ECONOMIC BENEFITS OF WATER SAVINGS WITH NO-TILLAGE AND COVER CROPS IN SEMI-ARID TEXAS COTTON PRODUCTION

Christopher Cobos
Joseph A. Burke
J. Wayne Keeling
Donna McCallister
Katie L. Lewis
Texas A&M AgriLife Research
Lubbock, TX
Will Keeling
Texas A&M AgriLife Extension
Lubbock, TX
Paul DeLaune
Texas A&M AgriLife Research
Vernon, TX

Abstract

Water availability and sustainability are essential to the continued agricultural production of the U.S. Great Plains. The Southern High Plains (SHP), located in the semi-arid southern portion of the Great Plains, produces approximately 30% of the U.S. annual cotton production. The continued unsustainable withdrawal of the Ogallala Aquifer for irrigation, paired with the potential increase in annual mean temperature due to climate change puts the future agricultural viability of the region at risk. Our objective was to quantify the amount of water saved using conservation tillage and cover crops in semi-arid cotton production systems compared to conventional continuous cotton systems (CT). The research purpose was to increase producer adoption of conservation systems (no-till continuous cotton with a single species cover crop, R-NT; and no-till continuous cotton with a mixed-species cover crop, M-NT) by reducing irrigation inputs to increase both water and economic sustainability on a regional scale. The total water content (mm) of CT was subtracted from the total water content of R-NT and M-NT to give the theoretical amount of water saved or lost throughout the year and multiplied by the regional value of water ($8.70/ac.-in.). Gross margins were then calculated after incorporating the water value into economic budgets to show potential increases in water and economic sustainability when using conservation systems in semi-arid cotton agroecosystems.

Introduction

Groundwater conservation is essential for agricultural production in the Southern High Plains (SHP) of Texas and the preservation of its main source of irrigation, the Ogallala Aquifer, is vital to the longevity of the region. However, the portion of the Ogallala Aquifer underlying the SHP has become an unsustainable, nonrenewable resource that cannot be relied upon for continued output. Projected climate change is expected to compound the issue with predicted increases in annual temperature in the SHP paired alongside more frequent extreme weather events such as droughts and dust storms (Banner et al., 2010; U.S. Global Change Research Program, 2018). The SHP region is the nation's top cotton-producer (Plains Cotton Growers, 2021). The future agricultural production is questioned as certain areas in this region have a projected useable aquifer lifetime of approximately 2 years, and the aquifer has a saturated thickness of less than 10 m in certain counties (Barbato, 2008; Mitchell-McCallister et al., 2021). As a result, many producers in this region have been transitioning to dryland cotton production systems (Ale et al., 2021). This transition comes with substantial decreases in lint yield and forces producers to depend on the harsh and extremely variable climate for success.

The future of agricultural production in the SHP will depend on the state of conservation systems available to producers in a dryland or deficit irrigated environment. These systems can include crop rotations, cover crops, conservation tillage, or a combination of these and other practices. Land use can alter aquifer recharge rates by impacting evapotranspiration and runoff, and increase soil infiltration (Haacker et al., 2014). Lack of adoption of regenerative agricultural practices may negatively impact soil quality and limit future land use. It is important to make efforts to improve soil quality of the region while water is still largely available to some producers. Even with ideal management practices, depletion of the Ogallala Aquifer is expected to occur to some degree in the SHP. The preservation of soil water will become paramount for producers in the future where the ability to combat water loss and evaporation will not only prolong the aquifer lifespan but allow producers to maximally intensify agricultural dryland production in the face of global climate change. Implementing regenerative agricultural cotton production systems now allows us to optimize these practices in semi-arid environments, obtain data from long-term research, prolong groundwater availability, and prepare producers with the ability to sustain production through resilient agroecosystems.

Previous work has demonstrated that no-tillage with cover crops increases and maintains soil moisture during active cotton growth in the semi-arid SHP (Burke et al., 2021) with no decline in gross margins (Lewis et al., 2018). This challenges farmers' perceptions of these conservation systems and combats the negative affiliations (reduced soil moisture from cover crops in semi-arid environments, reduction in yields and gross margins in conservation systems) of their implementation. However, there was no improvement in yield when implementing these conservation practices. Expanding adoption of these systems must first prove to be economically viable for the producer while simultaneously increasing sustainability. The need for more research in soil-water conservation for cotton production systems in the semi-arid SHP is evident. Economic gain must first be present for producers across the SHP to be willing to adopt these practices across the region. The preservation of soil water with no change in yield could potentially allow producers to save irrigation inputs during the growing season while implementing conversation practices in semi-arid agroecosystems. Our objective was to quantify the amount of water saved using conservation tillage and cover crops in semi-arid cotton production systems compared to conventional continuous cotton systems. The purpose was to increase producer adoption of conservation systems by reducing irrigation inputs to increase both water and economic sustainability on a regional scale.

Materials and Methods

Field experiments were conducted at the Agricultural Complex for Advanced Research and Extension Systems (AG-CARES) near Lamesa, TX (32°46'22"N, 101°56'18"W). The soil is classified as an Amarillo fine sandy loam (fine-loamy, mixed, superactive, thermic Aridic Paleusalfs; Lewis et al., 2018; USDA-NRCS, 2016). Amarillo soil is a benchmark series for the SHP and covers approximately 315,995 ha across western Texas (Lewis et al., 2018; USDA-NRCS, 2016). The following systems were evaluated: (1) continuous cotton with conventional tillage and winter fallow (CT); (2) no-till continuous cotton with a single species (rye, *Secale cereal*) cover crop (R-NT); and (3) no-till continuous cotton with a mixed-species (50 % rye, 33 % winter field pea [*Pisum sativum* L.], 10 % hairy vetch [*Vicia villosa* Roth], and 7% radish [*Raphanus sativus* L.], by weight) cover crop (M-NT). The field was irrigated using Low Energy Precision Application (LEPA) irrigation and received approximately 60 % evapotranspiration replacement as supplemental irrigation during the growing seasons when irrigation capacity was able to meet crop demand.

Soil water was monitored biweekly using a field calibrated CPN 503 neutron probe (InstroTek Inc., Raleigh, NC) for volumetric water content (VWC) beginning in March 2015 and running through the duration of the experiment unless field conditions did not allow entry (Pabuayon et al., 2019; Alfonso et la., 2020, Burke et al., 2021). Aluminum access tubes (8-cm inner diameter) were installed into the center of each plot on 10 March 2015 and measurements were conducted to a depth of 140 cm in 20-cm increments. The access tubes were constructed with a removable top piece (60 cm length) allowing most of the access tube to remain in the field during tillage events (CT), planting, and harvesting. The VWC for each depth was multiplied by the depth increment (20 cm) to determine soil water content (mm).

A constant rate of change between soil water measurements was assumed and the total soil water content was summed throughout the active growing season (May-August). The total water content (mm) of CT was subtracted from each the total water content of R-NT and M-NT to give the theoretical amount of water saved or lost throughout the year. Precipitation was subtracted from the total water content each year to account for only the water inputs derived from irrigation. The water value for Dawson County, TX was first determined by calculating the cost of access to water for agricultural use as the cost of irrigated land rent subtracted by the cost of dryland land rent. This value was then divided by the amount of irrigation water used to determine the regional value of water ($8.70/ac.-in. for Dawson County, TX; Table 1). Information from the 2021 Texas A&M AgriLife Custom Rates Survey and District 2 Extension Budget was used for the calculation of the regional water value and water value equation was derived from methods from Fei et al., 2016.

Economic budgets were created to analyze the variable costs associated with each management system following methods previously published in Lewis et al., 2018. Lint revenue was calculated using a loan rate of $1.15 kg^{-1} for all crop years to isolate market risk from production risk. Gross revenues ($ ha^{-1}) were calculated by multiplying the loan rate and crop yield. Total variable costs ($ ha^{-1}) were estimated for each year and were subtracted from gross revenue to calculate gross margin ($ $acre^{-1}$), a measure of relative profitability. Gross margins were then calculated after incorporating the water value into economic budgets (Table 2).

Results and Discussion

Summarizing Burke et al. (2021), conservation practices including no-tillage and cover crops increase water storage potential and decrease evaporation during the growing season compared to conventional tillage cotton systems. Soil water differences between the cover crop and CT treatments was greatest in 2017, which was the driest year of the study. This showcases that terminated cover crops in no-till systems can increase water storage following rainfall or deficit irrigation in some years, especially during drought conditions. These results suggest that, with a termination date at least one month prior to planting, cover crops can provide in-season drought mitigation by reducing evaporative losses and increasing infiltration.

Lewis et al. (2018) found significant differences amongst lint yield in 2016 and 2017, with CT outperforming both R-NT and M-NT systems. However, Burke et al. (2021) has shown soil moisture availability not to be the most limiting factor resulting in reduced yield in the conservation systems. Although yields were different among treatments in years 2016 and 2017 between CT and R-NT, gross margins were not statistically different in all three years or averaged across years. In fact, averaged across years, CT was numerically greater than both conservation systems. Lewis et al. (2018) concluded that, although there are environmental and biological benefits using cover crops and no-tillage, the economic constraints of these conservation systems will not justify their implementation amongst producers.

Table 1. Comparison of water saved or lost (-) in no-till systems with a rye or mixed species cover crop compared to the total water content from the conventional system (tillage w/ winter fallow) and the subsequent value of the water saved ($ $acre^{-1}$).

	Precipitation	Water Saved		Water Value	
	mm	mm		$ $acre^{-1}$	
Year		Rye	Mixed	Rye	Mixed
2015	465	-267.97	629.73	-37.14	87.28
2016	317	313.21	256.47	43.41	35.54
2017	238	1344.72	992.75	186.37	137.59

Table 2. Comparison of gross margins ($ $acre^{-1}$) of different management systems, continuous cotton w/ conventional tillage and winter fallow (Conv. Tillage), continuous cotton w/ no tillage

Management	Gross Margin w/ Water Savings			Gross Margin		
System	2015	2016	2017	2015	2016	2017
Conv. Tillage	340	356	502	340	356	502
Rye, NT	337	347	574	374	304	387
Mixed, NT	410	354	550	323	319	412

Conventional tillage, continuous cotton production systems in the SHP are the standard baseline in terms of expected average lint yield, economic gross margins, and irrigation inputs. For conservation systems to be successfully adopted by producers, they must meet or exceed these standards. R-NT and M-NT both had increased amounts of soil moisture compared to CT during the growing season but reduced lint yields. The exception of this was the R-NT system in

2015, which had a reduced amount of water (-267.97 mm) compared to CT and subsequently a negative water value and a lower gross margin (a reduction of \$37.40 acre^{-1}) when incorporating this loss. Reducing irrigation inputs in the R-NT and M-NT systems to match the lower soil water content of CT systems could save the producer money and result in gross margins that results in economically stable conservation practices while increasing soil chemical, physical, and biological properties. This approach can temporarily alleviate producer hesitation to incorporate conservation practices into their existing systems until conservation systems are optimized for semi-arid environments and we can see higher yields and more water storage in dryland systems.

References

Ale, S., S.K. Himanshu, S.A. Mauget, D. Hudson, T.S. Goebel, B. Liu, R.L. Baumhardt, J.P. Bordovsky, D.K. Brauer, R.L. Lascano, and D.C. Gitz III. 2021. Simulated Dryland Cotton Yield Response to Selected Scenario Factors Associated with Soil Health. Front. Sustain. Food Syst. 4. 617509.

Alfonso, C., Barieri, P.A., Hernandez, M.D., Lewczuk, N.A., Martinez, J.P., Echarte, M.M., Echarte, L., 2020. Water productivity in soybean following a cover crop in a humid environment. Agric. Water Manag. 232, 106045.

Banner, J.L., C.S. Jackson, Z.L. Yang, K. Hayhoe, C. Woodhouse, L. Gulden, K. Jacobs, G. North, R. Leung, W. Washington, X. Jiang, and R. Casteel. 2010. Climate Change Impacts on Texas Water: A White Paper Assessment of the Past, Present and Future Recommendations for Action. Tex. Water J. 1:1-19.

Barbato, L. 2008. Ogallala Maps: Estimated Useable Aquifer Timeline. Texas Tech University Center for Geospatial Technology [Online]. Available at https://www.depts.ttu.edu/geospatial/center/Ogallala/OgallalaPDFMaps.html (verified 7 May 2021)

Burke, J.A., K.L. Lewis, G.L. Ritchie, P.B. DeLaune, J.W. Keeling, V. Acosta-Martinez, J.M. Moore, and T. McLendon. 2021. Net positive soil water content following cover crops with no tillage in irrigated semi-arid cotton production. Soil Tillage Res. 208. 104869.

Fei, C.J., R. Hogan, B. McCarl, A. Vargas, and Y. Yang. 2016. Water Values in South Central Texas. Addressing Innovations at the Nexus of Food, Energy, and Water Systems. NSF Project 1639327.

Haacker, E.M.K., A.D. Kendall, and D.W. Hyndman. 2014. Water Level Declines in the High Plains Aquifer: Predevelopment to Resources Senescence. Groundwater. 54.2:231-242.

Lewis, Katie L., J.A. Burke, W.S. Keeling, D.M. McCallister, P.B. DeLaune, and J.W. Keeling. 2018. Soil Benefits and Yield Limitations of Cover Crop Use in Texas High Plains Cotton. Agron. J. 110:1616-1623.

Mitchell-McCallister, D., R. McCullough, P. Johnson, and R.B. Blake. 2021. An Economic Analysis on the Transition to Dryland Production in Deficit-Irrigated Cropping Systems of the Texas High Plains. Front. Sustain. Food Syst. 5. 531601.

Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. United States Department of Agriculture Handbook 296.

Pabuayon, I.L., Singh, S., Lewis, K.L., Ritchie, G.L., 2019. Water extraction and productivity of cotton, sorghum, and sesame under deficit irrigation. Crop Sci. 59, 1692–1700.

Plains Cotton Growers. 2021. Lubbock Area/High Plains Facts [Online]. Available at https://plainscotton.org/cotton-101/ (verified 10 May 2021)

USGCRP. 2018. Impacts, Risks and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program. Washington, DC, USA.