Issues and Implications for Central Arizona Agriculture Associated with the Colorado River Shortage

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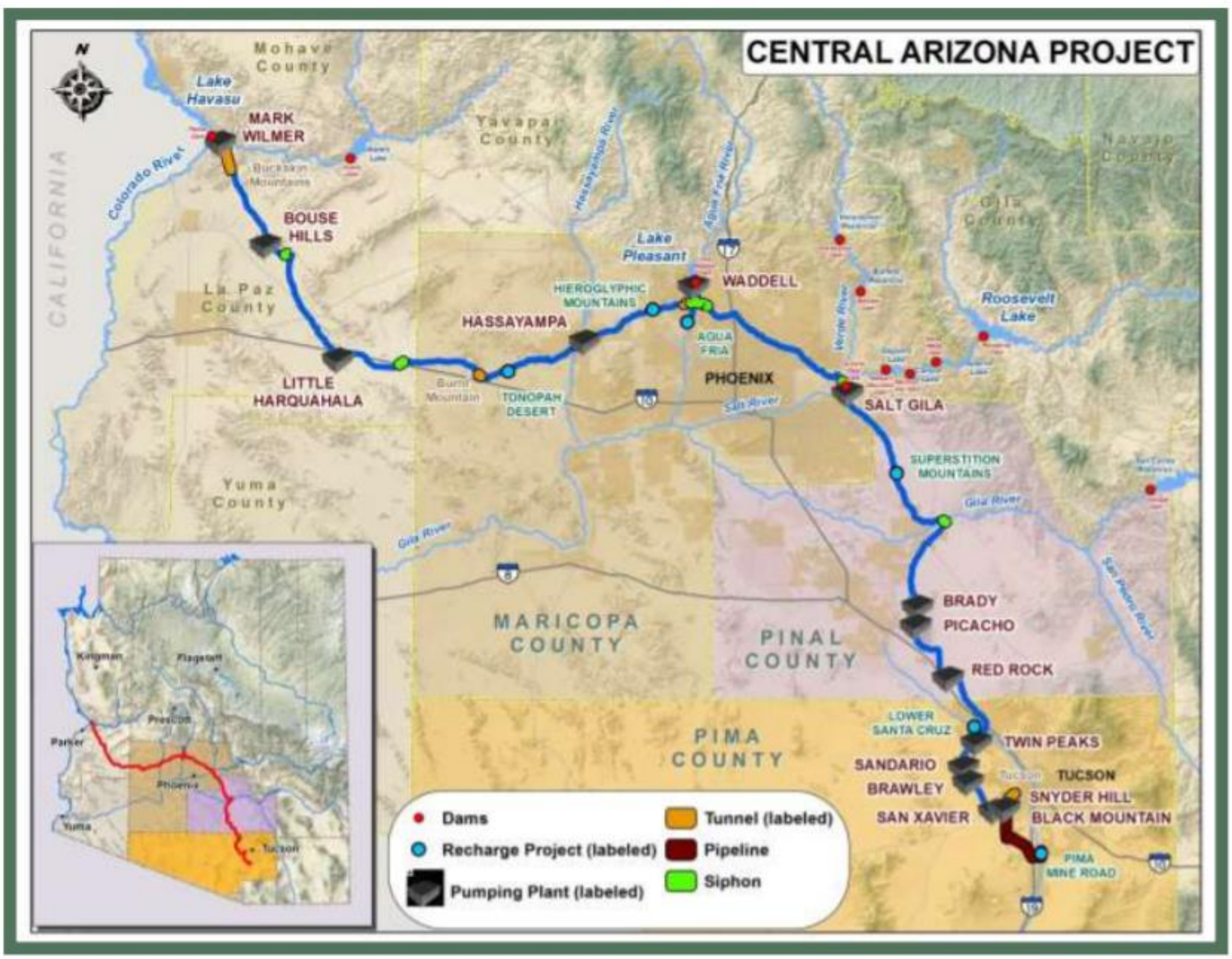
May 2nd, 2019

Abstract

Irrigated agriculture is essential to agriculture in the desert Southwest. Although the soils are arid and low in organic matter, a large portion of the Desert Southwest is used for agriculture. Arizona contains around 900,000 acres of cropland and Yuma, Arizona provides nearly 90% the leafy green vegetables (iceberg lettuce, spinach, etc.) to the rest of the United States in the winter months. The frequency and intensity of droughts in the western half of the United States is increasing. These changes require solutions to preserve resources, especially water. The growing intensity of droughts and structural deficits in the Colorado River Basin require stakeholders and governments to come together. In early 2019, the Arizona legislature authorized the director of the Arizona Department of Water Resources to sign onto the Lower Basin Drought Contingency Plan (LBDCP) to decrease chances of a Colorado River shortage declaration. This plan reduces the amount of CAP water that Central Arizona farmers depend on. Several management options for Central Arizona farmers are discussed in response to the LBDCP. To describe the reactions to the recent change in Colorado River availability, five interviews were conducted from members in the agricultural community in Central Arizona. Pinal County farmers in South-Central Arizona will be greatly impacted by Colorado River water shortages. The perspective about the soil-water connection from a large-scale agriculture producer is shared by Ron Rayner, winner of the 2018 Farm Press/Cotton Foundation High Cotton award in the Western Region. Rayner shares his success in water management using a minimum-till crop rotation method of growing cotton and wheat in Goodyear, Arizona. Small-scale producer Vicki Silvera shares her perspective about Arizona's water situation and her mixed crop-livestock system of farming at Blue Sky Organic Farms in Litchfield Park, Arizona. Alberto Diaz, an agronomist by training and agronomic consultant with TAB Ag Group, LLC., explains the common concerns he hears from farmers around the Phoenix valley and Pinal County. Lastly, Dan Thelander of Thelander Farms in Pinal County shares his concerns and the decisions he faces. The farming practices that can reduce the impact of the future water shortages are discussed including increasing the efficiency of irrigation, crop choice and rotation, minimum-till, and soil management through cover cropping and organic matter inputs. This paper will discuss policies that will affect the farmers as well as the options for water conservation methods.

Introduction

The Colorado River drives the economy of Central Arizona. The Central Arizona Project (CAP) delivers Colorado River Water from Lake Havasu to the central and southern portions of the state, actualizing the Five C's of Arizona. The water allows for intensive agricultural systems and large-scale mining operations. Three of the five C's are directly related to agriculture: cotton, citrus, and cattle (Dewalt 2014). Central Arizona's agricultural water will be the first sector to lose its share when a river shortage occurs. This water is the lowest priority of the Central Arizona Project's allocations. The Central Arizona Project has the junior priority of the Colorado River water allocations for Arizona, which means it will be the first to be surrendered in times of river water shortage (USBR 2019). With the predicted hotter, drier climate, the states within the Colorado River Basin had to design a plan to mitigate a shortage declaration. This paper evaluates the policy changes of the Lower Basin Drought Contingency Plan (LBDCP) and its impact on Central Arizona Agriculture.



"The CAP System"

Source: Central Arizona Project

Background

The farmers within three of Arizona's five active management areas (AMAs) have been using a combination of water sources including CAP water, groundwater, and surface water. The Phoenix, Pinal, and Tucson active management areas have 180,000, 230,000, and 30,000 acres of irrigated agriculture, respectively (USDA 2012). Across the state, the number of irrigated acres has decreased since the 1980's (Lustgarten & Sadasivam 2015). While agriculture in Arizona benefits from the ability to produce year-round, the supply of water must be strategically managed. Prior to the CAP, the Central Arizona agriculture sector was pumping groundwater at a rate greater than the groundwater was being replenished. This leads to land subsidence and fissuring, which are mostly irreversible (Moran et al. 2014). In the 1980's, the CAP offered a valuable, albeit short-term, solution to continue irrigated agriculture without the unsustainable groundwater over-drafting. Civic leaders claimed the CAP would improve the agricultural financial welfare. However, economists critiqued the water delivery system; Young and Martin (1967) and Barr and Pingry (1977) predicted that the future prices of CAP water would be higher than expected. The civic leaders claimed that the CAP would provide many benefits; these benefits quickly switched to a problematic situation as the farmers could not afford the original contracts for the CAP water. In the 1990's, irrigations districts began to file bankruptcy and the State of Arizona needed to come up with a plan to preserve its vulnerable agricultural sector. The State created a new, short-term plan to free the farmers from their original CAP contracts and receive CAP water at fixed rates until 2003 (Hanemann 2002). After that, the Arizona Water Settlements Act of 2004 was created to establish the repayment system for the CAP. Through this agreement, the Agricultural Settlement Pool was established, originally allowing the excess left after municipal and tribal sectors, or about 400,000 acre-feet of water per year, to be designated for non-Indian agricultural users until 2017. The plan was to decrease the allotment to 300,000 acre-feet per year in 2017 and decrease the allotment a second time to 225,000 acre-feet per year between 2024 and 2030. The agricultural sector pays the Pumping Energy Rate 1 for the water they use. In 2006, the Pumping Energy Rate 1 was expected to increase. The increase in energy cost would mean farmers need to pay more for the CAP water. The increased cost could lead to farmers switching to groundwater pumping to meet their irrigation needs because it would be cheaper than CAP water. CAWCD created the Agricultural Incentives Program in order to keep agricultural users from switching to groundwater pumping as energy costs increased. The Agricultural Incentives Program was established in 2009 to reduce the cost of using CAP water for farmers ("Agriculture and the Central Arizona Project," 2016). There are three goals in the incentives program: Agricultural settlement pool utilization goals, Arizona Water Banking Authority (AWBA) & Central Arizona Groundwater Replenishment District's (CAGRD) Groundwater Savings Facility goals, and the CAP recovery goals. Agricultural CAP water users who meet these goals can decrease their irrigation water cost. (CAP Board of Directors, 2016). The purpose of the Agricultural Incentives Program was to encourage the agricultural sector to use Colorado River water delivered by the CAP rather than the groundwater. This would allow the Arizona Water Banking Authority and the Central Arizona

Groundwater Replenishment District to use the aquifers for their own water storage needs ("Agriculture and the Central Arizona Project," 2016). This plan was a relatively short-term fix for farmers within the irrigation districts that signed into the agreement.

While the financial turbulence between farmers, CAWCD, and the United States ensued, the supply of the Colorado river basin was decreasing due to structural deficit and an ongoing drought (Cooke 2015). The contractual rights of the Arizona Water Settlements Act of 2004, which require certain amounts of Colorado River water to be delivered each year through the CAP, ends in 2030; the plan optimistically emphasized the best-case scenario where physical water in the Colorado River Basin is available each year. The 2007 Interim Guidelines for the Operation of Lake Powel and Lake Mead laid out shortage scenarios that depend on the level of Lake Mead. The guidelines required reductions from each of the Lower Basin States according to the severity of the shortage. The scenarios are referred to as tiers one, two, and three (Colorado River Interim Guidelines… 2007). The agricultural pool is a portion of the excess CAP water, which will be the first to lose its share of Colorado River water if Lake Mead levels decrease into the Tier 1 scenario (Orme 2019).

As Lake Mead levels continued to fluctuate near the level of shortage declaration, a new plan was created to increase Lake Mead's water levels to extend any shortage declaration into the future. This plan is titled the Drought Contingency Plan (DCP). The DCP includes mitigation plans from both the Upper Basin states (Colorado, New Mexico, Utah, and Wyoming) and the Lower Basin states (Arizona, California, and Nevada). As mentioned previously, the best-case scenario of the Arizona Water Settlements Act of 2004 for the period between 2017 and 2023 allows for 300,000 acre-feet to be delivered each year. The Lower Basin Drought Contingency Plan (LBDCP) changes this allocation, requiring a 192,000 acre-feet reduction of Arizona's Colorado River water allocation when the Lake Mead elevation is below 1090 feet in addition to the preceding reduction requirements in each shortage tier in the 2007 Interim Guidelines (see Figure 1). The purpose of the LBDCP is to reduce water usage in the lower basin states to store more water in Lake Mead, thus slowing the potential reductions in the near future when there is a shortage declaration on the Colorado River. The 192,000 AF reduction of CAP water greatly impacts farmers, specifically those in the two districts that heavily depend on CAP Water: the Maricopa-Stanfield Irrigation & Drainage District and the Central Arizona Irrigation and Drainage District. The farmers will need to convert to groundwater as their main source by the time the proposed delivery of mitigation water becomes unavailable to them (Orme 2019). The further reductions will still be required if the Lake Mead water level lowers; the LBDCP is not the final solution but rather a way to extend the amount of time needed for future drought planning. Sarah Porter, director of the Kyl Center at Arizona State University, shares her optimism toward the plan, "Overall, I believe the state is better off for the stakeholders having arrived at a deal that enabled Arizona to sign on to the [Drought Contingency Plan], chiefly because it provides the Lower Basin states and Mexico a means of conserving water in Lake Mead to keep the system functional". From the farmers perspective, the LBDCP pushed the CAP reductions on the farmers seven years earlier than was declared in the Water Settlements Act of 2004. Ron Rayner of Tumbling T Ranch in Central Arizona explains that the farmers "expected that they could go back to groundwater, but the Drought Contingency Plan thrust it on them earlier than they expected". The LBDCP will allow farmers receive 105,000 acre-feet of Colorado River water until 2022. Then, the farmers will receive 70,000 acre-feet of groundwater each year between 2023-2026. The periodic reductions are to give farmers time to shift their water sourcing to back to groundwater. The plan also provides the farmers with $5 million to cover the costs of groundwater pumping wells and construct water delivery systems. But farmers want even more (Fischer 2019). If the farmers switch to using groundwater, there will be the potential for groundwater overdraft and eventually the use of groundwater for agriculture will become unsustainable; the Pinal AMA has a goal to continue agriculture production within the AMA for as long as it can sustain (A.R.S. § 45- 562(B)).

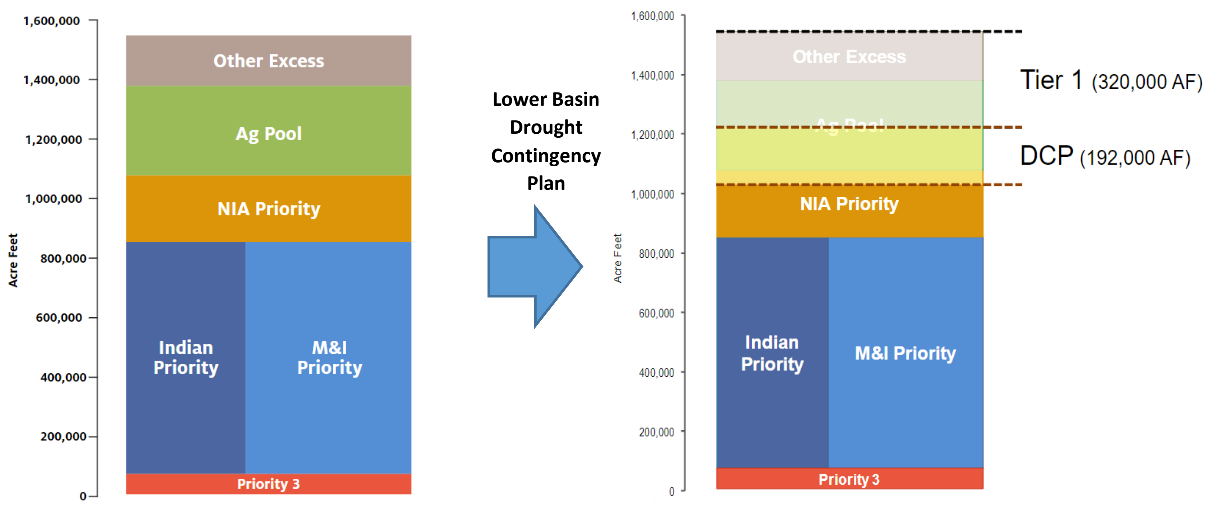


Figure 1: Central Arizona Project priority pools and the water reductions proposed in the LBDCP.

Methodology

Peer-reviewed literature about drought-resilience and forthcoming technologies were included in the compilation of research. Information gathered from speakers in Dr. Sharon Megdal's Spring 2019 Water Policy Class at the University of Arizona was used to provide policy history. Recent articles about the Drought Contingency Plan were included to preview the opinions of farmers and stakeholders. In addition to publications, presentations, and new articles, five interviews were conducted with farmers, agronomists, and university researchers. The purpose of the interviews was to gather the opinions on the matters regarding the LBDCP from multiple points of view. Three farmers shared their histories and thoughts on the future. Dan Thelander is a farmer that is directly affected by the LBDCP. He shares his concerns and optimism about the next few years of farming in Central Arizona. Ron Rayner, a farmer in Goodyear, Arizona, has a well-managed farming system that cuts down on the irrigation volume as well as overall agricultural inputs in his fields. Vicki Silvera of Blue Sky Organic Farms shares her farm's techniques for sustaining agriculture in the desert by focusing on soil health.

Alberto Diaz, an agronomist from Central Arizona, gives recommendations on where we should focus research to benefit both farmers and the economy of Central and Southern Arizona. Sarah Porter, the director of the Kyl Center for Water Policy at Arizona State University, explains the research initiatives that are underway at the university which involves stakeholders all around Arizona. Each interview was conducted in April 2019.

Results

Several options exist for the farmers of Pinal County to extend the lifetime of their farms. Farmers. Ron Rayner explains that there are a few key elements about the water issue. The first element is simply the cost; people will stop farming if the cost is too high. The LBDCP provides a certain amount of funding to the farmers that are facing CAP water reductions. The funding is intended to be used for drilling wells to shift to groundwater for their irrigation needs (Fischer 2019). These farmers are facing decisions about which aspects of their practices can be altered to decrease their water use. While allowing a field to fallow for a crop rotation can be beneficial for the soil fertility (Sarmiento 1995), crop yields (Tian et al. 2005), and pest management (Lopez-Lima et al. 2012), farmers in Pinal County are fallowing fields to reduce the costs of water (Mendoza 2018). Fallowing the fields that provide the alfalfa and silage for the Arizona and California cattle industry will be detrimental to the beef and dairy producers as the cattle ranchers will need to import their cattle feed from elsewhere. Pinal County's agriculture and related activities generated roughly $2.3 billion in sales in 2016 (Bickel et al. 2018). Losing an impactful farming community would cost more than just the local livelihood. To adapt the agricultural systems of Central Arizona to the predicted drought conditions and water shortages, a few options are available to farmers looking to keep their field in production. The options include improving their irrigation efficiency, growing drought-tolerant crops, practicing a minimum-till system, and enhancing their soil structure. Each farm is different and will benefit differently from each option, so it is imperative that the farmer evaluates the advantages and disadvantages of each option and which will work best in their system. Fortunately, extension services from universities offer support for making these changes.

Improve Irrigation Efficiency

Arizona's agricultural sector is highly dependent on irrigation. The majority of Central Arizona's irrigated acreage uses gravity irrigation, also referred to as flood irrigation. This method of irrigation is normally thought of as wasteful and inefficient (Lehr 1983; O'Mahony 2017). However, for the farmers that do not have the financial means to convert to other methods of irrigation, improvements to their gravity irrigation are possible. There are steps that farmers can take to improve the efficiency of their gravity irrigation system. First, laser leveling fields can dramatically improve the irrigation efficiency (Howell 2003). A comprehensive study about Yuma, Arizona defines irrigation efficiency as "water used by the crop consumptively (ETc) relative to that applied to the crop" (Frisvold et al. 2018). Gravity-flow systems in Yuma have improved and Yuma was able to change their cropping systems from perennial and solely summer crops to multi-cropping systems that include a winter growing season. First, nearly 44,000 acres were leveled to increase the water infiltration into soil. Next, farmers focused on their irrigation management; crops yields would decrease if over-irrigated just as they would if there was insufficient irrigation. The farmers needed to irrigate with a precise volume of water and be conscious of the timing to improve the irrigation efficiency. Specific multi-cropping systems also helped to increase the irrigation efficiency in Yuma.

The 2013 Farm and Ranch Irrigation Survey performed by the USDA ERS (2017) reached out to Arizona's 4,380 irrigated farms to understand what barriers exist when improving their irrigation systems. The results are compiled in Table 1. The farm's lack of financial ability was number one reason that farms were not improving their irrigation systems.

Reason	Number of Farms
Investigating improvements not a priority	1,099
Lack of financial ability (even if improvements reduce costs)	1,209
Risk of reduced yield or poorer quality yield from not meeting water needs	269
Physical field/crop conditions limiting system improvements	436
Improvement installation costs greater than benefits	560
Will not be farming the farm in the near future	243
Lack of landlord participation in cost-sharing irrigation improvements	297
Uncertainty about future water availability	598
Improvements will increase management time or cost	142

Table 1: Data adapted from the USDA ERS: Irrigated Agriculture in the United States Set 15. Barriers to irrigation system improvements. Source: USDA ERS

Drip irrigation is method of irrigation that is generally more water-use efficient than other irrigation methods. Back in 1976, The Wuertz family at Sundance Farms in Coolidge, Arizona began testing the advantages and disadvantages of using surface drip irrigation in their sugar beet fields. They concluded that drip irrigation had "tremendous potential" after they found that it doubled their Yield to Water Use Ratio. The Wuertz family decided to make their drip irrigation more user friendly. The created a subsurface system that would allow for running tractors over the fields (Wuertz 2001). With drip irrigation, the chances of losing unused water to evaporation and run-off are much lower. Switching to drip irrigation requires quite a bit of planning. The crop water needs must be continuously monitored and maintenance costs can add up. The initial installations costs are high; Jeffrey Silvertooth told Cronkite News that the transition from flood irrigation to drip irrigation can cost a farmer $1,500 to $2,000 per acre with ongoing operation and maintenance costs (Medoza 2018). The economic benefits of transitioning to drip irrigation were studied by Luhach et al. (2004). Drip irrigation and sprinkler irrigation had higher net present values, internal rate of returns, and benefit cost ratios in several agricultural systems involving guar, wheat and cotton.

A study from 2000 in Marana, Arizona compared the water-use efficiency of drip irrigation and furrow irrigation for one growing season of cotton (Norton & Silvertooth 2001). The drip irrigation also allows for fertigation, which is a fertilization method that incorporates liquid fertilizer into the irrigation water. The conclusion of the study found that the furrow irrigated fields used about 60 acre-inches of water and the two drip irrigated fields use less than 30 acre-inches of water. The crop response was also in favor of the drip irrigation method despite receiving roughly half the irrigation volume. While one of the drip irrigated fields had a lint yield similar to the furrow irrigated field at about 1,500 pounds per acre, the second drip irrigated field had a lint yield of 1,700 pounds per acre. The calculated water-use efficiency of the drip irrigated fields was more than twice as high as the furrow irrigated field. Although this is just one example of an irrigation method comparison and the experiment was only observed for one year, many similar examples exist.

Vicki Silvera at Blue Sky Organic Farms in Litchfield, Arizona says her farm uses sprinkler irrigation to reduce water use. At its inception in the early 1990's, the farm was one of few farms in the region that did not use gravity irrigation in their fields. Blue Sky Organic Farms uses both CAP water and groundwater. Although Blue Sky Organic Farms will not lose their CAP water share, they do what they can to reduce water use. The method of sprinkler irrigation uses more energy than gravity irrigation to provide the system with enough pressure. In terms of water use, an accurate and well-designed sprinkler system can reduce water use (Zou et al. 2013)

Drought-Resistant Plants and Crop Rotation

Ron Rayner describes another key element to the water issue: Central Arizona farmers want to keep farming. Many are willing to make the switch to viable crops. As an example, many California farmers are planting high value crops; they are investing their time in nut trees including pistachios, almonds, and pecans as well as grapes for wine and raisins rather than low value annual crops. They are doing it because as the water cost increases, they want their higher value crop to make up for the high water cost. Rayner also mentions that California cattle farmers buy hay that is grown in Arizona because California is growing less of their own alfalfa. These California cattle farmers are suffering from low dairy prices; they are going out of business.

Hopi farmers have proven us that dryland farming is not impossible. Each year, the Hopi farmers plant their corn along alluvial flood plains and use seasonal rainfall as their water source. Future climatic shifts could harm their agricultural systems as well (Ferguson et al. 2017). The main crops produced in Central Arizona are not drought-tolerant and, in fact, use quite a bit of irrigation water. These crops include cotton, wheat, and alfalfa (although cotton can tolerate dry conditions considerably well) (USDA 2018; Thelander 2019). Several options are available to farmers willing to change their crop choice. Scientists at the University of KwaZulu-Natalin in South Africa are breeding wheat specifically to be drought tolerant (Mwadzingeni et al. 2016). Additionally, the Arid Lands Research Center in Tottori, Japan aims to increase the water-use efficiency of the wheat. Their method of genetically modifying the wheat has been successful; their findings are indicative that other crops can undergo the same method of genetic modification to increase water-use efficiency (Mega et al. 2019). However, innovations like these examples take time to perfect.

Dan Thelander of Thelander Farms in Pinal County is working in collaboration with tire producer Bridgestone Americas, Inc. to produce natural rubber from guayule plants. The USDA National Institute of Food and Agriculture granted funds to Bridgestone Americas Inc. to establish a source of rubber that is sourced from within the United States. Currently, the largest source of natural rubber comes from a single source and can be diminished by disease and pests. The goal is to increase the sources of natural rubber to avoid losing the material altogether ("Plant to Produce Rubber…" 2019). Dan Thelander has grown guayule for about six years. This year, Thelander has 220 acres of cotton and alfalfa, 700 acres of silage, and the 45 acres of the guayule for the collaboration. Where he planted had corn in 2018 they now have guayule, a drought-tolerant flowering shrub that is native to Southwestern United States. Guayule uses about half the water that alfalfa uses. Additionally, no pesticides or fertilizers need to be applied. The plan for the guayule is to grow for 6 years total and every two years the plants are harvested. This means there is no annual cultivation. The guayule plants will regrow after harvest as long as they are harvested in cooler weather as opposed to a summer harvest. Six years of guayule that does not require replanting is economically desirable because the transplants for guayule are expensive. This year, Thelander decided to try to establish the guayule from seed. He says it may be cost prohibitive to only use transplants. Bridgestone Americas Inc. tire production facility in Mesa, Arizona, plans to use the guayule that Thelander grows as their natural rubber source for car tires. According to Thelander, the natural rubber offers desirable characteristics that are preferred over synthetic rubber. Regarding the potential water shortage, Thelander says "it is going to be a challenge, but you got to be optimistic". If the guayule takes off, he will still grow alfalfa and corn silage because having crops in a rotation is always preferable; the nutrient cycling and pest management benefits cannot be underestimated (Stoner 2012; Rangarajan 2012). "We will always be looking for other crops" says Thelander.

Dan Thelander comments that many people have asked him why he does not plant a lower water-use crop. He explains that alfalfa uses about 5.5 acre-feet while barley uses less than 3 acre-feet. However, if he grows just one acre of alfalfa, he will earn more profit from it than two acres of barley. The demand for alfalfa is high in Arizona. Cattle in Central and Southern Arizona will always need feed and it makes logistical sense for them to buy it locally.

Minimum Tillage

Tillage reduces the water-holding capacity of soil in two ways. First, the soil compaction caused by heavy tractors can decrease the soil's ability to retain water and the water infiltration rate. Abu-Hamdeh (2004) found that the water infiltration rate decreased as the axle load increased. Second, the presence of soil organic matter can increase the water-holding capacity of soil. Williams et al. (2016) compiled 14 years of soil and weather data from the Midwestern United States to present the relationships between maize yield and soil organic matter. The Midwest is known to have a continental climate with cool winters and warm, humid summers. The research found that there was less 'volatility' of the annual yields in soils with greater organic matter content, even during the drought years. Digging deeper into the mechanisms behind the stable maize yields, the researchers found that the soils with greater moisture retention had higher levels of soil organic matter; the extra organic matter plays a major role in maintaining yields throughout periods of drought. How do Arizona soils compare? The arid soils contain little soil organic matter with little capacity to retain water (Rasmussen 2006; "Soil Water Holding Capacities…" 2001). Ron Rayner of Tumbling T Ranch in Goodyear, Arizona has been practicing minimum-till agriculture for decades. He says "the key element to planting no-till is to leave the plant residue from the previous crop. That's the primary element". His practice involves leaving the standing wheat residue after harvest and planting the cotton directly into it. His crop rotation includes alfalfa, wheat, and cotton. The leftover crop residue increases the soil organic carbon, which is like a sponge for water. Rayner collaborated with The University of Arizona College of Agriculture and Life Sciences to quantify the effects of minimum-till. He saw a reduction in water-use early on that has continued (Adu-Tutu et al. 2003). An effect of leaving the residue in the field is that the field stays cooler than a conventionally tilled field (Wang et al. 2013). While fields in cooler, wetter agro-climate zones may find decreased crop establishment from the 'cooling effect' of minimum-till (Halvorson et al, 2006). However, Rayner's arid Southwest fields are reaping the benefits. Paul Brown, a scientist at the University of Arizona studied the temperature differentials, confirming that Rayner's fields are cooler. This causes the plants to have lower evapotranspiration rates; the crops require less water because the evaporation rate is lower. The temperature is so much lower that Rayner needs to shift his growing season forward into the spring; he plants cotton later than conventional cotton because additional warmth from the succeeding season is required.

Proper management of the minimum-till systems is required for success; Rayner mentioned that it took several years of trial and error to create the successful system. Rayner's farm also participates in a conservation agriculture program that requires producers to follow three premises for sustainable agriculture. The first is to disturb soil to the least extent possible. The second is to achieve ground cover to greatest extent possible using residue and cover crops. The third is to use plant associations that are beneficial to each other, meaning strategic crop rotations.

Further Adapt Agricultural Soil

There is a relatively new effort to increase the organic matter content in soil to improve the soil health and increase the amount of water the soil can hold. Soil organic matter is also referred to as soil organic carbon (SOC). A benefit of minimum-till farming that is mentioned previously is the natural increase in SOC. In addition to minimum-till, farmers can add organic matter in the forms of biochar and compost to improve the soil's ability to hold onto water

(Basso et al. 2013). Biochar and compost are two organic materials made from recycling organic waste. A study in Sri Lanka found that adding compost or cow dung or both to soils with coarse textures had the greatest increase in soil water-holding capacity (Vengadaramana 2012). A study in Germany observed the increase in soil water-holding capacity after adding biochar to sandy soil (Abel et al. 2013). Similarly, a study in arid Western Australia added biochar to wheat fields with various amounts of fertilizer. The wheat yield with in the biochar plots had higher yields than the plots with the fertilizer alone. The combination of increased soil moisture and nutrient retention from the biochar benefits the wheat growth (Blackwell et al. 2010) The widespread quantification of the effects of organic wastes used as agricultural organic matter inputs indicates that organic matter inputs have the potential to benefit many agro-ecosystems. This is especially relevant to the arid Southwest where soils in the agricultural regions are predominantly coarse textured.

The application of soil amendments and soil conditioners to increase the water-holding capacity is unrealized in the desert Southwest as many farmers may be expecting to end their farming practices before the inputs pay off (recall the results of the 2013 Farm and Ranch Irrigation Survey in Table 1. regarding investments in improved irrigation efficiency). For most, incorporating these inputs is too expensive to provide an economically feasible route; the farmer’s year-to-year budget is too tight to change a practice that may end in any year. Alberto Diaz, an agronomist from Maricopa County in Arizona, explains that a farmer’s budget does not allow room to take risks and the lack of research on organic matter inputs like biochar in arid soils is not sufficient. One application of biochar to soil persists for hundreds to thousands of years while acting as a soil conditioner (Lehmann et al., 2015; Sohi et al., 2010). Although biochar is a one-time application, the high price can be cost prohibitive. The cost to add the biochar product to a field at the recommended rate of nine tons per acre is around $1,700 per acre, not including shipping. Diaz says the farmers want to focus on increasing the limiting nutrients, such as phosphorus, to maximize yield. Supplying more of a limiting nutrient will maximize yields. In short, the farmers would like to see more benefits in their fields beyond saving water.

Fortunately, current studies are proving multiple benefits to crop viability and nutrient retention that organic matter applications can provide. Recent research uses soil organic carbon to increase the fertilizer-use efficiency and decrease fertilizer loss, similar to the behavior of water (Laghari et al. 2015; Zhang et al. 2017). The organic matter additions can act as a long-term food source for soil microbes (Lehmann et al. 2011). These microbes consume the organic matter and produce natural chemical byproducts as well as plant available nutrients. These byproducts are called extracellular polymeric substances (EPS) and act like a sponge for water. EPS improves soil structure, thus improving soil fertility and crop production (Chenu & Roberson 1996; Colica et al. 2014).

A study in the Netherlands titled “What drives farmers to increase soil organic matter” included a survey of the farmers. The results showed that 90% of the farmers had intentions to increase the organic matter in their soil (2018). The benefits of organic matter are well-known in the Netherlands; the Southwest U.S. is slower to embrace these organic matter inputs. Vicki Silvera says Blue Sky Organic Farms grows cover crops and tills them into the soil to increase and maintain the levels of organic matter in their soil. Additionally, they utilize compost that is created on-site to increase the organic matter, as well.

Recommendations

Amundson & Biardeau (2018) produced a list of policy and economic challenges that farmers face when deciding if and how to increase the carbon content in their soil. They indirectly mention inputs like biochar and compost and cultivation practices like minimum-till and cover cropping. A factor in their paper that is not mentioned often in other literature is that many farmers rent their land. Their discussion begins with identifying the challenges that arise from how land is managed; in 2012, 40% of the 915 million acres of agricultural land in the U.S. was rented. The 2012 Census data also showed that only 13% of the landowners actually farm or ranch on their own land. The other 87% of land owners rent their land (USDA NASS, 2012 Census of Agriculture). To encourage long-term soil health improvements, there are incentives such as the Environmental Quality Incentives Program that offer financial assistance to farms that meet certain criteria with sustainable practices similar to the conservation program in which Rayner participates.

My first recommendation for legislature is to create a program that funds the implementation of a plan to increase soil organic matter in the farmer's fields. The farmers can create a plan and apply for the funding. Opportunities to apply for funding may work better for farmers than an incentives program. This is because incentives programs can praise farmers that have the financial ability to make changes while farmers without the financial means to make changes will not have the opportunity to earn the incentives. The plans can include requests for the capital costs of methods like incorporating biochar into their soil or purchasing tractor attachments for producing compost on-site. The plans could also request funds that act as crop insurance for the errors that come with practicing minimum-till.

My second recommendation is for farmers to meet with each other and university extension services to spread knowledge about successful methods of increasing irrigation efficiency. Ron Rayner has two field days a year to invite university extension employees and neighboring farms to share advantages and disadvantages of his minimum-till system. Table 1 shows that a large number of farmers share their opinion that "investigating improvements is not a priority". Farmers will benefit from other farmers and extension personnel that have done the investigating for them. Sometimes new technologies and practices sound too difficult to implement, so having experts available to help will improve the likelihood of adopting the new practice with success.

Conclusion

The Lower Basin Drought Contingency Plan directly affects the agriculture sector of Pinal County. With agriculture as the main driver to Pinal County's economic prosperity, it is desirable to continue their agricultural operations for as long as possible. The current options that exist for the farmers of Pinal County to extend the lifetime of their farms including improving their irrigation efficiency, crop switching and rotation management, reducing tillage, and utilizing soil inputs that increase the water-holding capacity of the agricultural soil. "I see the [Drought Contingency Plan] as a major step toward adaptive management of the Colorado River system as well as managing with less Colorado River water" comments Sarah Porter. Ron Rayner knows how well the farmers avoid wasting their water, he says "In an area wide system, people pick water up and reuse it and reuse it and reuse it. I'd say we are maybe more like 80-90% efficient. I'm not letting water go by my farm". The Colorado River Basin states have been working hard to manage the water and will keeping planning for future changes. The predicted water quantity in the Colorado River Basin is a moving target and each stakeholder must be included in the future planning.

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