2023

Arroyo

ARIZONA'S AGRICULTURAL OUTLOOK: WATER, CLIMATE, AND SUSTAINABILITY

Authors: Luke Presson and Susanna Eden
Layout: John Polle
Executive Publisher: Sharon B. Megdal
Cover Photo: David Quanrud - Chasing a Rainbow, Sulphur Springs Valley, AZ, 2010

INTRODUCTION

Arizona's development has been dominated by the five Cs—copper, cattle, cotton, citrus, and climate—three of which are products of agriculture. However, the cultural and economic contributions of the agricultural industry have declined with the increase of urbanization and economic diversification. Climate conditions and ongoing drought pose additional challenges to farmers. A megadrought has persisted in the western states for more than 20 years, resulting in a dangerous drop in available water storage. As drought forces difficult decisions on water use, food security — assured access to sufficient safe and nutritious food — is emerging as a key concern. Given these conditions and ever-increasing needs for food and fiber, what is Arizona's agricultural outlook? This *Arroyo* aims to address this question by focusing on how the state can adapt to a new climate reality and sustain the agricultural productivity and culture that has defined the character of the state for so long.

With water shortages in the Colorado River, policymakers and stakeholders are looking for every opportunity to increase water efficiency and decrease water use. Urban areas have been implementing successful conservation measures, but continued population growth still raises concerns about

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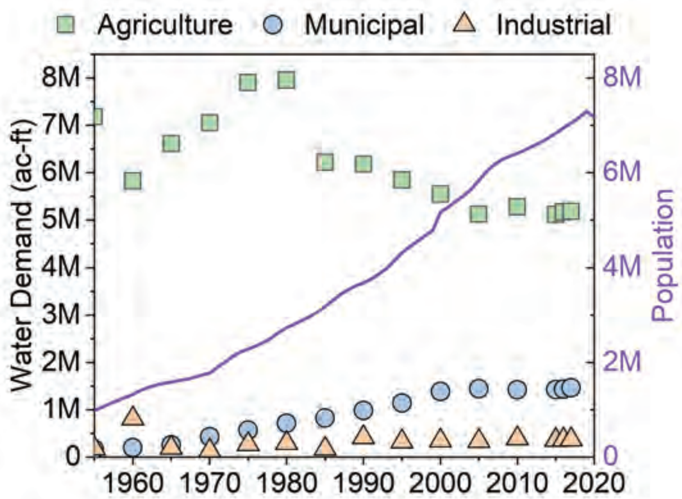
Cooperative Extension, University of Arizona
350 N. Campbell Ave., Tucson, Arizona 85719; **Phone:** 520-621-9591
Email: wrrc@arizona.edu; **Website:** wrrc.arizona.edu

rising water use. Although irrigated agriculture in Arizona improved its efficiency, it still accounts for roughly 72 percent of the state's water use. For this reason, it continues to receive attention as a potential source of water for other uses. With such a



Yearly water demand by sector and population in Arizona.

large portion of the state's water budget, agriculture likely will have to absorb a large share of any cuts in Arizona's water supplies, beyond the large cutbacks that central Arizona agriculture already has suffered from mandated reductions associated with the agreements that apportion Colorado River shortages. However, given agriculture's significant economic, social, cultural, and historical value, water management decisions affecting farming and ranching must be weighed carefully.

In summer of 2022, the WRRC's annual conference, *Arizona's Agricultural Outlook: Water, Climate, and Sustainability*, highlighted the diversity of the state's agriculture. Several topical themes emerged, including interactions between water and land use, adaptation to a new water regime, and sustainable agriculture.

To better capture the insights into Arizona's agricultural landscape and outlook that were shared during the conference, this *Arroyo* has a new structure. It first presents a summary of the discussions around the three above-mentioned themes and then directs readers to relevant factsheets to learn more about specific topics.

ARIZONA'S AGRICULTURAL DIVERSITY

Arizona's agriculture industry is diverse. According to the most recent US Department of Agriculture census (2017), 19,086 farms operated in the state, and most of them—nearly 74 percent—were smaller than 100 acres. Of these small farms, 84 percent were owned by individuals or families with sole ownership. Of producers in Arizona, 59 percent were indigenous farmers and 47 percent were women.

The climate in much of Arizona allows for year-round production, making the state critical to the nation's food supply during winter months. For example, the lower Colorado River Valley in the Yuma area, stretching into the Imperial Valley of California, grows 90 percent of the nation's leafy greens from November through March.

Some of the most valuable among the wide range of agricultural commodities produced by Arizona farms are lettuce, cattle, and dairy. Lettuce is a key crop grown in Arizona, responsible for over 16 percent of the revenue from agricultural commodities. Arizona farmers hold an inventory of around 171,000 beef cattle, and the state's dairy cows produce almost five billion pounds of milk yearly. Many varieties of wheat are cultivated in the state, including large quantities of durum wheat, and local bakeries use heritage crops like White Sonora wheat to great acclaim.

There is a strong effort by Native American growers and others to continue growing traditional crops, like corn, beans, and squash, that have been grown in the region for centuries. Indigenous farmers cultivated crops over generations that had

Rows of mature lettuce plants in a field ready for harvest - Arizona.

adapted to the climate, making them critical to sustainable agriculture in the face of severe water shortages.

Additionally, farmers are introducing to the area crops with high economic value and relatively low water use. The state is home to a burgeoning wine industry, as grapes grow well in the arid

A field of guayule in Arizona.
Image: https://sbar.arizona.edu/

climate. The production of guayule, a crop with desert shrub characteristics, long growing cycles, and no need for re-seeding, is in the early stages of development as a long-term crop that can reduce our dependence on imported natural rubber. Some of these newer enterprises face challenges in market development—historical perceptions about the provenance of good wine, for example, can dampen consumer enthusiasm—but the high quality of the product is opening doors.

THEMES

Interactions between Water and Land Use

The high water demand of irrigated agriculture often begs the question, why farm in the desert? The agriculture industry is important for Arizona's economy, despite its relatively small percentage of the state's GDP (about 1.7 percent), and it provides stability for rural communities. Farming and ranching also contribute to the state's culture and tradition, adding value that is hard to quantify. In addition, local food security is related to local sourcing. For example, much of Arizona's demand for milk and cheese is supplied locally. Many people, significantly native communities, aim to rely less on processed foods by increasing the share of food staples produced by local farms.

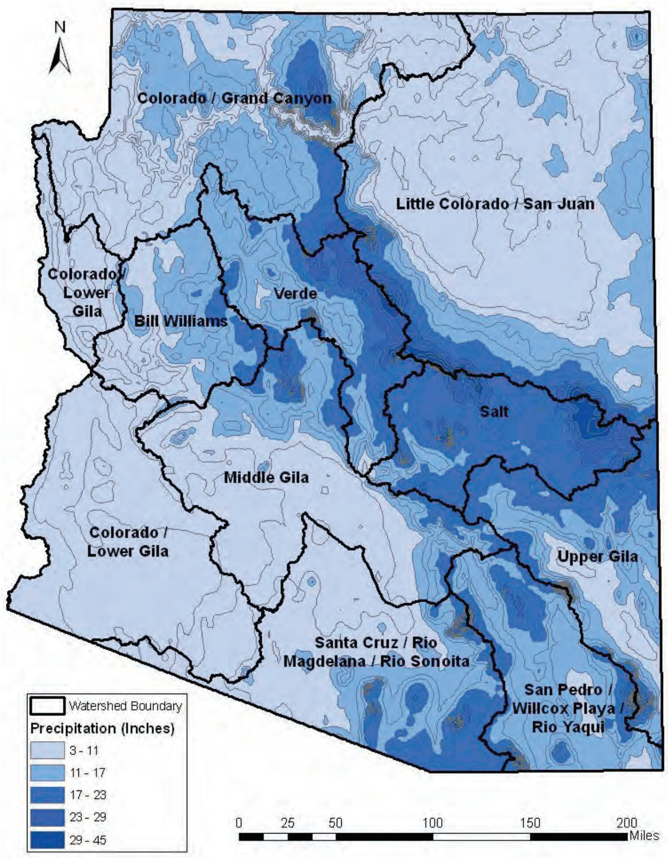
Maintaining land in agriculture also maintains flexibility and adaptability in ways that urban development cannot do. Farmland can be fallowed, a practice in which land typically used for crop production is set aside for one or more cycles. Fallowing allows farmers to restrict water use while keeping the land available for future crops, although it can lead to land degradation through the loss of topsoil and soil fertility. Some crops like alfalfa are often maligned for high water use, but cultivating them makes intermittent fallowing possible, which is useful given water supply uncertainties.

Further, some agricultural land use patterns can contribute positively to desert environments. They can support wildlife and play an integral role as avian flyways. Additionally, healthy agricultural soils can encourage microbial diversity, soil retention, and even carbon sequestration, and farms near urban areas can alleviate some heat island effects.

The agriculture industry has decreased water use in recent decades but still uses more water than other land uses. *How exactly do farms and crops use water?* ***See Factsheet 1 to learn more***. The projected population growth rate in Arizona is double the national average. Pressures of a growing population have resulted in the conversion of some of Arizona's farmland to houses and businesses. Arizona is a desirable place to live and people will continue to move here. Converting farmland with established infrastructure and water uses to residences and businesses may be better water management than developing raw desert, which frequently results in urban sprawl and new water uses. If planned properly, however, smart urban development can benefit cooperating farms. Urban infill and dense communities provide local markets for agricultural products. Cooperative fallowing and water leasing arrangements can generate funds for new equipment that can be used to increase agricultural water efficiency and conservation. Finally, with proper design, regulation, and infrastructure, farms on or even beyond the urban fringe can benefit from agritourism.

Adaptation to a New Water Regime

One of the major themes of the WRRC conference was adaptation; that is, how agriculture in Arizona may change to thrive in the new climate reality. *What is the state of drought and water supply in the region?* ***See Factsheet 2 for details***. Most of Arizona receives little precipitation, and with diminishing river flows and declining groundwater levels, farmers are developing creative approaches. Examples of farms experimenting with new ideas include Oatman Farms, which is embracing regenerative agriculture strategies and exploring new markets to restore farmland and conserve water. BKW Farms is another local producer that has adopted new approaches, including controlled environment facilities in which to grow mushrooms in reusable pails. In fact, cutting-edge technologies like controlled environment agriculture and



Average annual precipitation in each watershed in Arizona. Image: Gregg Garfin

agrivoltaics are gaining attention as they become more economically and technologically viable. *What are these new technologies and their benefits?* ***See Factsheet 3 to learn more***.

Farmers may also adapt by changing which irrigation technologies they employ. *How do farmers in Arizona get water from the source to the plant?* ***See Factsheet 4 for more information***. These technologies can increase the percentage of diverted water used directly for the growth of crops. *But does increased irrigation efficiency always lead to water conservation?* ***See Factsheet 5 to learn more***. Financial barriers, however, may hinder adoption of newer, more water-efficient technologies, especially for the many farms on leased land. Farmers who do not own their fields are unlikely to invest in new infrastructure.

Other significant adaptations to water conservation have been discussed. Electing to plant crops like grapes or guayule that have relatively low water use and high economic value is an option, though undeveloped supply chains and market access often limit adoption. Fallowing fields for one or more crop cycles can conserve large volumes of water, although this practice has an economic penalty. Farmers may be more willing to participate in fallowing programs if incentivized by conservation subsidies or other mechanisms.

Vineyard in Sonoita, AZ.

With these adaptations, protecting public health is critical. Water is often used to clean food and facilities, a practice that must continue despite water cuts. Additionally, as farmers search for and adapt to alternative water sources, maintaining water quality becomes increasingly important. *Reclaimed water is one alternative water source for agriculture.* ***See Factsheet 6 for more information***. There is some concern over the presence of trace organic contaminants in water sources and how they might accumulate in soils or plants. These substances are largely unregulated, as research focusing on them is in the early stages, and methods of dealing with them are relatively undeveloped. Although irrigators are not required to test or treat water for these substances, some do. Better understood, bacteria and other pathogens are a main concern for irrigators, but these can be deactivated and removed by good filtration and disinfection procedures.

Sustainable Agriculture

Ensuring that farming in Arizona remains viable over the long term is critical. Agricultural sustainability includes practices that meet current needs while ensuring the sector continues to thrive for generations to come. Regenerative agriculture, mentioned earlier in this issue, is a broad term concerned with ensuring that lands and waters remain healthy for future generations. One aspect of this approach to sustainability focuses on soil health and methods farmers can use to minimize soil erosion and other accelerants to land decline. Adhering to regenerative agriculture principles is essential to slowing and preventing desertification and the permanent loss of land productivity. *What* *are some ways farmers are improving soil health?* ***See Factsheet 7 for a further description.***

Regenerative agriculture could also be considered a philosophy that encourages practitioners to draw on their imaginations and optimism to form a more holistic food and fiber supply. This philosophy could include encouraging practices that ultimately decrease crop yield but ensure sustainability.

These approaches to sustainability are not necessarily new, and many have been practiced in some way by Indigenous farmers for generations. With an emphasis on land stewardship, practices that native communities use are gaining attention. *What are some examples of these practices?* ***See Factsheet 8 for more information***.

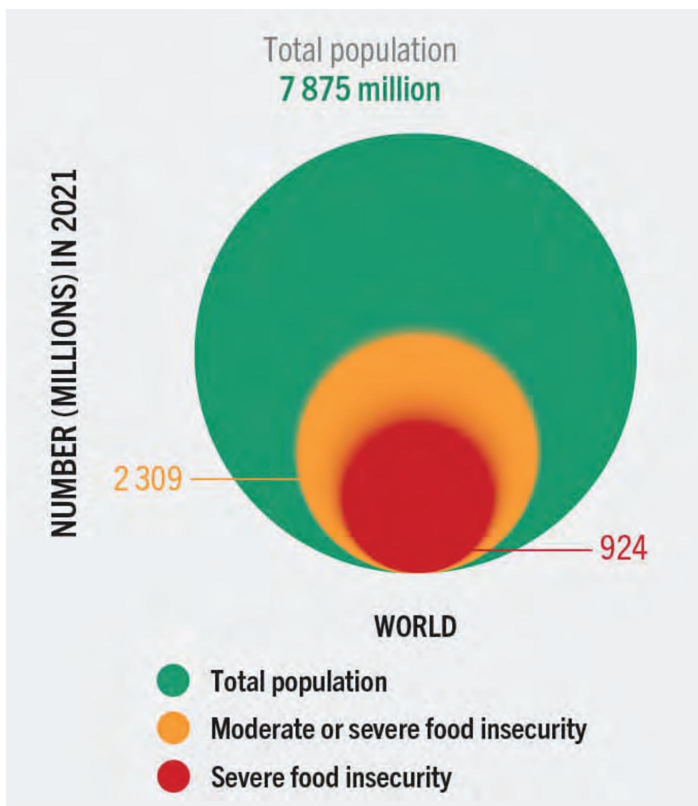
Native voices have much to contribute on philosophical approaches to agricultural sustainability. Being mindful and respectful of crops and ecosystems can affect how farmers interact with the land and inspire more sustainable methods. Discussions throughout the WRRC conference highlighted the idea that growing only within your needs can allow the land to survive and thrive during difficult times. It is increasingly rational to take these approaches seriously; after all, it is no accident that Indigenous communities protect 80 percent of the Earth's biodiversity on only 5 percent of the land.

In Arizona, efforts to improve the local supply chain, limiting waste and increasing product traceability, are supporting an increased focus on local food supply and resilience. The US Cotton Trust Protocol, for example, is an organization and movement that aims to improve the transparency and traceability of cotton from farm to consumer. By prioritizing experimentation, measurement, and data reporting throughout the supply chain, the organization encourages continuous improvements in sustainability, particularly when focused on responsible consumption and production. These approaches are consistent with sustainable development goals espoused by the United Nations. It is estimated that one-third of food produced globally is never consumed due to supply chain inefficiencies. By focusing on these improvements, Arizona agriculture can continue to provide high-quality food and fiber while conserving significant quantities of water.

Sustainability also can refer to the future vitality of agricultural professions. Less water available for agriculture creates concern that farmers will leave the industry and fewer new producers will join. The resulting loss in experience, knowledge, and expertise could have detrimental effects on food security. If increased fallowing and other conservation actions are required, attention will need to be focused on keeping farming economically viable.

Individual growers or the agricultural community can only do so much on their own. Other sectors of society have a role in solving sustainability problems with respect to water and agriculture. This could be a role for government action at the local, state, and federal levels. With increased investments in infrastructure and appropriate regulations and incentives, agriculture can continue to flourish in Arizona. Revenue generated through growth could be directed to sustaining the local food and fiber supply. In fact, significant state investments have been authorized that aim to help farmers conserve water while remaining profitable. Many policy questions and issues remain that well-informed, responsive, and cooperative government partnerships can address. Arizona could implement policies defined through consensus on issues from water quality and reuse to groundwater pumping.

One of the most important discussions on water shortages remains Colorado River water allocations within Arizona and among neighboring states. Interstate negotiations about cutbacks gain



Fraction of people experiencing varying levels of food insecurity globally. Image (cropped): https://www.fao.org/

Center pivot sprinkler irrigation with drip lines is a water saving innovation. Image: https://img.agriexpo.online

urgency as key reservoirs reach critical levels. A drought contingency plan was passed in 2019 and began the crucial process of devising mechanisms to ensure sustainability in the face of drought and climate change. The process of negotiation among the multiple various interests at regional, state, and federal levels is ongoing. Providing incentives may be the most viable and effective method to encourage the deployment of costly but necessary conservation technologies and strategies. Funds for these incentives can come from federal programs like the Inflation Reduction Act (IRA), which contributes significantly to the development of drought resilience. The IRA provides funds for water conservation and projects that mitigate the effects of drought. Some funds are earmarked for disadvantaged communities. In addition, Arizona is investigating water augmentation and committing an unprecedented funding pool for promising strategies.

CONCLUSION

While the trends in water supplies in Arizona are worrying for all water users, including irrigators, the clear-eyed and collaborative approaches offered at the 2022 WRRC conference show promise. With coordination and smart development, land use can be designed in a way that benefits agriculture and urban areas. Farmers are adapting to the new climate reality by testing and installing more efficient irrigation methods, and tests of innovative technologies like agrivoltaics are promising. With less predictability in water availability, some farmers are switching crops to gain flexibility or selecting crops with low water demand. To keep the agriculture industry resilient, many farmers are modeling more sustainable practices. Strengthening and improving the soil through regenerative agriculture and prioritizing sustainability over yields is increasingly important. With influential farmers involved in these discussions and some signs of optimism, Arizona's agricultural outlook remains positive.

Photo: Clayton Lyon

WRRC 2022 Annual Conference Day-1 Agenda

The WRRC 2022 Annual Conference, *Arizona's Agricultural Outlook: Water, Climate, and Sustainability*, was the inspiration and basis for this *Arroyo*. The hybrid conference consisted of one day of live-streamed in-person sessions on July 12, and two days of webinar sessions on July 13-14. The July 12 agenda is reproduced below. To see the complete agenda and link to the recorded presentation, visit the WRRC website at wrrc.arizona.edu or go to ***https://wrrc.arizona.edu/news-events/past-conferences/2022***.

July 12, 2022

Opening Keynotes: Arizona's Agriculture, an Overview

Mark Killian, Director, Arizona Department of Agriculture
Jeffrey Silvertooth, Environmental Science, University of Arizona

Highlight Talks – Part 1: Arizona's Diverse Agriculture

- Tom Davis, Yuma County Water Users Association - Irrigated Agriculture in the Yuma Area
- David Proctor, BKW Farms - Heritage Crops
- Michael Kotutwa Johnson, Indigenous Resilience Center, University of Arizona - Tribal Heritage Agriculture
- Sarah King, King's Anvil Ranch - Ranching

Moderator: Faith Sternlieb, Lincoln Institute of Land Policy

Highlight Talks – Part 2: Arizona's Diverse Agriculture

- Ashley Ellixson, United Dairymen of Arizona - Dairy Farming
- Phyllis Valenzuela, San Xavier Cooperative Farm - Tribal Community Farming
- Brandon Merchant, Community Foodbank of Southern Arizona - Community Gardens
- Dax Hansen, Oatman Farms - Regenerative Organic Farming
- Mark Beres, The Flying Leap Vineyard - Viticulture

Moderator: Faith Sternlieb, Lincoln Institute of Land Policy

Afternoon Keynote #1: Agricultural Renaissance

A.G. Kawamura, Solutions from the Land

Panel – Advancing Sustainable Agriculture in Arizona

- Greg Barron-Gafford, School of Geography, Development & Environment, University of Arizona - Agrivoltaics
- Murat Kacira, CEA Center, University of Arizona - Controlled Environment Agriculture (CEA)
- David Dierig, Agro Operations, Bridgestone - Guayule
- Andrea Carter, Native Seeds/SEARCH - Sustainability Through Diversity

Moderator: Paul Brierley, Yuma Center of Excellence for Desert Agriculture, University of Arizona

Afternoon Keynote #2: Sustainable Responses to Water Scarcity – Examples from Israel

Uri Shani, Former Director, Israel Water Authority

Storytelling – Voices of Arizona's Agriculture

- Ron Rayner, A Tumbling T Ranches
- Maegan Lopez, Mission Garden
- Delia Carlyle, Ak-Chin Indian Community

Moderator: Daniel Sestiaga Jr., AIRES/Haury Indigenous Resilience Center, University of Arizona

Land Acknowledgement

We respectfully acknowledge the University of Arizona is on the land and territories of Indigenous peoples. Today, Arizona is home to 22 federally recognized tribes, with Tucson being home to the O'odham and the Yaqui. Committed to diversity and inclusion, the University strives to build sustainable relationships with sovereign Native Nations and Indigenous communities through education offerings, partnerships, and community service.

About the Authors

Luke Presson is a graduate student in the Department of Chemical and Environmental Engineering. His research focuses on membrane technologies for potable water reuse. He expects to graduate in summer 2024 and after graduation plans to work in the public sector helping to bridge the communication gap from scientific research to policy. Since 1988, Susanna Eden has held various positions at the university's Water Resources Research Center, including 10 years as assistant director. She holds a Ph.D. from the UArizona Department of Hydrology and Water Resources (now Hydrology and Atmospheric Sciences).

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1 Water Use by Crops

Irrigated agriculture makes up 72% of Arizona's water use.

Water applied to crops is consumed mainly by evapotranspiration or "ET" – evaporation plus transpiration.

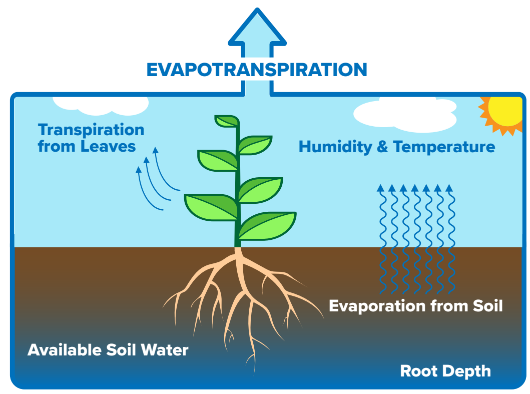
- Evaporation – when liquid water on the surface or in the soil transforms to water vapor
- Transpiration – when liquid water taken up by plants is 'exhaled' as water vapor (Plants 'breathe in' CO_2 and 'breathe out' O_2 and water vapor.)
- ET can be calculated from satellite data.

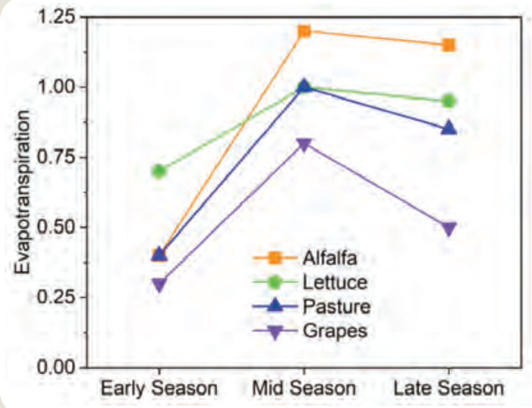
ET is an essential variable for calculating crop water needs. It depends on many factors, including local climate and crop type.

- $ET = ET_0 \times K_c$
    - ET_0 – Reference ET for a specific location dependent on local climate factors like temperature, humidity, and wind.
    - K_c – The ET coefficient unique to each crop at different growth stages.

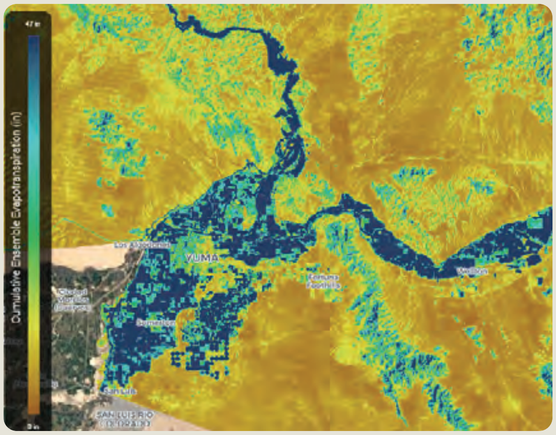
Water is also used to leach away the salt left behind when water evaporates, because salinity reduces a plant's ability to extract water and nutrients from soil.

- Removing salt from irrigated fields is a significant portion of farmers' water use.
- Leaching water carries salt down below the root zone and may reach the aquifer.





ET coefficients for common crops.



Satellite map of 2021 cumulative evaporation in the Yuma area. Source: OpenET.

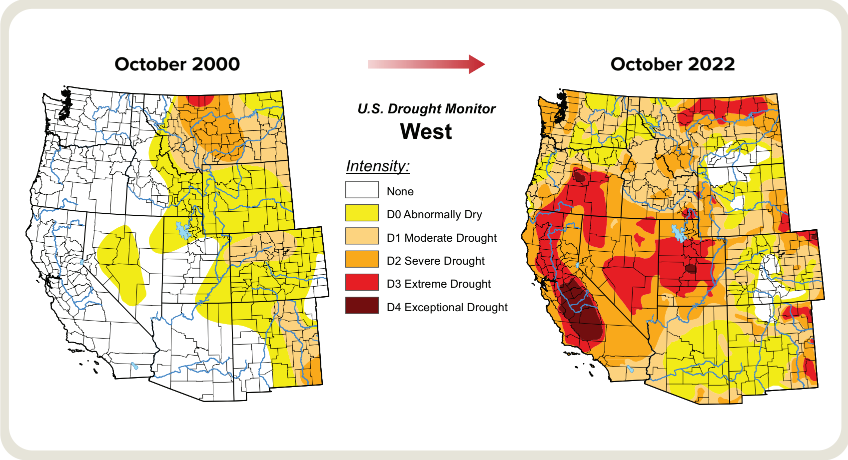
Up to 99% of the water taken up by a plant is used for transpiration.

2 Water Scarcity Trends

Most of Arizona is desert, where average annual precipitation ranges from zero to 16 inches, but where flowing rivers and large aquifers are sources of abundant water. A history of reservoir, canal, and groundwater pump development has meant that over the past century, water was readily available for almost any use in most of the state. Improvements in water efficiency and increases in conservation have allowed continued growth; however, drought and groundwater overdraft signal a new era of limits.

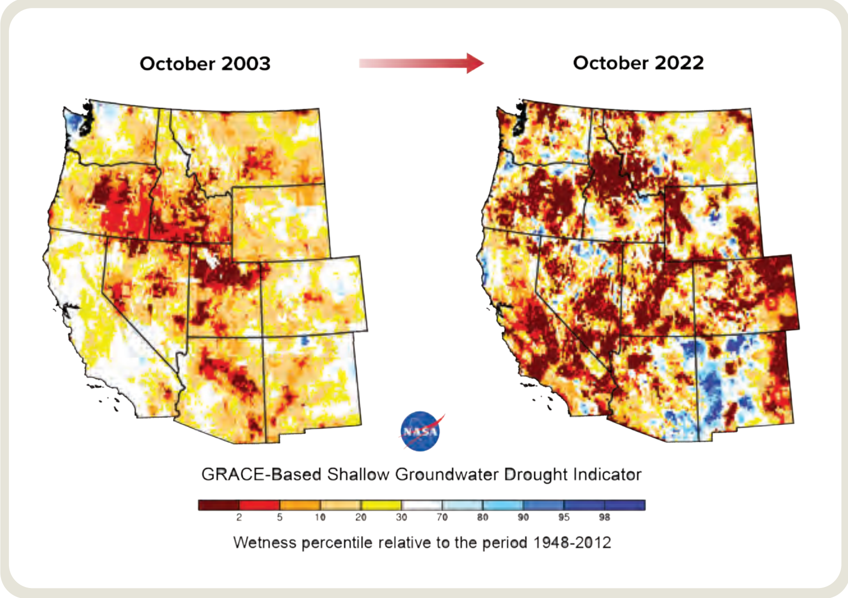
Surface Water

- For the past two decades, the American West has been enduring a hot "mega-drought" that may indicate a new normal.
- The drought in Arizona has been less intense than in other western states, and local surface water remains relatively reliable.
- **BUT** much of the Colorado River Basin has been experiencing exceptionally hot dry conditions, resulting in low runoff.
- The river's diminished flow volume threatens Arizona's Central Arizona Project (CAP) surface water supply.



Groundwater

- With proactive policies, Arizona has maintained and even improved aquifer storage in some areas;
- **BUT** CAP water has been central to the state's groundwater strategy. It replaced groundwater use by agriculture in much of Central Arizona and was the main source of water for aquifer recharge.
- With less Colorado River water delivered through CAP, some farmers will return to groundwater use. To maintain adequate water supplies it is increasingly important to find alternatives and additional water efficiencies.



Controlled Environment Agriculture (CEA)

In CEA, environmental factors such as temperature and humidity are controlled. The most common example of CEA is a greenhouse. Inside a basic greenhouse, temperature and humidity will increase, CO_2 concentration will vary, and some sunlight will be blocked.

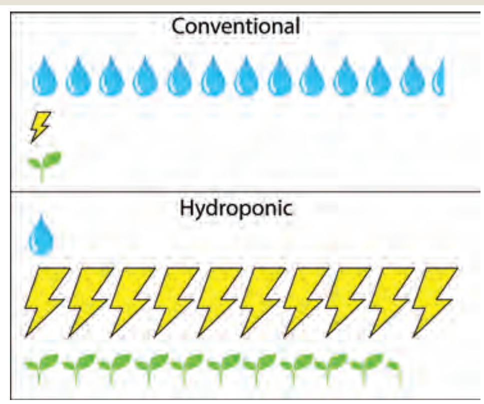
Initial effect of basic greenhouse enclosure.

Temperature	Humidity	CO_2 Concentration	Light Intensity
↑	↑	↑ or ↓	↓

Adding technology and automation allows these and other factors to be precisely controlled, and the use of water recycling technology makes CEA extremely water efficient.

Hydroponic greenhouses are a popular form of CEA. In Yuma, for example, hydroponic greenhouses

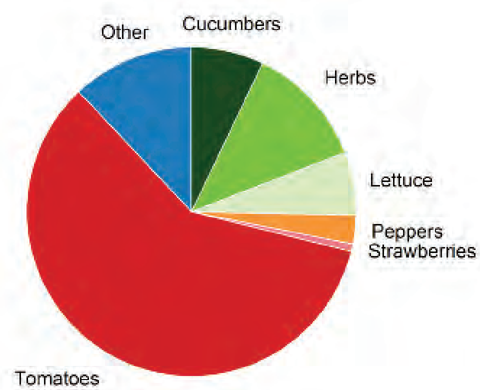
- use about 13 times less water than conventional agriculture for the same lettuce yield.
- can yield 11 times more than conventional agriculture from the same land area.
- **BUT** require 82 times more energy to produce the same yield.



Relative resource use and yield for hydroponics v conventional lettuce production

Adoption of CEA depends on specific benefit-cost calculations.

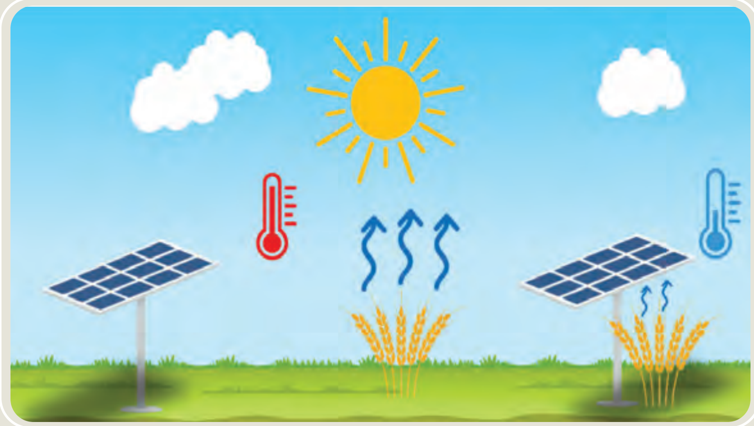
- CEA's high capital and operational costs limit its use to high-value crops.
- **BUT** its relatively small water and land area demands make CEA well suited for areas with water or land scarcity while minimizing waste and transportation costs.



Crops produced in CEA greenhouses in the United States

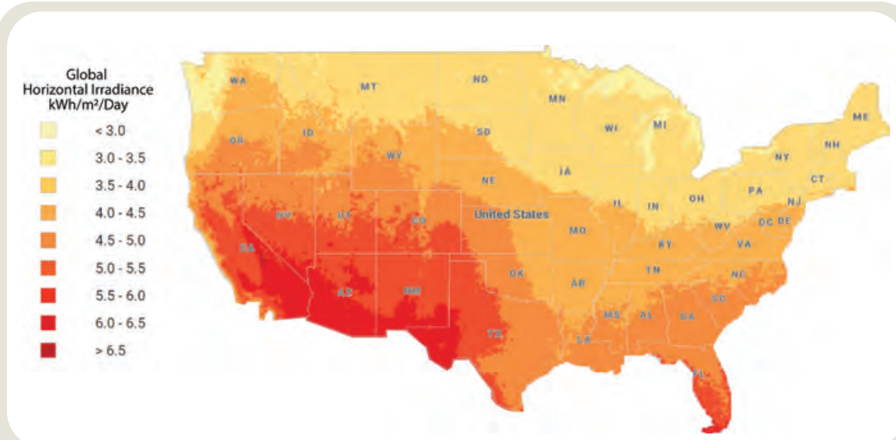
Agrivoltaics

Agrivoltaics can combine solar energy production with agricultural production. Placing solar energy panels on agricultural land promises to produce energy while reducing water use and maintaining or slightly improving crop yields over time.



- Shade from photovoltaic panels moderates the temperature near the crop, decreasing evaporative water loss.
- Evapotranspiration from the crop cools the photovoltaic panels, increasing their efficiency.

Arizona's climate is particularly well suited for adopting agrivoltaics



- The state receives a lot of solar radiation with little cloud cover
- Arizona has very high global horizontal irradiance (GHI)
- GHI is the total solar radiation experienced on a horizontal surface and is one of the most important factors in predicting solar panel output.

Limits on water supplies and high water and energy costs may force some farmers to fallow land and potentially abandon farming.

- Agrivoltaic energy production augments income and makes farms resilient to costs and price volatility.
- Temporary fallowing and investments in water efficiency are more politically and economically viable with a more resilient agriculture industry.

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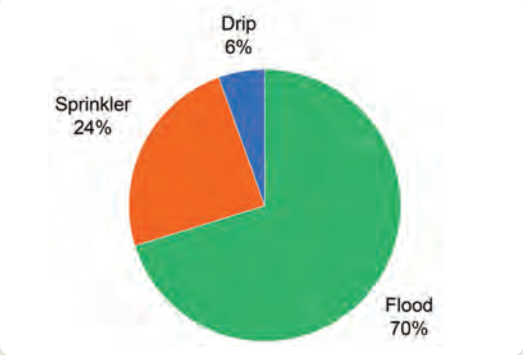
4 Irrigation Methods

The most common irrigation methods are flood, sprinkler, and drip irrigation. Each method has pros and cons, and the best choice depends on variables such as crop type, soil type, and cost.

Flood irrigation:

Water flows across a field, usually through furrows, and seeps into the soil.

- The simplest, least costly method;
- Considered the least efficient method;
- **BUT** best for some specific uses;
- **AND** efficiency can increase to 80% or more with land leveling, automation, and reuse of runoff.

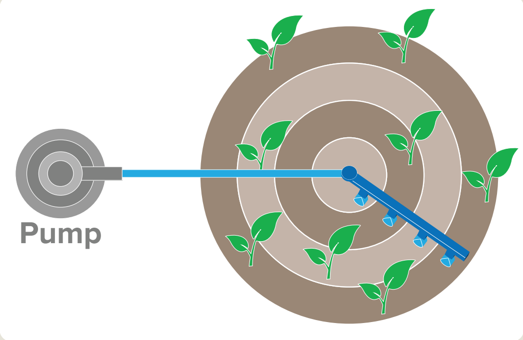


Percentage irrigation method in Arizona

Sprinkler irrigation:

Controlled spray of pressurized water is aimed at crops, often simulating rainfall.

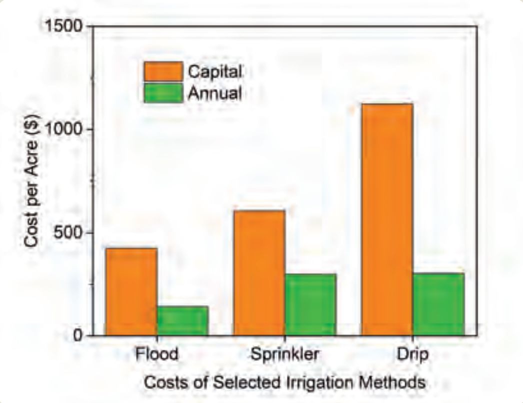
- Sprinkler technology is varied and includes center pivot (shown at right), linear move, traveling gun, etc;
- Relatively efficient, with little runoff or deep percolation;
- **BUT** airborne droplets may be blown away by wind and evaporate quickly;
- **HOWEVER**, some newer systems reduce losses by carrying sprinkler heads close to the soil surface.



Drip irrigation:

Distribution lines apply small volumes of water with extreme precision.

- Considered the most efficient irrigation method. Evidence suggests it can produce higher yields with less water than other methods;
- Each installation can be designed and customized;
- **BUT** Changing a field or crop is more burdensome;
- **AND** soil salinity may be a problem. Salt builds up in soil if irrigation water is high in minerals, and drip irrigation alone does not flush salts to below the root zone.



Costs of Selected Irrigation Methods

One acre-foot of Colorado River water can leave behind around one ton of salt!

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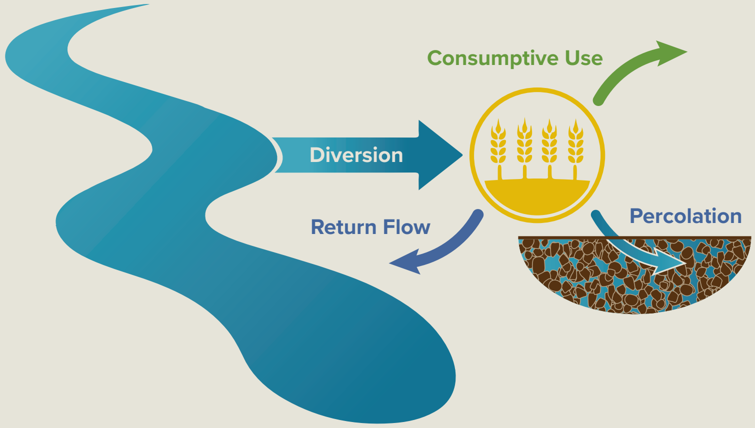
5 Conservation vs. Efficiency

Agricultural water **conservation** means diverting less water from streams or aquifers. Alternatively, water **efficiency** is defined as the amount of water consumed in comparison to the total amount diverted.

- Diversion – When a farmer diverts water to a field.
- Consumptive Use – Fraction of diverted water used to grow the crop.
- Return flow and percolation – Water not consumed can return to the stream or aquifer.

When efficiency is improved, a higher percentage of water is consumed and less returns.

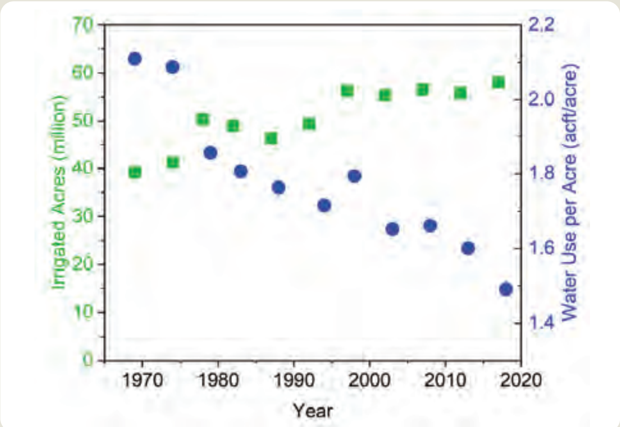


Takeaway: Improved efficiency reduces the amount of water used to maintain crop yield; but the saved water may be used to grow more. Return flows and percolation may actually decrease. Only if less water is diverted overall is water conserved.

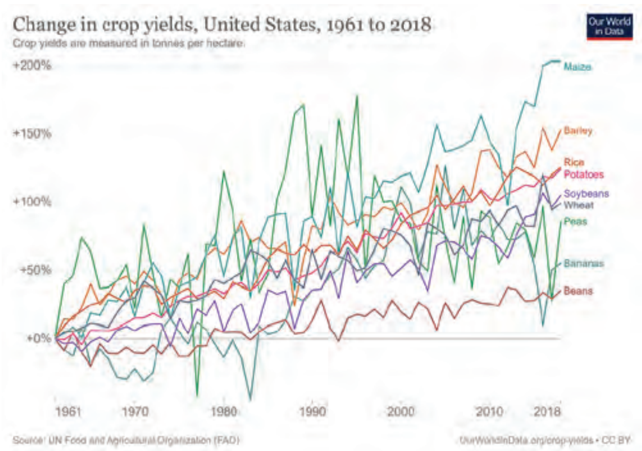
Agricultural Water Efficiency in the United States

Water efficiency of irrigated agriculture in the United States has been improving for decades, yet water use has not decreased.

- Water used per acre has gone down by almost 30%,
- **BUT** acres irrigated have increased by 48%

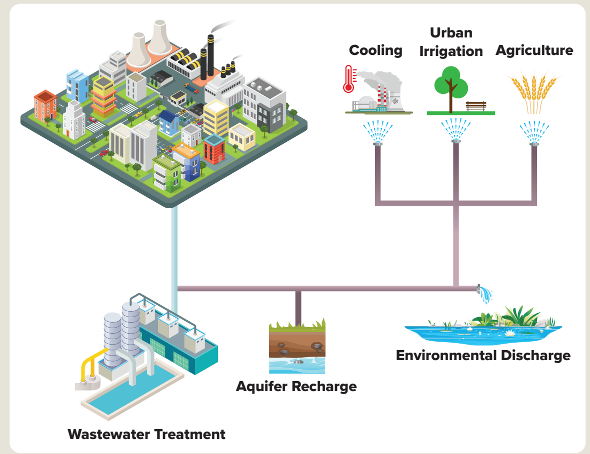


Efficiency doesn't always lead to water conservation, but with improved farming practices the United States can produce more food with about the same amount of water.



Reclaimed Water in Agriculture

Water reuse, or water recycling, reclaims wastewater and treats it to quality standards suitable for beneficial uses including irrigation.



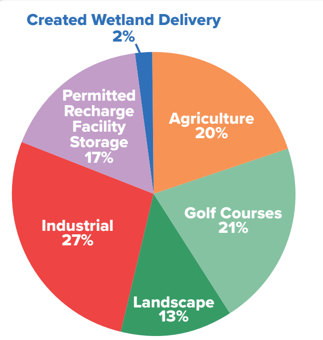
Although Arizona is a leader in the United States in reusing wastewater for irrigation, it still uses only 119,000 ac-ft/year or 2.3% of the water used by Arizona's irrigated agriculture. Nationwide, less than 1% of total water use for agricultural irrigation is reclaimed water.

Reasons for low utilization of reclaimed water by agriculture include:

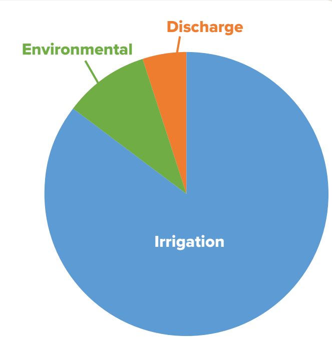
- Use for other purposes
- Difficulty transporting to agricultural areas
- Insufficient treatment

The proximity of wastewater treatment plants to urban areas favors urban reuse. Infrastructure investment in transport of reclaimed water would be needed to boost agricultural reuse.

Israel provides an excellent example of using reclaimed wastewater beneficially. Almost 90% of Israel's treated wastewater is reused for irrigation; the remainder is discharged to the sea or used for environmental purposes. Israel's small size (about 13x smaller than Arizona) and well-developed water transport infrastructure are key to this reuse.



Treated wastewater reuse in Arizona, 2010.



Fraction of reclaimed water used for different purposes in Israel.

While treated wastewater is not suitable for all crops, most of Arizona's treated effluent is high enough quality to use for most agricultural purposes. The state's water reuse regulations specify the minimum quality of reclaimed water for specific uses.

Water Class	Criteria	Type of Reuse
A	• 24-hour average turbidity is < 2NTU (measure of clarity); • No detectable fecal coliform bacteria in four of the last seven daily water samples taken, and • The maximum concentration of fecal coliform bacteria in a single water sample < 23 per 100 mL	Irrigation of food crops, residential and open access landscape irrigation, spray irrigation of an orchard or vineyard.
B	• The concentration of fecal coliform bacteria in four of the last seven daily water samples taken < 200 per 100 mL; • The maximum concentration of fecal coliform bacteria in a single water sample is < 800 per 100 mL	Surface irrigation of an orchard or vineyard, golf course irrigation, restricted access landscape irrigation, pasture and water for dairy animals.
C	• The concentration of fecal coliform bacteria in four of the last seven daily water samples taken < 1000 per 100 mL; • The maximum concentration of fecal coliform bacteria in a single water sample is < 4000 per 100 mL	Pasture and watering for non-diary animals, irrigation of sod farms, fiber, seed, forage, and similar crops.

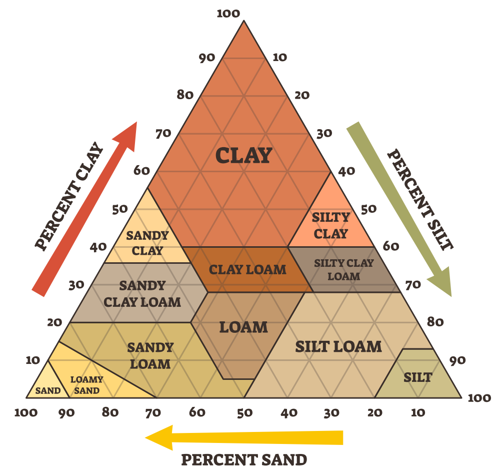
Soil Texture

Soil texture is a crucial component of a soil's water holding capacity (WHC).

- Sandy soils have a low WHC and must be irrigated frequently.
- Clay and silt have high WHC and can be irrigated less frequently.

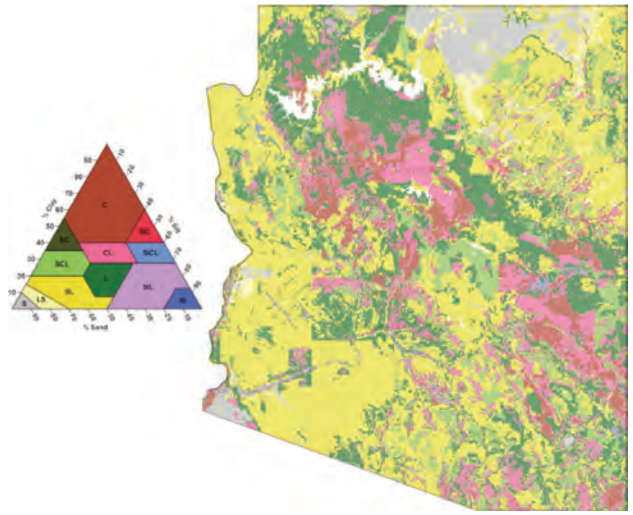
BUT the amount of water a plant can extract from the soil also depends on texture.

- Clay soils may be farmed, but clay holds water so tightly it impedes extraction by plants.
- Silty soils are great for farming as they hold a lot of water available to crops.

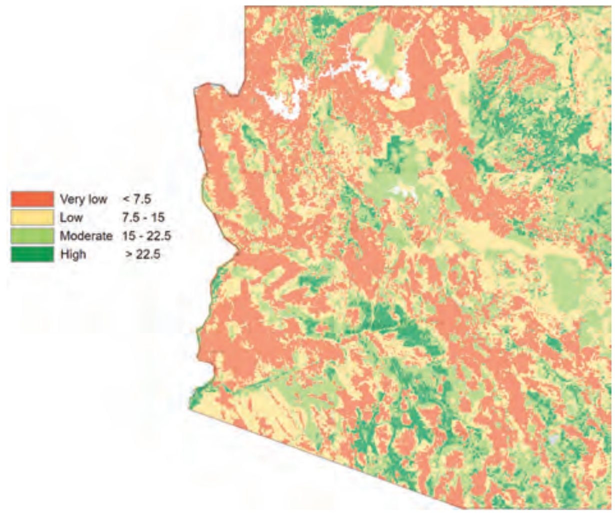


Soil Types

AND higher WHC is not always better. Sandy soils have low WHC but great drainage with little risk of waterlogging.



Soil Texture



Water Holding Capacity (cm)

Soil Organic Matter

- Can hold large volumes of water—much of which is available to crops.
- High SOM can also improve infiltration rates by providing structure to the soil and protecting against crusting and compaction.

Soil Improvement Practices

While soil texture is largely out of farmers' control, soil health can be improved.

Crop Rotation – Alternating crops seasonally or annually

- Balances and cycles nutrients while minimizing risk from pests and disease.
- Diverse root systems improve soil structure and provide soil microbes with different food sources.

Cover Crops – Planted primarily to support soil health rather than crop production

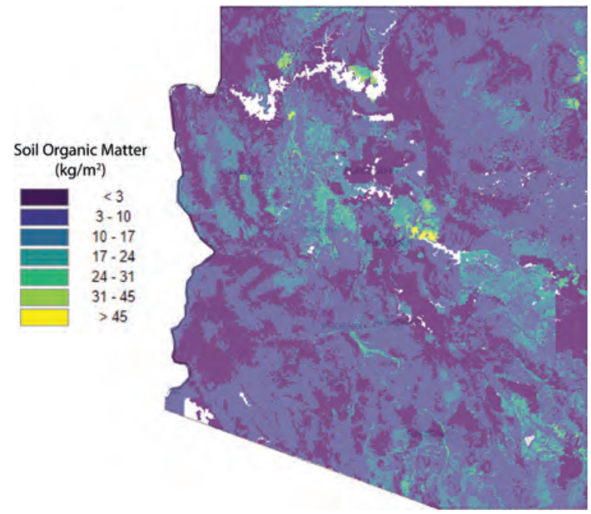
- Used on only ~6% of Arizona's farmland because the year-round growing season encourages planting and irrigating more profitable crops.
- **BUT** cover crops add nitrogen and improve soil health.
- **AND** can control weeds, reducing the need for herbicide.

Conservation tillage – Reducing or eliminating tillage on agricultural fields

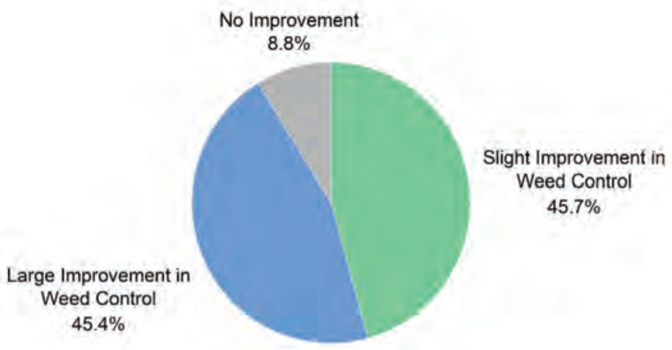
Most of Arizona's farmland is operated under intensive tillage, but between 2012 and 2017, no-till practices increased while intensive tillage decreased by nearly 14%.

Decreased Tillage can:

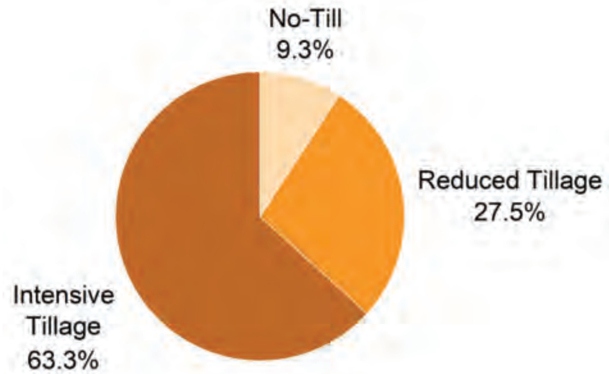
- Save time, money, and fuel;
- Increase SOM, water retention, and drainage;
- Prevent erosion, soil compaction, and CO_2 release;
- Improve yields over the long term.



Soil Organic Matter



US Farmer survey responses on cover crop weed control.



Fraction of acres under intensive, reduced, or no-till practices in Arizona. (2017)

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8 Native Agriculture

Several of Arizona's Native Tribes operate successful modern farms, using varieties of standard agricultural practices. However, many agricultural conservation practices have roots in native traditions and knowledge. A select few native agricultural traditions are discussed below.

Companion or Guild Planting - planting different crops together rather than in the separate fields of conventional agriculture

- Each plant benefits from the contributions of nutrients, structure, and/or shade from the others.
- The Three Sisters—beans, squash, and maize—are the primary example of companion planting.
- A diet based on the Three Sisters is nutritionally complete and healthy.
- The Three Sisters have cultural significance that connects the farmer to the land.

The Three Sisters by Anna Juchnowicz

Corn grown on Hopi land with dryland farming techniques.

Dryland Farming - farming without irrigation

- Crops grow with as little as 10 inches of yearly rainfall and often are cultivated by hand.
- Corn—perhaps the most important crop for many Native American tribes—is planted deep in carefully selected locations.
- Farming in these conditions relies on generational knowledge and familiarity with the land.

Desert-adapted Crops - the selection and cultivation of seeds adapted to local conditions

- Farmers select the seeds of successful plants from the recent harvest to use the following season.
- Successive seasons of this practice produce crops adapted to the needs of the land.
- This adaptation is critical for farm sustainability and land stewardship.

Tohono O'odham White Tepary beans (image from Nativeseeds.org)

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