2024

TEXAS

INTRODUCTION

The Ogallala Aquifer sustains agricultural productivity and rural communities across eight states in the US, providing water for 20% of irrigated land (Rosenberg et al., 1999; Steiner et al., 2021).

The Texas High Plains (THP) region is a crucial agricultural production area in the state, being a production hub for food and fiber crops with essential contributions to the national production of meat and dairy products, cotton, soybean, sunflower, grain sorghum, and winter wheat. The THP produces ~ 55% of Texas corn and > 20% of US cotton (USDA-NASS 2021). Mean annual precipitation in the semiarid Texas Panhandle provides 40% to 80% of crop water demand and the balance of crop water demand is usually supplied by irrigation from the Ogallala Aquifer. As such, Irrigation accounts for more than 90% of total groundwater withdrawals in the region. However, decades of pumping coupled with negligible recharge have resulted in declining water tables that threaten future production of crops in the THP.

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The increased frequency and duration of droughts have also increased the strain on the aquifer and risks for both crop and livestock production. Increasing water demand, depletion of groundwater, reduced rainfall, extreme droughts, and elevated temperatures from changing weather patterns will likely exacerbate problems in the future (Evett et al., 2020; Nielsen-Gammon et al., 2020). Because of the severity of aquifer depletion, water management strategies such as transitioning to less water-intensive crops, concentrating water on fewer acres, deficit-irrigated production, alternative cropping rotations, and conversion to dryland are being evaluated for their economic feasibility and effectiveness for extending the life of irrigated agriculture on the THP. Additionally, water saving technologies designed to increase crop water productivity are being developed and studied. These include surface and subsurface drip irrigation and automated sensor-based irrigation scheduling controllers. Other approaches and ideas have been advocated by the stakeholders, including restoration of native rangelands, enhanced pasture management, implementation of integrated crop-livestock systems, breeding less water-intensive and drought tolerant crops, promoting soil health and the adoption of regenerative agriculture methods. Strengthening agricultural resilience by incorporating various water conserving solutions, systems, and technologies can be crucial for sustaining aquifer levels and irrigation-dependent agricultural production in the Texas High Plains. However, technological solutions alone will not sustain the aquifer but must be coupled with appropriate public policy that offsets productivity gains arising from technology adoption with reductions in water withdrawal.

OGALLALA-RELATED ACTIVITIES

The **Texas Alliance for Water Conservation (TAWC)** is an agricultural “producer-teaching-producer" demonstration and education network in West Texas that promotes water conservation through best management practices and technologies. Established in 2005, TAWC has worked with 36 growers covering over 6,000 project acres on farms, constituting over 136,000 total acres, and overlaying the southern Ogallala Aquifer. TAWC field sites were initially located only in Hale and Floyd counties but have expanded to 14 counties with 45 participating producers as of summer 2023. The organization aims to optimize the sustainability and profitability of producers in the region through effective management methods and state-of-the-art technologies. TAWC organizes various outreach activities, such as field walks, field days, farm demonstrations, workshops, and the annual water college, to showcase the project's findings and highlight the benefits of these technologies to optimize the sustainability and profitability of producers in the region.

The **Ogallala Aquifer Program (OAP)** is a research and education consortium seeking solutions to problems arising from declining water availability from the Ogallala Aquifer on the Southern High Plains. The consortium includes Kansas State University, Texas A&M AgriLife Research and Extension Service, Texas Tech University, West Texas A&M University, and the USDA ARS NP211 research projects at Bushland and Lubbock, TX. OAP funding is from the USDA ARS at Bushland, and OAP management is led by ARS at Bushland with cooperation of a management team composed of the principal investigators for the funding agreements with the four universities. With the high rate of depletion of the Ogallala Aquifer, particularly in Texas and Kansas, the OAP's focus is to improve the sustainability of agricultural industries and rural communities through innovative scientific research and technology transfer. The OAP's current objectives are:

- Develop and evaluate water management strategies and technologies, including dryland cropping systems, that could reduce water withdrawals for irrigation while maintaining and/or enhancing the economic viability of the agriculture industry and the vitality of the Southern Ogallala Aquifer Region.
- Develop and evaluate management strategies and technologies that would increase the productivity and profitability of forage or other short-season cropping systems that reduce or eliminate water withdrawals.
- Improve the understanding of hydrological and climatic factors that affect water use and economic profitability, and provide estimates of the climatic, hydrologic, cropping, and profitability conditions that are likely to occur on the southern High Plains over the next 50 years.
- Determine the impacts of alternative water withdrawal/use policies on the economic viability of the agriculture industry and the vitality of the Southern Ogallala Aquifer Region.
- Develop best management practices for alternative crops that increase the sustainability of dryland farming or high value crops that maintain farm income with decreased pumping from the Ogallala Aquifer.

Accomplishments to date that conserve water and promote agriculture include:

- Irrigation scheduling using evapotranspiration demand has reduced water application by 15 percent over the past 10 years, saving farmers approximately $200 million in production costs
- Advances in the design and management of subsurface drip irrigation have led to the doubling of the acres using this water-conserving technology since 2003
- New irrigation automation systems, which could benefit six million acres by reducing labor costs by $7 per acre while maintaining crop yields, have been developed and tested

- Development of drought-and heat-resistant crop varieties for corn, cotton, sorghum, wheat and peanuts has been advanced
- Extension programs have educated thousands of farmers in water conservation practices and millions have been exposed to the importance of the Ogallala Aquifer to national and world food and fiber supply via public media stories.

The **Master Irrigator Program** is an educational collaboration between North Plains Groundwater Conservation District and Texas A&M AgriLife Extension to provide classroom education on water management, irrigation systems, energy conservation, agronomics, and economic optimization to receive a Master Irrigator Certification. Participants who complete the course and receive their certification have priority access to the NRCS EQIP funding. Follow up surveys have demonstrated knowledge gained and adoption.

OTHER KEY ACTIVITIES UNDERWAY, POLICY SHIFTS, NEW/CORE INITIATIVES

Sensors Technologies in Agriculture

Figure 1: Counties in THP with TAWC demonstration sites

Comprehending the intricate and interconnected soil-water relationships is crucial to achieve sustainable agricultural production systems. We aim to transform agricultural systems by improving soil health by strategically implementing cover crops, crop rotations, and advanced irrigation technologies. Combining these elements promotes the development of healthy and nutrient-dense soils and substantially reduces water usage, thus driving the advancement of sustainable agriculture. We have diverse producer sites across West Texas following different cropping, tillage, and cover crop practices. We recently introduced new sensor technologies for irrigation water management on these sites.

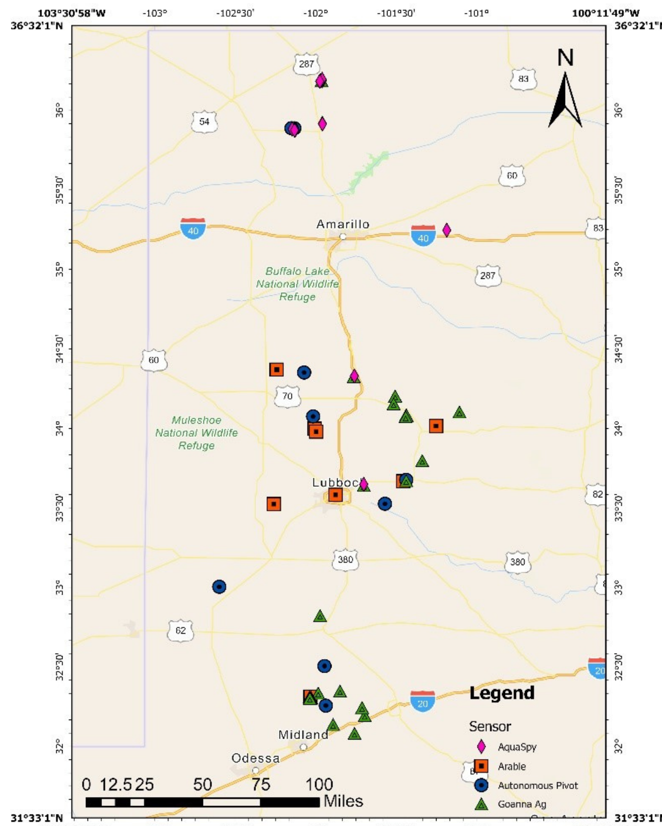


Figure 1. Location of different producer's field sites and sensor technologies tested across West Texas.

Starting in 2023, Texas Tech is working with four different sensor technologies Arable, Autonomous Pivot, AquaSpy, and Goanna Ag (Figure 1). These technologies have been incorporated into agricultural practices of cooperative producers in the West Texas region. These technologies assist farmers in making irrigation decisions based on real-time field data, mitigating both under- and over-irrigation, minimizing crop loss, avoiding excessive water use, saving water, and mitigating environmental concerns. This is done through the utilization of sensor technologies for surveillance of crop water consumption, soil moisture levels, and stress indicators. With all this information, Texas Tech is working with the producers to formulate irrigation schemes to match crop water needs.

Improved Low-Cost Soil Water Sensors

Better tools for irrigation scheduling using time domain reflectometry (TDR) type soil moisture sensors. Irrigation management for efficient use of scarce water resources can be greatly aided by use of accurate soil water sensors. USDA ARS scientists at Bushland, Texas, developed accurate, low-cost TDR soil moisture sensors, in cooperation with a commercial partner (www.acclima.com) who now provides them to agricultural producers, equipment suppliers, and irrigation equipment manufacturers. The scientists have written a guide to the best methods of using these sensors and similar TDR sensors for use in agricultural and environmental management, easing the way towards more widespread use of sensors to save water.

Precision Irrigation Scheduling

Precision irrigation scheduling methods could help sustain the Ogallala Aquifer and rural communities. However, some precision irrigation methods are complicated to implement and require a steep learning curve to understand. Under a collaborative effort between ARS scientists from Bushland, Texas, and University of Nebraska scientists, the ARS-patented Irrigation Scheduling Supervisory Control and Data Acquisition (ISSCADA) system was outfitted onto a center pivot sprinkler in Nebraska to test its feasibility for crop production of corn and soybean and to compare scheduling results side-by-side with the Spatial EvapoTranspiration (ET) Modeling Interface (SETMI). The ISSCADA uses canopy temperature sensors mounted on a center pivot and in the field coupled with data from soil water sensors and from a nearby weather station to automatically build prescription maps that guide the irrigation system.

The SETMI system requires satellite information at regular intervals and ET modeling to estimate spatially variable crop water use. Both precision irrigation scheduling methods were compared with the irrigation method commonly used by farmers in Nebraska. Irrigation amounts, grain yield and crop water productivity were similar between precision irrigation methods in both years and prescribed less water than the method commonly used by farmers. Providing producers with technology that performs well, saves water, and is easy to use, helps to facilitate adoption. Making collaborators aware of this distinction helps transfer irrigation scheduling technology in other regions of the United States (U.S.).

Subsurface Drip Irrigation

Scheduling subsurface drip irrigation (SDI) using evapotranspiration data and crop coefficients saves water and energy if the crop coefficients are determined using an SDI system. Previous coefficients determined using sprinkler irrigation systems overestimate crop water use with SDI systems and result in water waste. Fresh water supply for irrigation is decreasing. One solution to decreasing supply is to increase the productivity of irrigation water use through newer irrigation delivery systems, including subsurface drip irrigation (SDI). There are more than 430,000 acres of SDI on the Texas High Plains. However, best management practices for SDI are still under development. USDA ARS scientists at Bushland, Texas, have developed methods of accurately scheduling sprinkler irrigation of corn, cotton and other crops using crop coefficients and estimates of reference evapotranspiration. However, these methods have failed when applied for scheduling SDI. Accurate crop coefficients for SDI were thus needed for efficient irrigation scheduling. The Bushland researchers measured corn water use for two years, comparing it between SDI and sprinkler irrigation. Results showed that crop coefficients for SDI were 10% to 15% smaller than those previously developed for sprinkler irrigation. Similar results were found for grain sorghum and are likely for cotton. The use of new crop coefficients for SDI will decrease irrigation applications' using SDI, thus saving water and reducing associated energy costs.

No-Till Farming in Dryland Agriculture

Evidence supports using no-till and contour farming to promote dryland crop production. Precipitation is the only water source for increasingly important dryland crops in the Texas High Plains, and runoff decreases both stored soil water and crop yields. ARS scientists from Bushland, Texas, quantified storm water runoff and storage in the soil under field conditions using conservation practices of either no-tillage (NT) or contour farming. Increased yields of wheat and sorghum grown in a three-year wheat-sorghum-fallow (WSF) rotation were achieved with NT as compared to stubble-mulch (SM) tillage over a 26-year period. By reducing evaporation during fallow, NT had greater soil water and grain sorghum yield than SM. Greater landscape slope increased fallow runoff, but soil water and dryland crop yields were not significantly affected with contour farming. These results will help farmers and crop consultants improve semiarid dryland cropping practices by decreasing evaporation and soil erosion with NT residues. USDA-ARS research further demonstrates that conservation tillage slows further declines in soil carbon (Schwartz et al., 2015).

Cotton on the High Plains

A relatively drought-tolerant and salinity-tolerant crop, cotton historically has been the predominant crop in the Texas Southern High Plains, where irrigation capacities are generally insufficient for full irrigation of most crops, and localized salinity issues present challenges for irrigating more salt sensitive crops. As local groundwater availability and quality have declined throughout much of the Texas High Plains and surrounding areas, cotton production area has increased, advancing northward into Kansas. Investment in infrastructure, including some of the largest cotton gins in the world, in the area indicate cotton is expected to remain an important crop in the future. Several studies have indicated that transitioning of crop production systems from more drought sensitive crops, such as corn, to cotton can result in significant reductions in groundwater pumping in the Texas High Plains (Colaizzi, et al., 2009; Gowda, et al., 2007). Crop model studies (Chen, et al, 2021; Gowda, et al., 2007) have indicated potential advantages of strategies to balance objectives of reducing irrigation water use and crop yields. Even for drought-tolerant crops, drought stress reduces yield and quality; hence irrigation can often be economically beneficial. Where irrigation water capacities are limited, it is especially important to optimize irrigation rates and timing to ensure high water use efficiency without undue reduction in yields and quality. Much cotton production research has been conducted in the Southern High Plains of Texas, but less research has been conducted in the northern Texas High Plains (Texas Panhandle) and Kansas. Historically it had been considered risky in terms of limited potential accumulated heat units and limited growing season length; yet producers in the Texas Panhandle have been achieving relatively high cotton yields.

A collaborative research project addressing cotton production in thermo-limited regions of the High Plains, supported by the USDA-ARS Ogallala Aquifer Program*, is considering planting dates, varieties, irrigation strategies and plant populations to develop research-based recommendations for cotton production in the region. A Texas based team from USDA-ARS, Texas A&M AgriLife Research and Extension and other partners is conducting field studies at Bushland, Texas, and a Kansas State University team is conducting similar research at Garden City, Kansas. Extension and research faculty from Texas and Kansas are interpreting research results and recommendations for a range of audiences, including cotton producers and landowners, crop consultants, and other stakeholders. Texas A&M AgriLife Extension continues to conduct on-farm cotton variety trials with producers to identify stable varieties across different environments and management systems (Bell et al., 2014-2023).

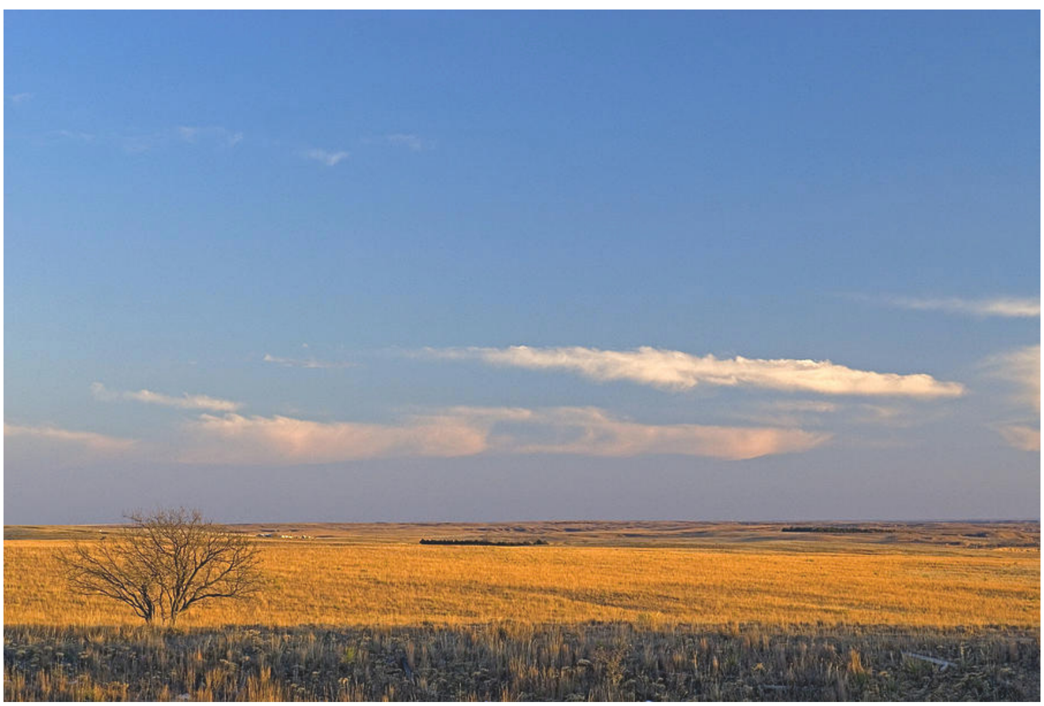
KEY CHALLENGES

Texas High Plains region is known for its arid climate and extensive agricultural areas. With the decline in Ogallala Aquifer levels, producers in the region would benefit from the introduction of precision technology for managing irrigation water. Sensor-based irrigation technology offers significant potential for optimizing water utilization and improving crop productivity. However, the actual implementation of these technologies on producer fields, would need to go through different challenges. Starting with monetary investment to a lack of incentive to use the technology, significant barriers exist to the widespread implementation of sensor-based irrigation technologies. Producers have limited exposure to the evolving sensor-based technologies and need help comprehending the process of incorporating sensors into their pre-existing irrigation systems or interpreting the data produced by these technologies. Ensuring the dependability and upkeep of sensor-based irrigation systems necessitates consistent calibration, monitoring, and maintenance, which might need to be improved. Several funding opportunities such as USDA NRCS, SARE, TWDB and others provide resources for supporting the testing and demonstration of these technologies for wider adoption.

WARMING OF THE TEXAS HIGH PLAINS

Author: B.A. Stewart - Researcher, Agronomy Department, Oklahoma State University and USDA 1953-1957; Research Soil Scientist, USDA Agricultural Research Service, Ft. Collins, CO 1957-1968; Director USDA Conservation and Production Research Laboratory, Bushland, TX 1968-1993; Director, Dryland Agriculture Institute, WTAMU 1993-2018

After spending my entire life and career in the Southern Great Plains and the last 55 in the Texas High Plains, I remain deeply interested in the climate. Historically, there are two climatic periods that stand out. The first was 1930s which I always refer to as the "Dirty Thirties" is the best known period because it spawned the infamous Dust Bowl which is thought by many to be the worst ecological and environmental disaster ever caused by human activities. Even more devastating were the economic and sociologic problems that resulted. I was not born until 1932 so only remember a little about the latter stages of the Dust Bowl. What I remember most was the pain and stress that I saw in my Daddy and Mother as they struggled to keep a small dairy operating in southwest Oklahoma. The second period was the 1950s that I call the Filthy Fifties. I not only remember this period well but was starting my career as a joint employee of Oklahoma State University and USDA Agricultural Research Service as a member of the Department of Agronomy at Stillwater.



Texas

My duties were to conduct fertilizer experiments throughout the western half of Oklahoma including the Oklahoma Panhandle. In many cases wheat yields were 5 to 10 bushels per acre or even less and dust storms were terrible. The temperatures were brutal, but the length of the Filthy Fifties was not as long as the Dirty Thirties and the economic were not as bad because there was more government assistance than during the Dirty Thirties that coincided with the worst economic depression ever experienced by the U.S.

Following those two periods, the Texas High Plains became one of the most productive agricultural regions in the entire U.S. and the world. Irrigation developed rapidly from the Ogallala aquifer that many people thought was an underground river that would never be depleted and approximately half of the cropland became irrigated land. At the same time agricultural research, extension programs, and agribusiness activities flourished that resulted in high and dependable yields on irrigated land and reasonable yields on dryland for most years.

In recent years, agriculture production in the Texas High Plains has become increasingly challenging. The Ogallala aquifer has been seriously depleted and dryland yields have been decreasing. While low and highly variable rainfall is always the major concern, the number one concern at this time in my opinion is the rapid rise that is occurring in temperature values. In this brief summary, I am sharing my concern regarding climate change and the tremendous challenge that agriculture producers are likely to face in the future and how this will affect the agriculture economy of the region.

RISING TEMPERATURES

The data I will be using are from Climate at a Glance, National Oceanic and Atmospheric Association (https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/). NOAA divides Texas into 10 climatic regions and the Texas High Plains region includes the area approximately from Dalhart south to about Big Spring. They have measured temperature and precipitation from a number of sites in the area since 1895. The average annual temperature and precipitation values are aggregated to determine single values that represent the average of the entire region. NOAA determines "Normal" temperature and precipitation values for all locations and areas every 10 years. Normals are calculated by averaging temperature, precipitation, and other climatic variables for a 30 year period. For example, the normal average annual temperature for the Texas High Plains today is 59.6 degrees Fahrenheit that is the average of the 1991-2020 annual temperatures. That value will be the normal until 2031 when it will be replaced by the average of 2001-2030 temperature values.

NOAA has data since 1895. The first normal values were calculated in 1930 based on 1901-1830 measurements. This is shown below along with all the subsequent normal values.

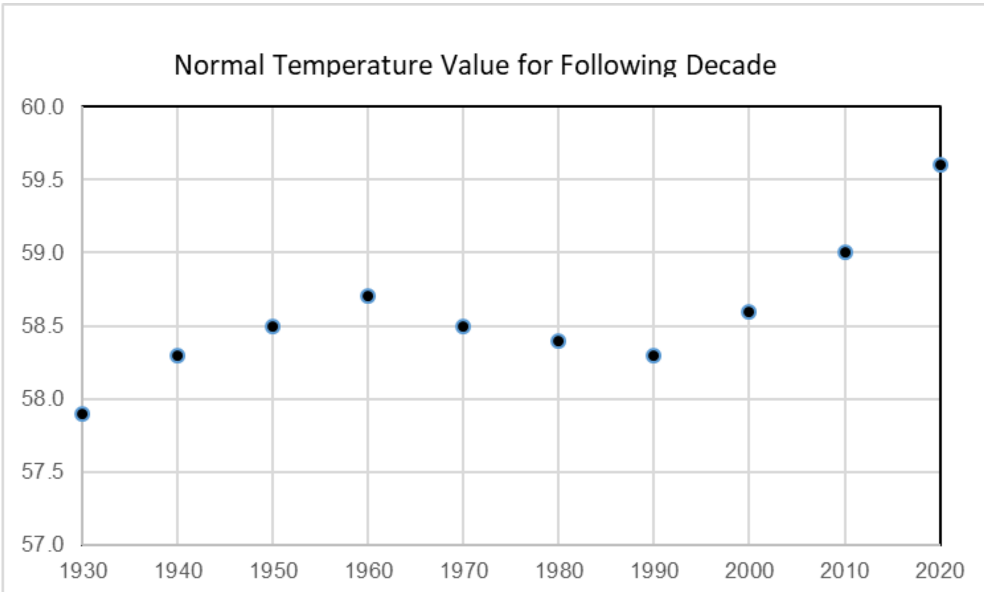


Figure 1.

The first normal value was 57.9 degrees for 1930 but increased to 58.3 for 1940. The reason for this rather big jump was due to the high temperatures during the Dirty Thirties. It remained fairly close for 1950, but took another jump for 1960 because the 30 years included in that calculation included the high temperatures of both the Dirty Thirties and the Filthy Fifties. Normal temperatures then began to decline slightly as the abnormal values from the Dirty Thirties or the Filthy Fifties were no longer included.. However, normal temperatures began to increase significantly with the 2000 normal. Figure 2 shows NOAA temperature values for 128 years for the Texas High Plains region, The Dirty Thirties and the Filthy Fifties stand out and clearly show that the high temperatures were similar but the Dirty Thirties was a longer period. The annual temperatures then returned to some sense of normality but remained variable. However, temperatures began to increase during the 1980s and have increased dramatically since1990. The present normal temperature value is 59.6, but to put this into perspective for the entire 128 years of record, only 27 exceeded today's normal. The first year was 1933 and only 10 years before 1994. During the Dirty

Thirties, 9 years were above normal but only three exceeded today's normal and during the Filthy Fifties 5 years were above normal but only 2 years above today's normal.

As bad as the past high temperatures were, they pale in comparison to temperatures today. Since 1990, only 1993 and 1997 had annual temperatures below normal even though the normal temperatures for which they were compared increased to 58.3 in 1990, 58.6 in 2000, 59.0 in 2010, and 59.6 in 2010. Thus, for the last 34 years, only 2 years have been below normal. This also indicates that unless significant cooling occurs shortly, the temperature normal for the 2030 decade will be even higher.

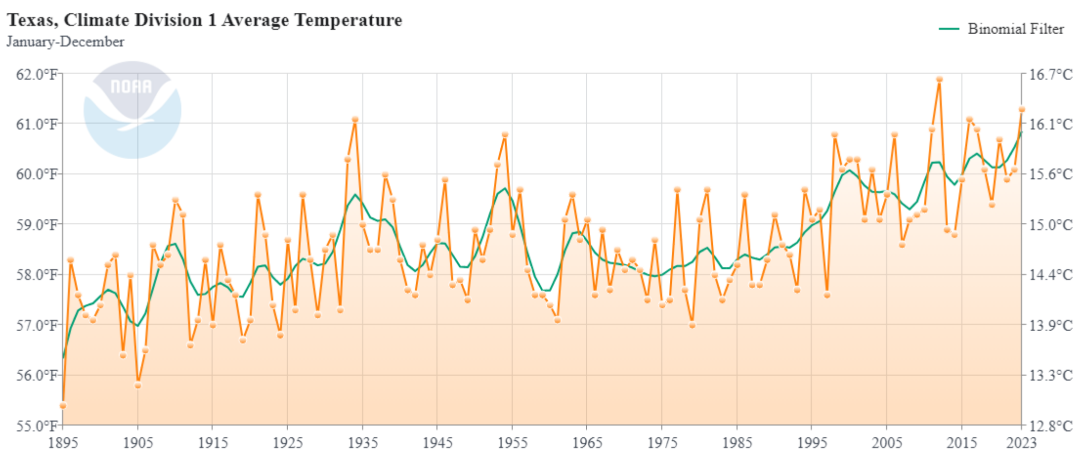


Figure 2.

PRECIPITATION DATA

NOAA also has precipitation data from the same sites as temperature and can be easily accessed as described for temperature data. Normal values are calculated in the same manner and the Figure 3 shows normal decade values from 1930 to 2020.

The changes in the normal precipitation values are somewhat more variable than I would have expected. However, it is easy to see the dramatic effect that the Dirty Thirties and Filthy Fifties had on the values. The normal values dropped from 19.19 to 18.58 inches when the 10 low years of precipitation during the 1930s were included, and a bigger drop for the 17.80 value for 1960 which included the dry years of the 1950s along with those of the 1930. A better understanding of the variable rainfall can be seen by looking at Figure 4 showing the entire 124 years of precipitation data.

Unlike the temperature data that showed a dramatic increase from the 1990s forward, the average precipitation values have remained somewhat the same but perhaps more variable. Since 1990, there have been 22 years below normal compared to 12 above.

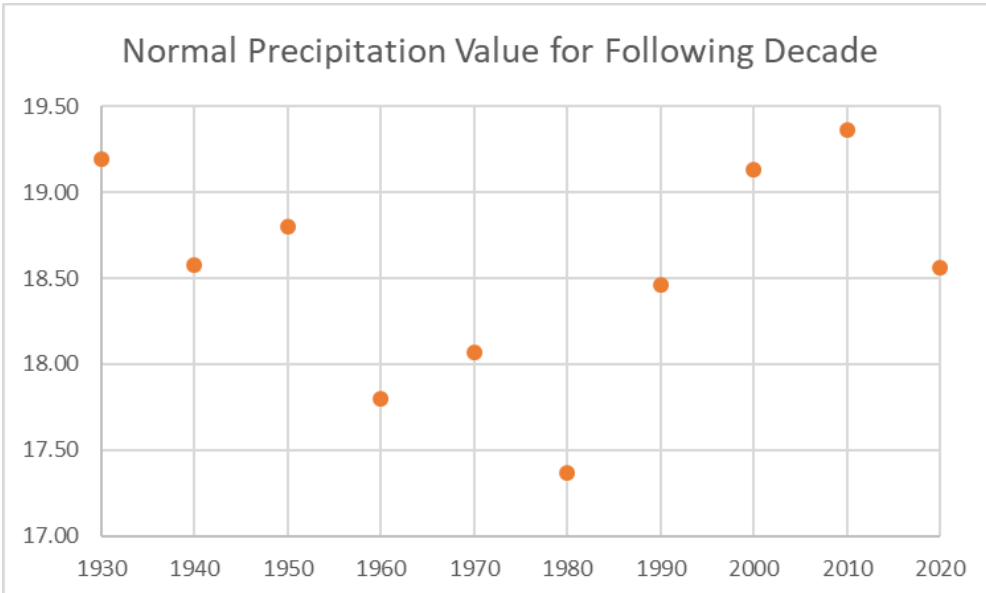


Figure 3.

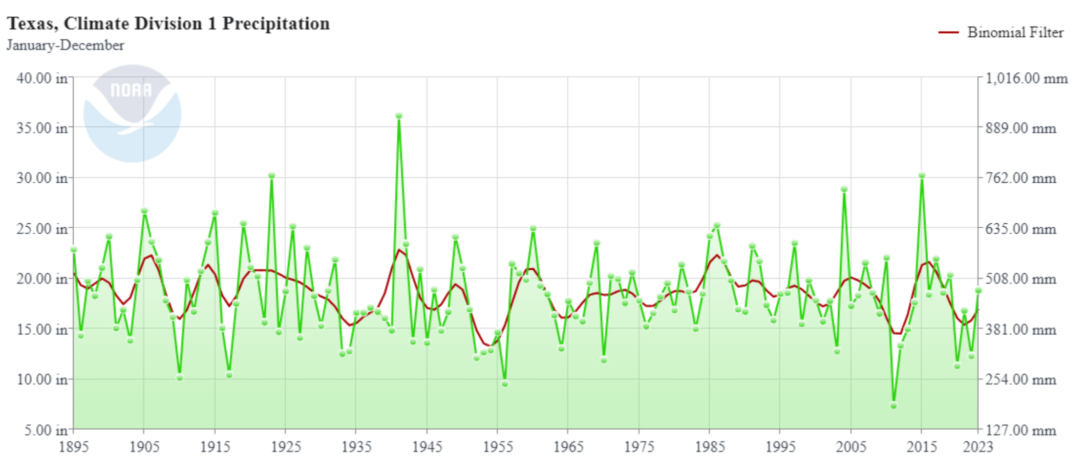


Figure 4.

SUMMARY

It is an undisputed fact that the climate is constantly changing. That is the reason that NOAA established a system to calculate normal values. The assumption was that the weather for the next 10 years would be somewhat similar to the average of the past 30 years but some years would be higher and some lower than the normal. It was also assumed that the change in normal would not change rapidly from decade to decade but would show gradual changes in climate. In recent years, for the Texas High Plains as well as for many other locations in the U.S. and world, temperatures have been rising almost every year and at an increasing rate. This is certainly true for the Texas High Plains as clearly shown in Figure 1. Starting with 1991, the average annual temperature increased 0.3, 0.4, and 0.6 every 10 years. While these numbers may seem small, their cumulative effect is huge. A degree or two can cause major changes in cropping systems as we know well by comparing agricultural systems from the southern to northern parts of the Texas High Plains. For example, Lubbock has an average annual temperature about 2.5 degrees higher than Amarillo and the cropping systems are drastically different. Since 1930, the average annual temperatures have increased 2 degrees, and 1.2 of those have occurred since 1990.

Figures 2 and 4 shows 124 years of annual temperature and precipitation. While precipitation values have been highly variable, there is little evidence that suggests precipitation has decreased significantly in recent years. In comparison, temperature values have increased dramatically in recent years and the rate of increase has greater each with each decade after 1990. The most alarming fact to me from analyzing the data is comparing the years 1931-1960 to 1991-2020. The 1991-1960 period includes both the Dirty Thirties and the Filthy Fifties that were the hottest and driest periods since the beginning of farming in the Texas High Plains. The average rainfall values for these periods were 17.80 and 18.56 inches, and average temperatures were 58.7 and 59.6 degrees Fahrenheit. It is difficult to accept the fact that the temperature values during those terrible years are now considered BELOW normal. This does not bode well for agriculture in our area. There is little likelihood that average rainfall values will increase but that large variations will continue and possibly even increase. In contrast, there is strong evidence that average annual temperature values will continue upward. The average annual temperature has only been below normal 2 of the last 34 years even though the normal value has increased every decade since 1990. It is also very likely the new normal temperature values will be even higher for 2030 because the values of the 1990s will be dropped and those of the 2020s added to calculate the normal. Higher temperatures increase water so dryland farming is becoming more challenging every year and a high percentage of the irrigated land in the area is already woefully short of water supply and becoming more so with each succeeding year. Producers will be required to make changes in choice of crops and cultural practices. However, if there is not some slowing or decrease in the rising temperatures, many areas within the Texas High Plains will reach a TIPPING point where farming is no longer sustainable. This is a difficult summary sentence to write, but the rapidly rising temperature values in an already marginal farming region are comparable to a slow growing cancer with medicines that can only delay, but not cure the problem.

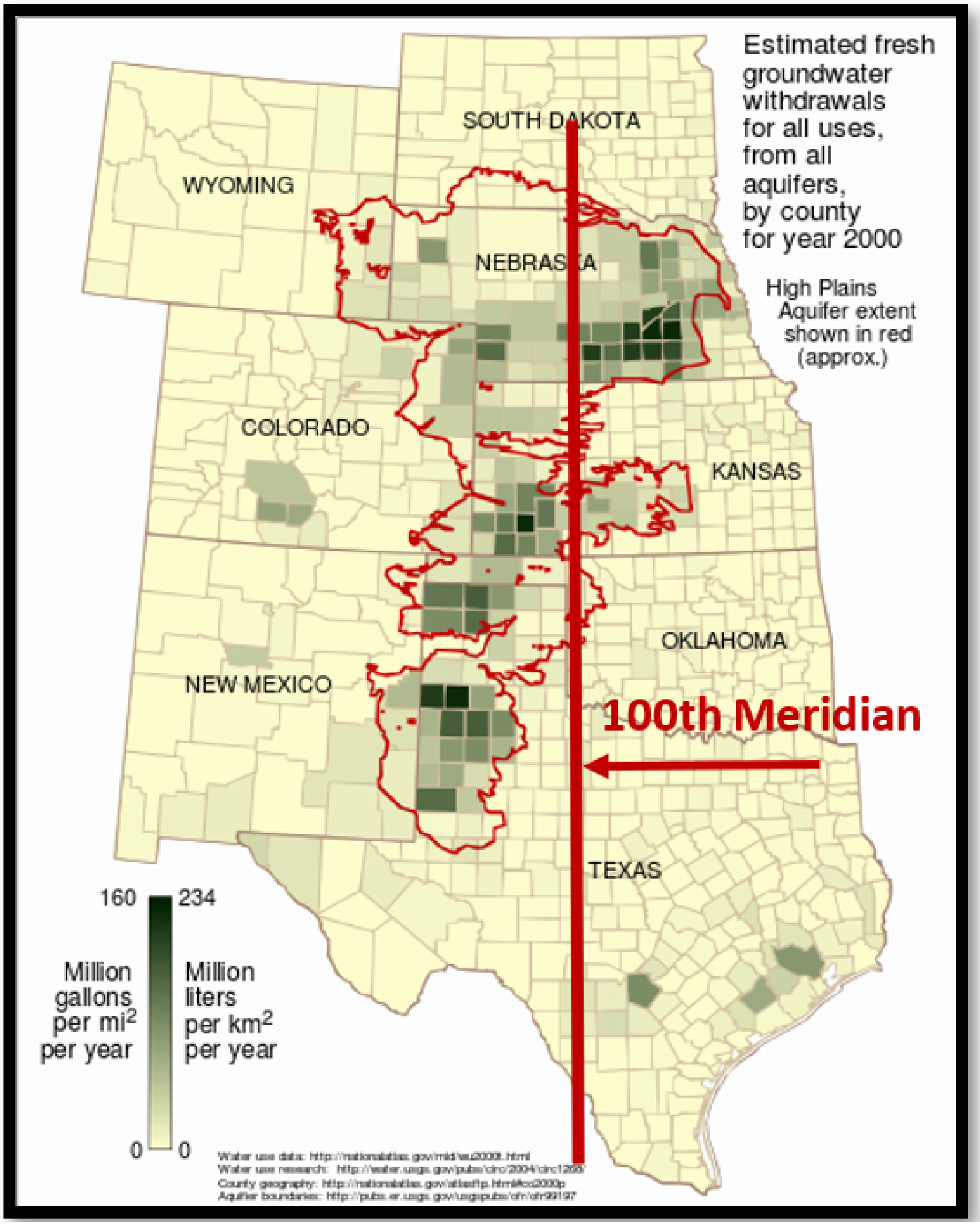
HOW WILL WE MOVE FORWARD?

Author: Jourdan Bell

Since the late 19th century, agricultural productivity across the southern Great Plains has been challenged by episodic droughts and water limitations. However, production challenges were not without warning. In 1878, John Wesley Powell explored the southern Great Plains, and when he crossed the 100th meridian, he identified this demarcation as the separation between the semi-arid west and the humid east (Krajak, 2018). Of significance, Powell (1879) reported that irrigation would be necessary for crop production west of the 100th Meridian because precipitation was less than 20 inches (Fig. 6). Although the extent of the Ogallala Aquifer was yet to be discovered, Carl Schurz, the United States Secretary of the Interior, proposed a bill to organize irrigation districts in response to Powell's report, but without a known irrigation water source, the region largely remained managed for livestock production and "dry farming". Following the drought of the 1890s, economic risks associated with "dry farming" resulted in regional depopulation, and it was determined that "dry farming" was not based on scientific principles (Seager and Herweijer, 2011).

The federal government responded to the drought and production challenges with a series of agricultural research stations across the southern Great Plains including the field sites of Lyman Briggs (Landa and Nimmo, 2003) to address questions surrounding the production potential of forages and response to water. While the government was quickly addressing regional production challenges through applied research, producers were digging irrigation wells with the understanding that irrigation would stabilize production.

The first irrigation well, dug by hand in Bailey County, Texas, in 1909 set the stage for water exploration and the future of irrigated agriculture, but crop production on the Texas High Plains remained predominately dryland for the next 30 years. The drought of 1917 followed by the drought of the 1930s coupled with the Dust Bowl marked two more periods of depopulation from the southern Great Plains and economic losses.



The Ogallala Aquifer including the location of the 100th meridian. Map source: National Atlas.

The USDA responded to the Dust Bowl by creating the current USDA-ARS Conservation Production Research Laboratory to address dryland cropping systems including tillage research and weed management in the 1940s. During this time, irrigated agriculture rapidly expanded, and research scientists and extension specialists also responded to producer's irrigation needs with applied research. Advances in irrigation management allowed farmers to more successfully overcome the drought of the 1950s. Continued improvements stabilized drought related yield losses over the next 70 years and optimized production even as groundwater started to decline. Today, approximately 9% of the northern Texas High Plains is irrigated (Benavidez et al., 2019), but because of declining saturated thickness and irrigation capacities, producers are reducing irrigated acreage to optimize water productivity (Dominguez et al., 2022). However, this practice potentially increases dryland acreage. Howard Finnel, the USDA Soil Conservation Service Soil Conservationist at Amarillo from 1934-1942, stated that "to be economical, the land must be used more intensively than ranching but not monoculture grain production… a special type of agriculture for marginal land is needed" (Helms,1992). Advancements in irrigation allowed research scientists, extension specialists, and producers to divert from this reality during the last 80 years, but we now must address this potential crisis moving forward.

Evett et al. (2020) detailed the history of irrigated agriculture from the Ogallala Aquifer including the regional economic impact. Irrigated agriculture led to the expansion of rural communities across the Texas High Plains. With every improvement in efficiency, both crop and livestock producers expanded agricultural enterprises resulting in a positive economic impact. Increased irrigated acreage allowed for the expansion of concentrated animal feeding operations (beef, dairy and hog) and associated jobs because of increased feed grain and forage production, but agricultural productivity has resulted in the inadvertent decline of the southern Ogallala. While the authors suggested that public policy would "play a role in regulating consumption and motivating on-farm efficiency", relaxed policy and fines managed (by some) as production expenses have not slowed the rate of groundwater extraction in Texas. Inconsistent water policy across the Ogallala Aquifer region magnifies intrinsic geological differences and water disparities. Today, pumping capacities are more restrictive than policy limitations in many areas, so it is important for districts to consider how they will regulate what they do not have. Furthermore, it is challenging, if not impossible, to determine pumping limits without considering the impact on economic productivity. This is not a decision that impacts only the producer.

This decision impacts entire communities because of reduced cash flow. There are social consequences to water conservation. We must consider the impact of water policy on the broader economy. If we slow economic productivity today without another industry to replace lost agricultural revenues, we will not only impede the economic growth of the remaining rural communities but also destroy the community structure. Today, the broader regional population has not declined because of the growing cities of Amarillo and Lubbock, but there is already depopulation of many rural communities. As rural populations decline, secondary agricultural industries go out of business, schools and hospitals consolidate or close, and main streets become vacant. Without jobs, the remaining population is at risk of increased dependence on social programs.

As we once again convene to discuss the value of the Ogallala Aquifer, we must recognize that without water, we are managing marginal lands, and marginal dryland production will not sustain rural communities. Policy is needed, but not policy that hinders economic growth and sustainability. Policy is needed that ensures the viability of regional water supplies and communities for future generations, and sound policy is not possible without unbiased long-term research. Regional research is needed to creatively investigate alternative cropping systems and generate unique data sets for climate-based models rather than continuing to validate business as usual production practices.

Note: There are currently pockets with good water, and there will continue to be small pockets with good water for years to come. However, these small areas cannot sustain the region and because of the right of capture, it will be up to a few landowners to ensure the long-term productivity of these areas. The discussed concerns are about the broader region.

PARTNERSHIPS, INTERSTATE INTERACTIONS, AND COLLABORATIVE EFFORTS

Partnerships with multiple organizations include but are not limited to the Texas Water Development Board, USDA-ARS, USDA-NRCS, High Plains Water District, Texas A&M University, Texas AgriLife Research and Extension, West Texas A&M University, and Texas Tech University. Agencies work closely with stakeholders to promote water conservation in the region by engaging the community through stakeholder meetings, annual water college events, irrigation workshops, and field days.

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