field Day took place on the farm of Lloyd Arthur. Speakers at the event included: TAWC project director, Rick Kellison; Texas Tech University's Dean of Agriculture and Natural Resources, Dr. Clint Krehbiel; TAWC producer, Lloyd Arthur; Vice President or GoannaAg, Paxton Peyton; Vice President of Sales of Autonomous Pivot, Daniel Jenkins.

Presentations were given showing different features of Goanna and Autonomous Pivot technologies with data from Lloyd Arthur's fields. After presentations, all participants were able to walk through the cotton fields and see the pivots installed with these technologies. There were about 45 participants at this Field Day.

Figure 14:Photographs from 18th Annual TAWC Field Day.

Annual Water College

The TAWC hosted its 10th Annual TAWC Water College on January 24, 2024, at the Lubbock Civic Center. Connecting today's producers and crop consultants with the latest in irrigation technology and research was the focus of the program at Lubbock Civic Center. 17 vendor booths were available for attendees to visit.

The event was attended by 180 producers, consultants, researchers, and industry leaders. Lunch was provided by Sorghum Checkoff and Texas Sorghum Producers, and coffee and donuts during registration and morning break was provided by High Plains Underground Water District. Three Certified Crop Advisor Continuing Education Units were offered.

A Sustainable Agriculture Photo Contest was hosted for the first-time during water college. We received 40 photo entries and were awarded the top three photos.

Agenda of the event can be found on the TTU's website along with PPT's of presentations made by the speakers (https://www.depts.ttu.edu/tawc/events/water-college/index.php).

Table 3: List of presentations annual TAWC Water College.

Time	Presentation/ Event	Speaker/Moderator
9:00 a.m.	Welcome Address	Clint Krehbiel, Dean, Davis College of Agricultural Sciences & Natural Resources
9:15 a.m.	Where's the Water At? A Hydrologist's View of the Ogallala	Amy Bush, Hydrologist, RMBJ Geo Inc.
9:45 a.m.	The Role Produced Water Can Play in Agriculture	Rusty Smith, Executive Director, Texas Produced Water Consortium
10:30 a.m.	Cotton Trust Protocol: How the Program Benefits Producers	Daren Abney, Executive Director, U.S. Cotton Trust Protocol
11:30 a.m.	Agricultural Water Research – Texas Tech Davis College Leading the Way	Krishna Jagadish, Thornton Distinguished Chair
1:30 p.m.	TAWC Field Site Data: What We Learned from the 2023 Growing Season	Paxton Peyton, Vice President, Commercial R&D, Goanna Ag
2:00 p.m.	Weather Outlook – What Can We Expect in 2024	Jennifer Puryear, Meteorologist, RMBJ Geo Inc.
2:30 p.m.	Water Is Our Future; Texas Tech Davis College Student Presentations	Texas Tech Davis College Students

Figure 15: Photographs from 10th Annual TAWC Water College.

This event was live broadcasted on KFLP 900am covering the Texas High and Southern Plains, New Mexico, Kansas and Oklahoma.

On January 23, 2024, the TAWC hosted an appreciation supper for our Producer Board. Deans from Texas Tech's Davis College of Agriculture as well as the TAWC management team also attended. Discussion was had about the past progress and future direction of the TAWC.

TAWC Newsletters

Samantha Borgstedt (TAWC Project Director) assembled the TAWC Newsletters working with Peyton Brown on the design. These newsletters were printed and set out in the Dean's office at Texas Tech Davis College. They were also mailed to TAWC producers and commodity offices.

The Newsletters are available online: https://www.depts.ttu.edu/tawc/news/newsletter/

Figure 16: Winner of Sustainable Agriculture Photo Contest.

THANK YOU

10th Annual Water College Sponsors

Figure 17: Sponsors of 10th Annual TAWC Water College.

Other Outreach and Engagement Activities

Samantha Borgstedt worked with the College of Agriculture at Texas Tech University providing footage of TAWC pivot irrigated cotton fields for a video played at the Texas Tech football game during Ag Week.

Samantha Borgstedt met with soil scientists on the irrigated cotton fields of Josh Tunnell installed Goanna irrigation management technologies.

Samantha Borgstedt attended and presented at the National Water Resources Annual Conference in San Antonio (Nov 8-10) titled, "Farm to Fork Messaging: The role of irrigation in food production" at the San Antonio Marriott River Center (101 Bowie Street, San Antonio). The conference had over 250 registrants. NWRA members comprise of irrigations districts, water authorities and municipalities in TX, KS, NE, ND, MT, ID, UT, CO, NM, AZ, NV, CA, OR, and WA.

Samantha Borgstedt attended the No-Till Texas Conference on February 14, 2024, in Canyon at West Texas A&M University. Lots of great presenters focused on soil and water health with a common message, "Ignorance stops today. Negligence begins tomorrow".

Samantha Borgstedt Spoke at the LEAP, Women in Agriculture Conference on February 29, 2024, at the Ranching and Heritage Center in Lubbock, Texas. This conference focused on current agriculture issues and was attended by 50 active women in agriculture.

Samantha Borgstedt attended and set up a TAWC display booth at the 2024 Stewarding Our Water Future Conference hosted by Ogallala Commons with major support from Tecovas Foundation. More than 150 attendees from a wide range of industries and locations gathered at the Harrington Center for Philanthropy March 21-22 for this event.

Task 4 – Revive TAWC Tools for Irrigation

West Texas Mesonet has revised its data sharing strategy and format. We are working on developing a new TAWC tools website which will be compatible with the new weather feed and will be based on local datasets from 150 West Texas Mesonet stations. The revised tools will include crop water use and irrigation scheduling calculators, growing degree days/heat unit's calculator, and basic system calculators for irrigation calculations. These tools will be accessible to everyone on the TAWC solutions site and made freely available to the West Texas producer community to enhance water conservation efforts. We have started to work with a faculty in computer science to either revive or develop these tools from scratch.

Conclusion

Advanced sensor technologies can provide data-driven solutions for irrigation management optimizing water usage, enhance crop yield, and reduce the environmental footprint of agriculture. But adoption of technology must fit into producers' management style which depends on farm conditions and weather. We saw a wide range of conditions among different producers' sites in terms of rainfall received and irrigation amount applied during the season. We observed a significant drop in irrigation pressure in pivots as the season progressed. Variability in farm condition resulted in vast difference in yield, WUE and economic outcomes amongst different producers' sites. We received feedback from producers regarding the use of different sensor technologies on their farms for irrigation scheduling. We conducted various outreach activities and events to promote sensor-based irrigation management approach for water conservation and long-term sustainability of farming systems in West Texas.

Acknowledgements

We are thankful to the Texas Water Development Board (TWDB Contract No. 2213582650) for supporting these demonstrations. We would also like to acknowledge all the support received from Davis College of Agricultural Sciences & Natural Resources, Department of Plant and Soil Science at Texas Tech University, Lubbock, Texas.