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Water Conservation in the Texas High Plains:
A systems research model of sustainable agroecosystems

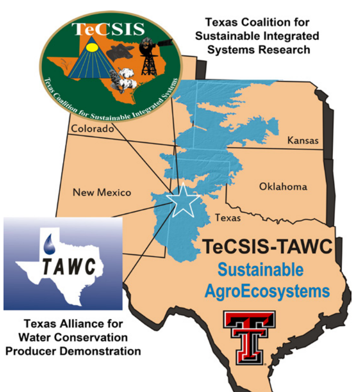
One can't talk about agriculture in the Texas High Plains without including "water" in the same sentence. The Ogallala Aquifer, which has kept ag production humming for nearly a century, is running dry. The Texas Panhandle and Southern Plain are at a crisis point.

For nearly two decades, researchers and producers across the Texas High Plains have been developing integrated crop/livestock production systems that address the growing need for water conservation, while keeping soils fertile, crop yields profitable, cattle production thriving, and surrounding communities viable.

Funded through nearly $1.5 million in Southern SARE Research & Education, Large Systems, and Graduate Student grants, the results showcase long-term alternative production systems, and how those results are being translated into practical field production practices and sustainable agriculture applications.

This model of sustainable agroecosystems in the Texas High Plains is changing the face of agriculture in the region and helping to conserve water, improve soil health, boost ag profits and keep the High Plains region thriving for generations to come.

This bulletin highlights these on-going efforts from Texas Tech University, Texas Coalition for Sustainable Integrated Systems (TeCSIS), Texas Alliance for Water Conservation (TAWC), and their many partners.



The Texas High Plains, that flatland making up the state's panhandle and South Plains, is a patchwork of cropland and grazing lands. The crop is mainly cotton, with some grains and improved grasses mixed in. It is the largest contiguous cropland area in the United States, roughly 15 million acres.

No doubt the High Plains region is one of the country's most important agricultural production centers for crops and cattle, but it is the scene of the some the nation's most extreme environmental conditions: severe heat, debilitating wind storms, flash flooding, and devastating droughts -- all of which demand careful land management.

High Plains farmers faced an agricultural disaster in the 1930s with the Dust Bowl. Now the region faces yet another potential ag crisis: The region is running out of water.

The Ogallala Aquifer

The Texas High Plains is blessed with water, but not in the form of rainfall. The region receives only 18 inches of rainfall annually in an *average* year.

Stretching from South Dakota south to the Texas Panhandle lies a crucial, but finite resource deep beneath the soil surface. Formed millions of years ago from the drainage off the Rocky Mountains, the Ogallala Aquifer traverses through

Cotton is king in the High Plains, but it's a thirsty crop, and we are running out of water." -- *Philip Brown, Texas Tech University TeCSIS program senior research associate.*

portions of eight states — Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas and Wyoming — providing 30 percent of the United States' irrigation, and contributing to an astounding 20 percent of the country's entire agricultural output.

In the early decades of the 1900s, with the advent of rural electrification and pumping technology, tapping into the Ogallala Aquifer for irrigation in the Texas High Plains made row crop cultivation, mainly cotton, possible. Today, roughly 25 percent of the total U.S. cotton crop is produced in this region. In addition, the High Plains serves as a grazing resource for stocker cattle before they enter feedlots. Wheat, alfalfa, warm-season grasses and other forages have served as feed for decades.

But the aquifer is drying up.

The U.S. Geological Survey monitors water levels in the High Plains aquifer. In the latest report, "Water-Level Changes and Change in Water in Storage in the High Plains Aquifer, Predevelopment to 2013 and 2011-2013", USGS reported that water levels in the aquifer in areas of the Texas High Plains have dropped more than 50 percent from predevelopment (prior to the 1950s) to 2013.

As droughts across West Texas Plains intensify and endure, the declining output from irrigation wells and lack of adequate recharge from rainfall are forcing High Plains agriculture to consider new cropping systems that use less water and prolong the use of the aquifer.

A Systems Approach to Sustainable Agroecosystems

The importance of crops, forages, and livestock to the Texas High Plains has highlighted the need to develop systems that enhance profitability, improve conservation of soil and water resources, and expand marketing opportunities for a more sustainable agricultural system.

In the late 1990s, a committed and dedicated team of researchers from Texas Tech University in Lubbock, TX took one of the first steps to begin exploring a systems approach to implement agricultural production alternatives that use less water. Researchers received a Southern Sustainable Agriculture Research & Education (SSARE) grant in 1997 to jump start those efforts.

The objective of the initial SARE grant, (**LS97-082**), "Sustainable Crop/Livestock Systems in the Texas High Plains," was simple: Demonstrate that farmers can save water through an alternative production approach to monoculture cotton.

Phase I

"Cotton is king in the High Plains, but it's a thirsty crop, and we are running out of water. We needed to come up with strategies to diversify crops, and remain economical and profitable,

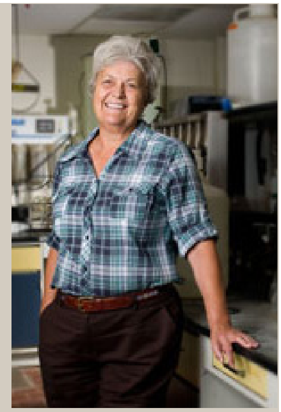
Why Systems Research?

When trying to define an elusive term like systems research, it's easier to start with what we know it is not.

Most agricultural field research is component research. Component research is easy to understand -- alter something, say, the amount of fertilizer two plots receive. Then measure something, such as the yield from each of the two plots. Assume the difference in yield resulted from the two different fertilizer rates and call that, well, your results.

Systems research is by design and definition different from traditional research approaches. With systems research, production is only one component of an agricultural system.

"Systems research is dynamic. It cannot be measured by snapshots. It must be tested across time and locations," said Vivien Allen, retired Texas Tech University, Thornton Distinguished Chair of Plant & Soil Science. "It is an understanding of the whole and the reasons for its behavior that allow us to begin to move in directions that accomplish our research purposes, i.e. water savings, profitability, environmental protection, as well as productivity.



Vivien Allen spearheaded Southern SARE research on alternative crop and livestock systems beginning in 1997. Photo credit: Vivien Allen

"This could never be accomplished in short-term small plot or animal experiments because we are looking at pieces taken from the system that no longer behave as they did within the system," said Allen. "Once we have the chance to study the system, then we can begin to look at the pieces because we are doing so within the system itself. Now they behave in response to all of the influences and interrelationships that cause them to react as they do."

The first SSARE-funded grant in 1997 (**LS97-082**), "Sustainable Crop/Livestock Systems in the Texas High Plains," set the stage for long-term systems study.

"The things we learned that first year were crucial to the ability to study these systems over time," said Allen. "SARE provided us with a unique opportunity to explore these relationships. We wouldn't be where we are today if it hadn't been for SARE support."

For nearly 20 years, that systems research has continued through nearly $1.5 million in SSARE funding, showcasing the results of long-term alternative production systems, and how those results are being translated into practical field production practices and sustainable agriculture applications.

while saving water," said Philip Brown, Texas Tech University Texas Coalition for Sustainable Integrated Systems Research (TeCSIS) program senior research associate. "So we compared continuous cotton with an integrated cotton/forage/livestock system."

Two systems were compared over 10 years: A continuous cotton system using best management practices, and an alternative integrated crop-livestock system of cotton in rotation with forages for grazing by stocker steers. Supplemental water was supplied to both systems by sub-surface drip irrigation. Criteria for evaluating these systems included plant and animal product quantity and quality, net profits, water use, soil conservation and fertility, and input requirements of pesticides, fertilizers, and mechanical operations.

Over a five-year period, researchers found that grazing stocker steers on perennial warm-season grass pastures ('WW-B.Dahl' old world bluestem) and on small grains (rye and wheat) in rotation with cotton required 25 percent less irrigation water, 36 percent less nitrogen fertilizer, fewer pesticide inputs, and provided more flexibility in marketable products than growing cotton in monoculture.

This research has become the benchmark for the comparison of integrated production systems in future SSARE-funded studies. Over the next two decades, researchers have played with integrated crop/forage/livestock systems a variety of different ways to explore the principles of why and how such a system works.

For nearly 20 years, Texas Tech University researchers have been studying various production systems. In 2008, they completed 10 years of data collection on the original comparisons of a cotton monoculture and an integrated cotton-forage-stocker cattle system from the 1997 Southern SARE-funded study. The integrated system used 25 percent less irrigation water (11.8 inches vs. 15.6 inches, respectively) compared to continuous cotton. Cotton yield was similar between the two systems (1217 lb lint/acre vs. 1215 lb lint/acre).

The alternative system provided about 185 grazing days with about 65 percent of the time spent on old world bluestem pastures. Stocking rate was 0.76 steers/acre. Steers gained about 306 lbs (1.7 lb/day) during the time grazing was allowed and were feedlot ready by mid-July.

Soil microbial activity and organic carbon were higher in the integrated system paddocks than in continuous cotton by the end of 10 years. The following is a look at the various research systems that have been studied.

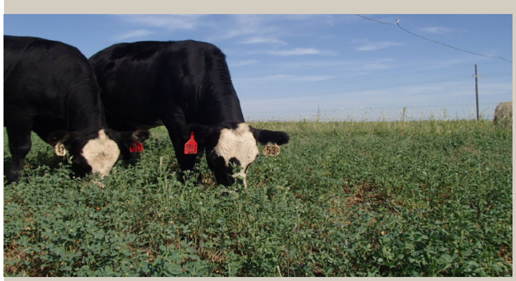


Photo credits: Texas Tech University TeCSIS

Non-irrigated system

This completely dryland system produced grazing for stocker steers and cotton. During the first 5 years, the system stocking rate (including land in cotton) was 0.23 steers/acre. Grazing began in May and was generally terminated by August. Averaged over the 5 years, steers gained about 313 lb or about 68 lbs/system acre and cotton yielded approximately 528 lbs lint/acre. This system was highly vulnerable to weather and precipitation patterns.

Deficit irrigated grazing system

The 3-paddock bermudagrass/old world bluestem system required the longest time to become established and research-ready. Initial seeding of bluestem paddocks began in 2003 with reseeding required during the next 2 years to ensure adequate stands. Bermudagrass was sprigged after adjacent bluestem paddocks were established to minimize encroachment of bermudagrass into these pastures. During 2005 and 2006, cattle were used to graze these paddocks as establishment was completed and research began in 2007. Data collection on this system continues. Appropriate stocking rate was determined to be 15 steers/system or 1.6 steers per acre. Steers gained 440 lbs/acre in this system with approximately 8.9 inches of irrigation water applied.

Buffer irrigated integrated cotton/livestock system

Stocking rates were increased from 0.23 to 0.36 steers/acre with the inclusion of the one irrigated forage paddock into the otherwise non-irrigated system. Averaged over 2 years, total gain/acre increased from 68 to 95 lbs/acre with a mean of 1.7 inches of irrigation water (system basis). Inclusion of the irrigated paddock increased flexibility of managing these sequence-grazed paddocks and improved forage management opportunities. Excess forage in both years was present. Stocking rate was increased in 2011. Non-irrigated cotton produced harvestable yields in both years with a mean of 450 lb lint/acre.

Forage finishing system

Research on this grazing system began in early May 2011. All pastures were fully established and interseeded of legumes into old world bluestem paddocks. During year one, stocking rates were lower than anticipated for subsequent years as forages became fully established. Burning of old world bluestems prior to interseeding legumes reduced growth during 2010 as anticipated. Stocking rates during 2010 were 0.8 steers per acre but were increased to about 1 steer per acre in 2010. Total gain per acre in 2010 was 198 lbs/acre with a mean of 6 inches irrigation water applied in this system.

Phase II

SARE research launched in 2002 (**LS02-131**, "Forage and Livestock Systems for Sustainable High Plains Agriculture"), added additional systems to the original research project: An integrated dryland perennial native grass/warm-season annual grass/cotton system and an irrigated perennial warm-season grass system. After five years, the non-irrigated system was modified to include one paddock of an irrigated perennial warm-season grass to buffer this system against extreme drought.

The systems were tested over seven years to allow researchers to evaluate and test a wide array of approaches to conservation of water, soil, and other natural resources while evaluating the ability to maintain profitability and rural economies.

Integrated systems continued to use 25 to 85 percent less irrigation than the cotton monoculture, while the dryland system received no supplemental irrigation. Economic return per unit of irrigation water invested was greater for the integrated systems than for the cotton monoculture in every year. Buffering the dryland system with one irri-

Teaching Farmers How to Manage Water Like Money

TAWC director Rick Kellison (black shirt) leads a program for producers on water conservation. Photo credit: Texas Tech University TeCSIS

For over a decade, producers across the Texas High Plains have been educating other producers on production methods and new technologies that help save water.

The Texas Alliance for Water Conservation (TAWC) consists of about 30 producers across 8 counties who use 6,000 acres of land to demonstrate a range of agricultural practices, including monoculture cropping systems, crop rotations, no-till and tillage practices, land applications of manure and fully integrated crop and livestock systems. The demo sites, along with resources, events and other activities, follow an outreach/educational model similar to the Cooperative Extension Service.

TAWC director Rick Kellison said that SARE funding helped launched the TAWC.

"It helped create an avenue to disseminate information and to better maximize production, while conserving natural resources," said Kellison.

In 2004, information generated from a SSARE-funded research grant project, "Forage and Livestock Systems for Sustainable High Plains Agriculture," was the basis in obtaining a $6.2 million grant from the Texas Water Development Board to test concepts of integrated systems in an on-farm demonstration project. The TAWC was born.

"The one thing that the TAWC helps farmers understand is that there is no "one size fits all" system," said Kellison. "As someone once told me, there is no silver bullet, but a bunch of silver BBs, and if you throw enough of them, you're bound to hit something. The TAWC helps provide producers with a toolbox of options."

The outreach effort in the TAWC project has been very successful in reaching farmers and disseminating information on best practices for managing irrigation. An additional $3.6 million was obtained from the Texas Water Development Board to continue TAWC through 2019.

gated paddock resulted in more forage produced per unit of irrigation water used than where the entire system was irrigated.

Additional benefits to integrating crop and livestock production have included improved soil microbial and enzymatic activity and soil organic carbon (**LS10-229**, "Integrated Crop and Livestock Systems for Enhanced Soil Carbon Sequestration and Microbial Diversity in the Semiarid Texas High Plains"), reduced soil erosion to below levels targeted for sustainable resource management, and diversification of income to reduce economic risk.

Phase III

Beginning in 2009, the original integrated systems were revised to include legumes and all perennial forages with an objective of forage-finishing steers. In addition, the monoculture cotton system was converted to monoculture sorghum.

"By redesigning the original irrigated integrated systems to compare perennial forages for finishing beef cattle with a sorghum monoculture, we can further reduce water use and meet a growing market demand for forage-fed beef," said Chuck West, Texas Tech University Thornton Distinguished Chair of Plant & Soil Science.

"Additionally, sorghum, drought-tolerant and water-use efficient, may flexibly meet needs for grazing, silage, or biofuels," he said.

The Future of Agroecosystems Research

Research on integrated crop/forage/livestock systems in the Texas High Plains continues. In 2011, Texas Tech University received a SSARE Large Systems grant (**LS11-238**), "Long-term Agroecosystems Research and Adoption in the Texas Southern High Plains," to expand studies on alfalfa as a forage for grazing.

"We wanted to look at alfalfa as a forage to finish the cattle so that they spend a shorter period of time in the feedlot," said Philip Brown. "We are also looking at teff as a forage for grazing."

The project also funds the general maintenance of the long-term field site at the Texas Tech New Deal Research Farm. This effort was renewed by SSARE in 2015 (**LS14-261**, "Long-term Agroecosystems Research and Adoption in the Texas Southern High Plains").

Texas Tech researchers visualize the following low-irrigation management trends in Southern High Plains agriculture in the coming decades: Smaller acreages of irrigation of value-added crops with remaining acres returned to forage and livestock; continual improvements in water use efficiency of major row crops such as cotton; partial replacement of irrigated row crops with perennial grasses and legumes and with dryland crops, especially sorghum; greater use of precision water management technologies such as ultra-low and variable-rate irrigation; greater dependence on online decision aides for guiding inputs; and warmer temperatures leading to greater evaporative demand and more droughts.

These trends will require constant testing of forage systems across the range of weather conditions experienced to offer options to landowners on how to maintain profitability.

High Plains Water Conservation Resources

General Information

Texas Coalition for Sustainable Integrated Systems (TeCSIS)
http://www.orgs.ttu.edu/forageresearch/

Texas Alliance for Water Conservation
http://www.depts.ttu.edu/tawc/

TAWC Solutions
http://www.tawcsolutions.org/

Texas Water Development Board
http://www.twdb.texas.gov/groundwater/aquifer/majors/ogallala.asp

Texas High Plains Water District
http://www.hpwd.org/

USDA-ARS Ogallala Aquifer
http://ogallala.ars.usda.gov/

Publications

High Plains Water Conservation Bulletin No. 2: Sustainable Crop/Livestock Systems in the Texas High Plains Phase I

High Plains Water Conservation Bulletin No. 3: Sustainable Crop/Livestock Systems in the Texas High Plains Phase II

High Plains Water Conservation Bulletin No. 4: Sustainable Crop/Livestock Systems in the Texas High Plains Phase III

High Plains Water Conservation Bulletin No. 5: Diversifying in the Texas High Plains

High Plains Water Conservation Bulletin No. 6: Agroecoystems Economics in the Texas High Plains

High Plains Water Conservation Bulletin No. 7: Soil Quality of Integrated Crop/Livestock Systems

High Plains Water Conservation Bulletin No. 8: Texas Alliance for Water Conservation

High Plains Water Conservation Bulletin No. 9: Water Use of Old World Bluestems in the Texas High Plains

High Plains Water Conservation Bulletin No. 10: Cover Crops and Cotton in the Texas High Plains

High Plains Water Conservation Bulletin No. 11: Agroecosystems Research in the Texas High Plains

Grant Projects

GS15-152 Evaluation of Winter Annual Cover Crops Under Multiple Residue Managements: Impacts on Land Management, Soil Water Depletion, and Cash Crop Productivity

LS14-261 Long-term Agroecoystems Research and Adoption in the Texas Southern High Plains: Phase II

LS11-238 Long-term Agroecosystems Research and Adoption in the Texas Southern High Plains: Phase I

LS10-229 Integrated Crop and Livestock Systems for Enhanced Soil Carbon Sequestration and Microbial Diversity in the Semiarid Texas High Plains

LS08-202 Crop-livestock Systems for Sustainable High Plains Agriculture

LS02-131 Forage and Livestock Systems for Sustainable High Plains Agriculture

GS07-056 Allelopathic effects of small grain cover crops on cotton plant growth and yields

GS02-012 Optimizing Water Use for Three Old World Bluestems in the Texas High Plains

LS97-082 Sustainable Crop/Livestock Systems in the Texas High Plains

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