Local Food In The Sonoran Desert:

How Water And Land Influence Production

A Report For The
Maricopa County Food System Coalition's
Food Assessment

Prepared by Grant Falvo[a]
[a]School of Sustainability, Arizona State University, Tempe Arizona, 85287
[a]Correspondence: falvogra@msu.edu

A report for the Maricopa County Food System Coalition

prepared by Grant Falvo in partial fulfillment of a capstone requirement

for a Bachelor of Science degree in Sustainability from Arizona State University.

The Maricopa County Food Systems Coalition (herein 'the Coalition') is a voluntary community organization advocating for the regeneration and advancement of the food system in Maricopa County, Arizona. They focus on innovative and collaborative solutions to issues such as food distribution and access, land and water use, nutrition education, food waste, sustainable farming practices, and others. The Coalition is made up of members interested in improving their local food system from groups that work on health, food access, agriculture, distribution and processing, and public policy. They are currently concluding their comprehensive Food Assessment with the help of a grant from the Gila River Indian Community.

The Coalition's Mission: To support and grow a food system in Maricopa County that is equitable, healthy, sustainable, and thriving.

The Coalition's goals: Inform ourselves and other stakeholders on the comprehensive nature of the food system as it currently operates within Maricopa County and the Gila River Indian Community. Inform ourselves and other stakeholders on the existing assets, needs and opportunities for supporting and growing a food system in a way that is consistent with our Charter. Apply the results of the assessment to the development of short and long-term coalition action plans.

The Coalition's objectives relevant to this report: The Coalition will describe the current and future productive capacity of agriculture in Maricopa County with a focus on land-use, water, regulatory environment as well as the key characteristics of current food and agriculture in Maricopa County and the Gila River Indian Community.

Regional boundary: Maricopa County and the Gila River Indian Community.

Scope of work:

(1) Conduct research on the policies and use of agricultural land and water in Maricopa County and the Gila River Indian Community to better inform the Coalition of the current and future social, economic, and environmental sustainability of the region's local food production system

and

(2) Produce a report compiling the full research project into a professional document ready for publication and dissemination for a range of detail-oriented audiences.

Table of Contents:

Abstract:

Agricultural resources such as land and water are the foundations of all terrestrial food systems. In Arizona's section of the Sonoran Desert, millions of people maintain an oasis-like food system that is mostly supplied by the purchasing of food from elsewhere, and to a small extent by the production of food in the region. In fact, as this report will show, trends and pressures with substantial inertia are moving this food system further away from the production of food and closer to the near-complete reliance on imported food. Many cities across the world have overtime outgrown their local food-producing resources but the unique dynamics of this process in central Arizona have not been adequately explored and addressed.

This report identifies key historical forces, patterns, and policies that shape the present use of water and land resources in the context of agriculture and local food in the region. Using multiple sources of publicly available data, this report documents the decline of agricultural production as the region's population continues to grow. These dynamics are explained using the unique legal frameworks and biophysical circumstances of each of the region's major water sources. Urban and agricultural land use patterns serve to further explain the exponential decline of agricultural resources per capita in the region.

This report concludes by discussing potential interventions that might support the Coalition's mission through the use of both local and outside examples from comparable food systems that exhibit similar or revealing circumstances. Illustrative anecdotes are included to stimulate discussion and to provide a larger context for the seemingly insurmountable challenges inherent in the transformative work required to fulfill the Coalition's mission.

Introduction: Water in Central Arizona

Maricopa County (herein 'the County') and the Gila River Indian Community (herein 'the Community') are situated at the confluence of the Salt, Gila, and Verde watersheds. Water falls as snow and rain in the uplands of these watersheds and each of them drain into their namesake rivers. As the water comes down from the mountains some of it is used up by plants, some is stored as groundwater, and some enters the tributaries of the valley's major rivers. The Salt and Verde rivers join as they enter the County near Fountain Hills, and later they join the Gila River near Goodyear. The Gila River then leads to the southwest corner of the County and continues on to Yuma.

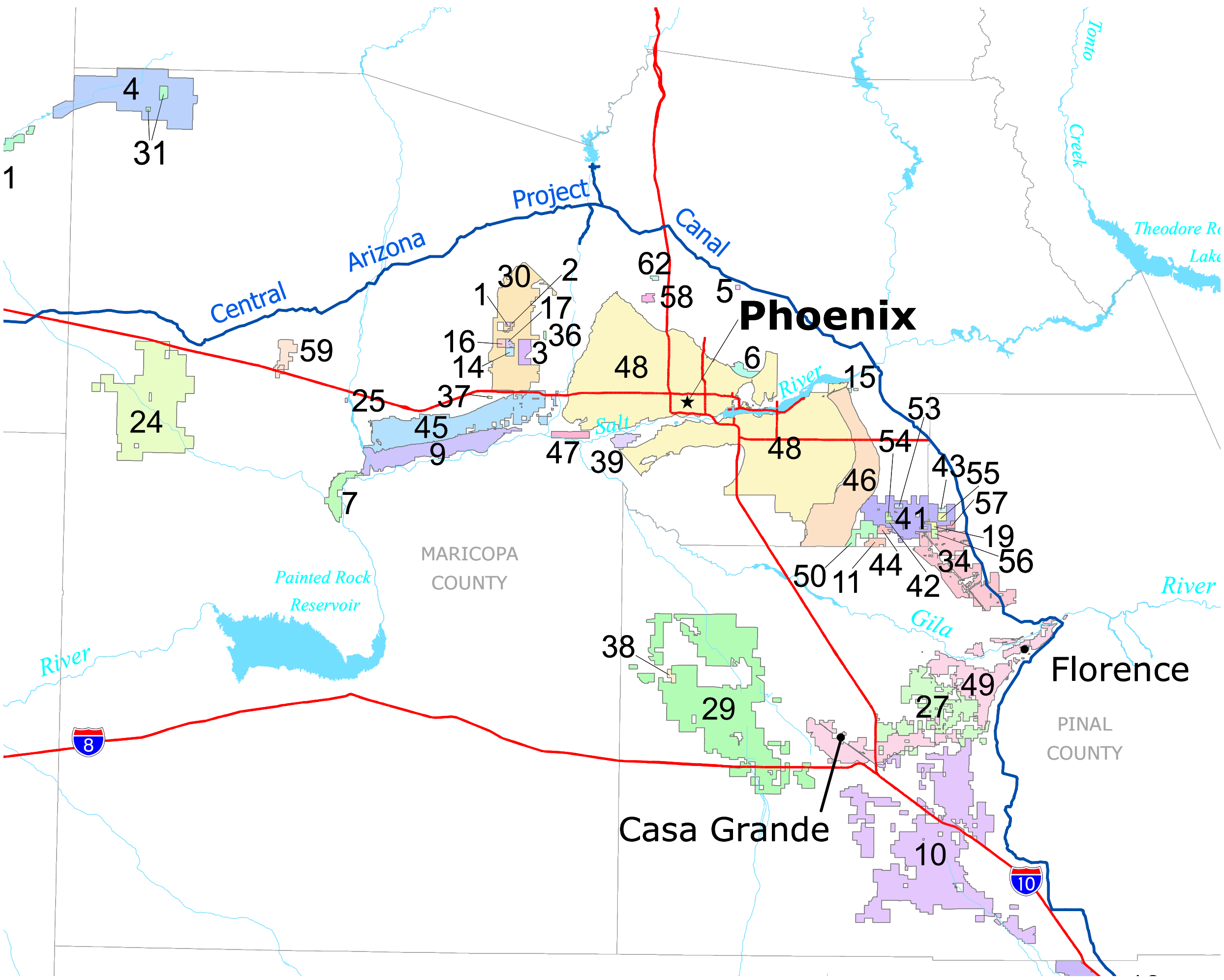


Figure 1. Irrigation districts in central Arizona. (ADWR 2014).

These rivers have multiple dams controlling their flow and their ecology. Farmers that are adjacent to these rivers may have direct access and rights to use river water. However, most farmers use infrastructure such as pumps, canals, and gates, to get water to their fields. Farmers organize the use of these rivers and infrastructure by organizing themselves into numerous irrigation districts. These districts have internal governance and elections and also abide by certain regulations and mandates from the state water authority, the Arizona Department of Water Resources (ADWR).

One important source of water for the region's farmers that crosses state and national boundaries is the Colorado River and so it is administered through the United States Bureau of Reclamation as well as state and local agencies. For Arizona, the river's main administrative agency is the Central Arizona Water Conservation District. This agency operates the Central Arizona Project, which is the infrastructure that conveys the Colorado River water from the western border of Arizona to the central valley. A complex legal system regulates how this water is distributed among diverse interests, most notably, farmers, municipalities, and tribes (described in **Box 1**).

The most important source of water for central Arizona farmers is groundwater. The County and the Community sit on top of many partially interconnected aquifers that hold water much like water would sit in a jar filled with sand. Groundwater is not an underground river nor is it an underground lake. Like a jar of sand filled with water, groundwater takes up the space in-between the rocks beneath the surface. Farmers can then stick a straw into this jar and suck up the water. In central Arizona this is done with wells, pipes, and pumps. Before Arizona became a state in 1912 and before any major regulations were put in place, colonists could take it upon themselves to drill these wells without restriction and acquire the first legal groundwater rights, something that indigenous people, not being citizens, could not do. 'If you can punch it you can pump it' was the legal doctrine of early territorial Arizona. As this report will discuss, central Arizona now has considerably more regulation of groundwater use, most notably, the 1980 Groundwater Management Act.

Farmers in central Arizona use a combination of these three main sources of water (1) surface water, (2) Colorado River water, and (3) groundwater. Some farmers also have access to reclaimed water, though this is a small proportion of total water use. It is important to note that this report will focus on cropland and pasture which, in this region is irrigation dependent. Grazing on dryland is also irrigation dependent because livestock require ample drinking water. This livestock water is provided in stock-ponds that dot state, federal, and private grazing lands in the region. However, this report will not address stock-ponds.

The portfolio of water sources used by an individual farmer varies in relation to how close they are to surface water or Colorado River water (herein 'CAP') and if they have the necessary infrastructure to access it (Figure 2). Those too far away from supportive infrastructure rely on groundwater (i.e. west-valley farmers). The detailed data for this portfolio is quantified for the Phoenix Active Management Area (described in the Groundwater section below) which overlays the Phoenix Metro-Area and the majority of the irrigated agriculture of the County.

Overall, farmers in the County today receive about one-half of their water from groundwater, one-quarter from CAP, one-fifth from surface water and the rest (~5%) from reclaimed water (ADWR 2018). Over time, farming in the County and the Community has changed dramatically. Since 1980, farmers in the County reduced their consumption of water by *half* in concert with taking half of their land out of production (ADWR 2018; USDA 2017). This trend shows no sign of stopping (Figures 3 and 4). What is driving this trend? What consequences does it have for supporting and growing a food system that is equitable, healthy, sustainable, and thriving?

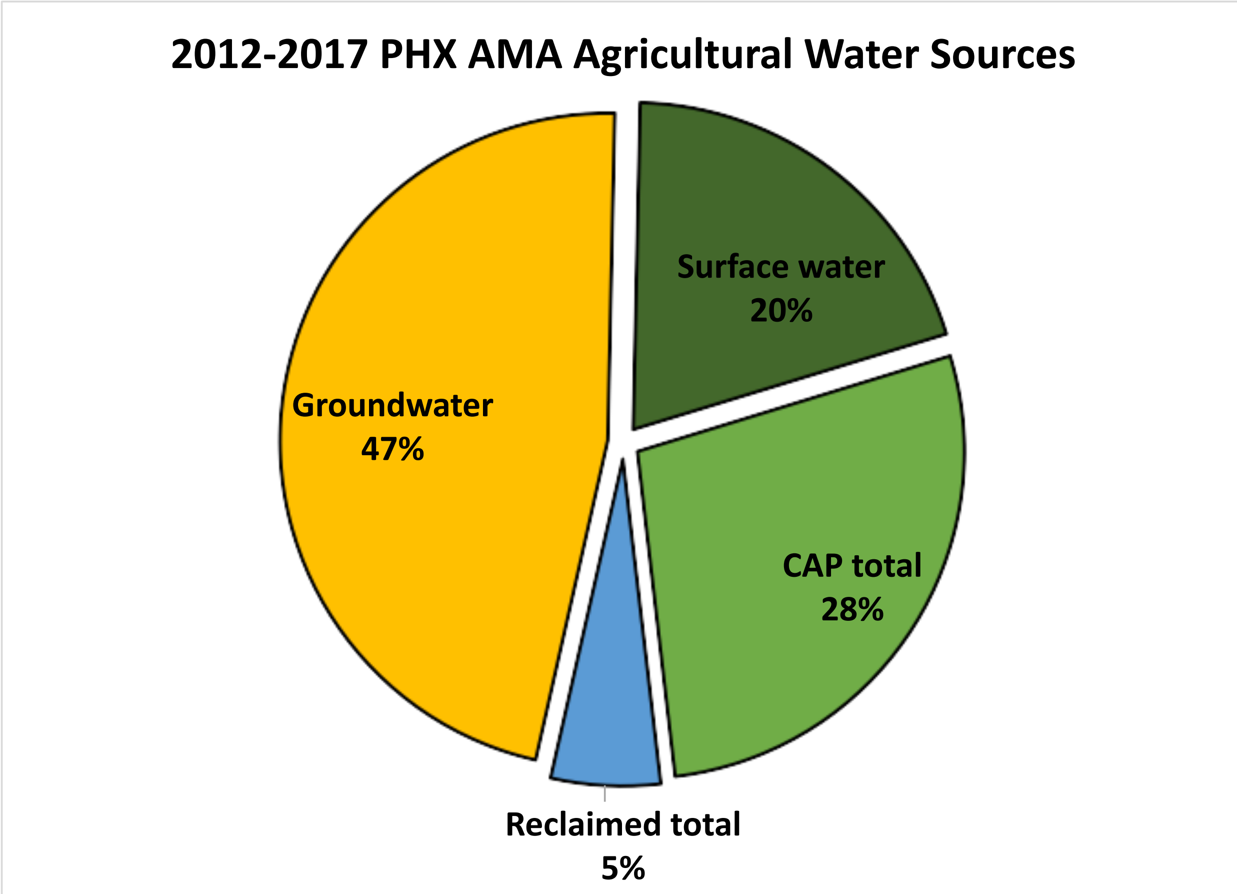


Figure 2. Average annual portfolio of agricultural water use in the PHX AMA (Phoenix Active Management Area) over the 5 year period from 2012 to 2017. CAP means Central Arizona Project water and includes Groundwater Savings Facility (GSF) water sourced from CAP. Reclaimed total includes GSF water from reclaimed sources (see Groundwater section below; ADWR 2018)

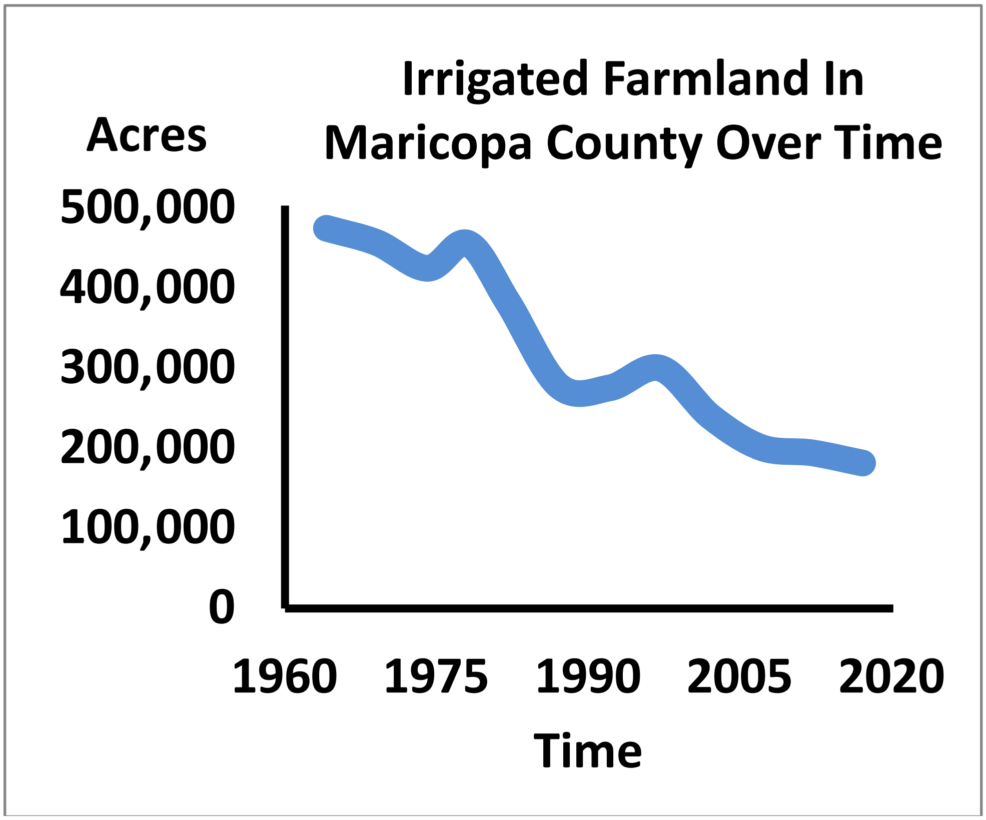


Figure 3. Irrigated farmland (including cropland and irrigated pasture) in Maricopa County over time. This period (1964-2017) showed a *>60% decline* in acres irrigated. (USDA 2017).

Surface Water

The Salt River Project (SRP) is the major source of surface water for irrigation in the County. Under the umbrella of SRP, (which also provides electricity) the Salt River Valley Water Users Association is the institution that provides irrigation water to farmers. It is a private non-profit company that holds elections for its council (30 members) and board (10 members). Additionally, a president and vice president are elected. The voting system for these elected positions is quite different from modern day American governmental elections (though it is similar to early American elections where only property-owning white men could vote). The president and vice president are elected not by the of-age citizens within the service district, but rather the *landowners*. In many cases this can be landlords, it can be the patriarch of a household, it can also be a farmer. However, the council and board are elected by acreage (i.e. one acre = one vote). This means that each acre in the service district is worth one vote so landowners with larger acreage hold more power in the elections (SRP 2019). Farmland ownership in the County is heavily concentrated as this report will describe below. This leads to a concentration of political power and a substantial status-quo inertia that will be crucial to understanding the necessity of informed and targeted interventions discussed in the concluding sections of this report.

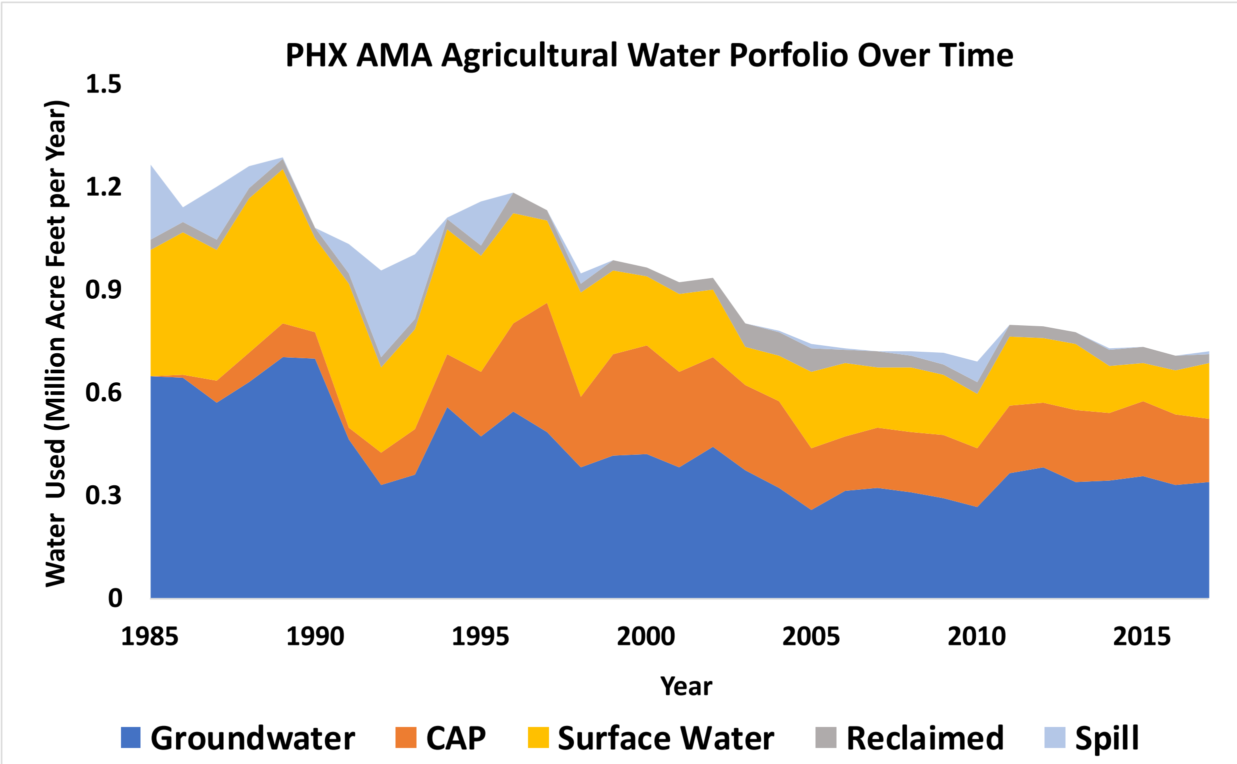


Figure 4. Agricultural water use in the PHX AMA (Phoenix Active Management Area) over time. This period shows a steady decline (~50%) in the use of groundwater and surface water, one-third of this decline was abated by newly developed CAP water. CAP means Central Arizona Project water and includes Groundwater Savings Facility (GSF) water sourced from CAP. Reclaimed total includes GSF water from reclaimed sources (see Groundwater section below; ADWR 2018).

Many farmers in the County are situated in the Salt River Project (SRP) service area. This means that they are eligible to operate their own irrigation district to act as an intermediary with SRP. SRP mostly uses their own infrastructure to supply these farmers. SRP's water supply comes from the Salt and Verde watersheds shown below in Figure 5.

About one-fifth of the water that farmers in the PHX AMA use is surface water, most of which comes from SRP and is used in the east valley (ADWR 2018). Currently, this amounts to enough water to irrigate about 33,000-81,000 acres each year depending on which crops are grown. The use of surface water by farmers has also declined rapidly since the 1980's. SRP water is considered highly renewable and dependable in comparison with other sources of irrigation water in the region. Farmers that have land in the service district recognize that access to SRP gives their land a high value, as do developers and land speculators. However, as municipal demand within the service district grows and climate change shrinks the supply, less water may be available to farmers in the future. In fact, a study of the potential effects of novel climate change-induced temperature and precipitation regimes projects that the Salt and Verde watersheds will yield *22% less* runoff than they historically have by mid-century, largely due to increased evapotranspiration (Ellis et al 2008).

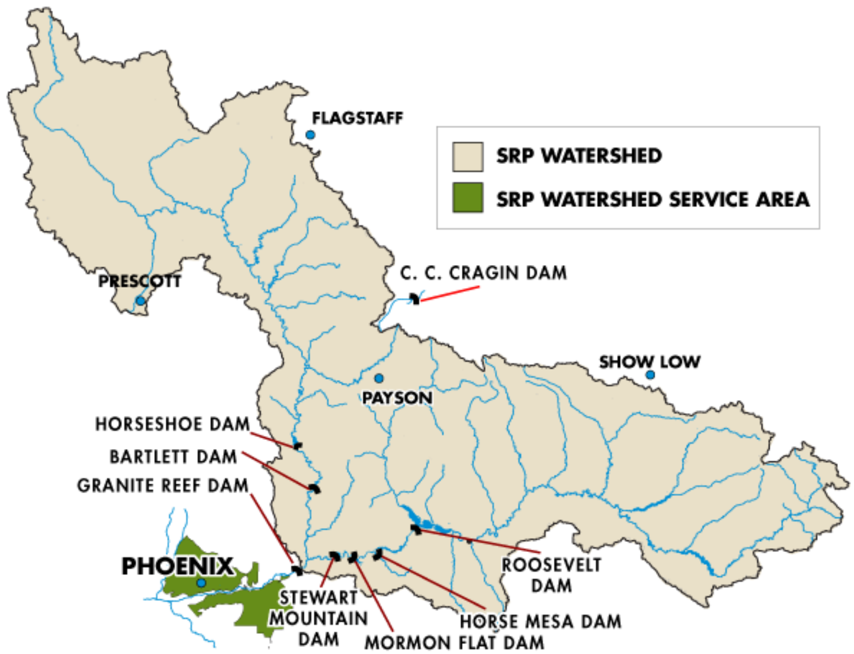


Figure 5. The Salt and Verde River watersheds, their dams, and the SRP service district that uses that water. The 13,000 square mile watershed feeds the 375 square mile service district (SRP 2019a)

Central Arizona Project Water:

Overall, Farmers in the PHX AMA receive about one-quarter of their water from the Central Arizona Project (CAP). About 300 farms (71-463 with 95% confidence) receive CAP water in the County (USDA 2017). CAP water is also used extensively to recharge the groundwater that farmers overdraft **(**see Groundwater section below; ADWR 2018**)**. Knowing this, it can be conceptualized that farmers in the PHX AMA receive more CAP water than they pay for directly, making it a more important source of agricultural water than it would seem. This water travels over one thousand miles from the Colorado Rocky Mountains into the Colorado River and passes through a series of reservoirs before being conveyed in canals to the PHX AMA (USGS 2016). A complex set of binding legal arrangements between states, municipalities, tribes, and Mexico govern the flow of the water with the United States (U.S.) federal government playing a dominant role. The U.S. Bureau of Reclamation makes decisions about how much water to release from the reservoirs, at what time, and to whom (Reclamation 2018a). The Secretary of the Interior holds the ultimate authority, which is especially important during times of shortage. This will be discussed later in this report (see **Box 1**).

As with surface water, only farmers that are in close proximity to CAP infrastructure can directly use CAP water, though, complex supplemental arrangements do exist where water is swapped on paper to balance the water budget. One such mechanism, called a Groundwater Savings Facility, involves temporary trading of water between cities and farmers. 'Groundwater Savings Facility' is a fancy name for a farm that uses a city's CAP water instead of their groundwater. The arrangement goes like this: If a city does not use their full legal allocation of CAP water (which many do not), they may then sell that water to a farmer who, as part of the deal, will use it instead of pumping groundwater. The city not only gets the money for the CAP water, but also gets a long-term storage credit for the groundwater not used by the farmer, meaning that they can pump that groundwater later. Even though no new water is 'created' by this mechanism, it allows several maneuvers to be made but they will not be covered here (for more information see ADWR 2010).

Community farmers currently use a small amount of CAP water but have recently settled a large water rights case whose water will mostly come from CAP. This settlement will be discussed in detail in the Gila River Indian Community section. The impending shortage CAP (described in detail in **Box 1**) will dramatically alter the supply availability, the price structure, and allocation priorities of CAP water.

Figure 4. Map of the Colorado River system (Reclamation 2012).

Box 1
How is the Colorado River Regulated?

The current state of the Colorado River system is critical (Barnett & Pierce, 2008; Colby & Jacobs, 2007). Supplies have been yielding much less than that of the historical record and projections estimate that this trend will continue as the basin warms. Seasonal variation in water supply to the Colorado River is high but is buffered by a number of dams. The two major dams are The Glen Canyon Dam which impounds Lake Powell, and The Hoover Dam which impounds Lake Mead. Both of these important reservoirs generate hydroelectric power and have federal legislation mandating their operation. Lake Powell flows into Lake Mead. Both reservoirs regulate how much water they release by the elevation of their impounded water above mean sea level. The relevant thresholds for the near future will be the Mid-Elevation Tier threshold of Lake Powell at 3,575 feet, and the Tier One threshold of Lake Mead of 1,075 feet. Historically, water has been maintained above these levels, but the current drought, a structural deficit, and the already present effects of climate change in the region are bringing the water levels in both Lake Mead and Lake Powell down to their critical thresholds of mandatory water cutbacks. When Lake Powell is projected to be above 3,575 feet on January 1st of the following year, only 8.23 million acre feet (maf) of water will be released. However, if the level of Lake Mead is projected to be below 1,075 feet, then up to 9.00 maf of water can be released to equilibrate Lake Mead. When Lake Powell is projected to be below 3,575 feet, then only 7.48 maf will be released with a possible release of 8.23 maf if Lake Mead is projected to be below 1,025 feet (Reclamation, 2018a). Current trends in both Lake Powell and Lake Mead Elevations (Storage) show that these critical thresholds are likely to be crossed in the next 1-2 years (Reclamation, 2018; 2018b; 2018c).

Drought, Structural Deficit, and Climate Change: The Near and Mid-Term Future of the Colorado River

Historically, the Colorado River has been underutilized, but this is no longer the case (Interior, 2018). The drought from 2000-2018 has had significant impacts on the water received from the Upper Basin. Through this period the Upper Colorado River Basin, which provides 90% of the Colorado River's water, yielded an average of 8.54 maf (after Upper Basin withdrawals), which is only 79 percent of the 1981-2010 average (Reclamation 2019).

The Colorado Basin River Forecast Center issued projections on 05/01/19 that forecast inflow in the Lake Powell at 12.07 MAF (111% of average; Reclamation 2019). The projected elevations of Lakes Mead and Powell will trigger a mid-year adjustment to the amount of water released from Lake Powell due to its implications for the elevation for Lake Mead. A 9.00 maf release is likely and is projected to leave Lake Powell at 3,606 feet (Reclamation, 2019). Based on the Colorado River Basin Forecast Center's Most Probable Water Supply Forecast Model Run ID: 3092 Processed On: 5/9/2019, Lake Mead will sit 10 feet above the Tier One threshold at the end of 2019 and will sit 5 feet above the Tier 1 threshold at the end of 2020, coming close to triggering a cut to Arizona's CAP water by 320,000 acre feet.

This cut will amount to 21.3% of Arizona's CAP water and 11.4% of Arizona's total Colorado River water allocation (CAP 2019). This mandatory cut, enforced by the Secretary of the Interior, will largely be absorbed by the Central Arizona Project, a key water supply for the regions food system. This cut will dramatically alter the water dynamics of the state, rendering some uses and users with no alternatives. Water will first be completely withheld from the 'excess pool' which comprises water banking, groundwater replenishment, and conservation. Additionally, non-priority, non-indigenous agricultural users in the central valley will receive a significant cut to their CAP water.

With this level of cutbacks, most of Maricopa County's farmers will not have their water taken away, but some can expect a price increase as CAP provides water based on fixed costs and the volume of water (Central Arizona Water Conservation District, 2017). However, Pinal County farmers will see their physical CAP water taken away. Dire times like these may rebound in the near future as this current drought will end, however, climate change analysis suggests that reductions in water supply are already evident and that further reductions are expected as the century continues. Due to the fact that the Lower Basin Drought Contingency Plan is (1) not, even in its most ideal execution, going to change these fundamental consequences, (2) only pushes off cutbacks a few years, and (3) is complicated to explain, it will not be discussed here however see Arend et al (2017) for an overview and the ADWR website for up to date information.

Contemporary climate change analysis and projections for annual Colorado River water supply agree that declines are already being felt and that further declines are expected. However, considerable uncertainty still exists as to the precise magnitude of these declines (Vano et al. 2014). Udall and Overpeck (2017) followed the review done by Vano et al. (2014) and explored the implications of the literature value ranges for basin temperature and precipitation induced river flow sensitivity under moderate and high emissions scenarios. These are empirical measures of how the river flow responds to changes in temperature and precipitation on a year to year basis. With a temperature flow sensitivity of -6.5% (+/- 3.5% sd) per °C, Udall and Overpeck model moderate and high emission scenario mean temperature-induced flow reductions to be -11 and -55%, respectively. A precipitation flow sensitivity factor of 2.5 (+/- 0.5 sd) coupled with an end of century range of +4% to -20% could compensate for some of the temperature induced loss but will likely add further reductions.

The United States Bureau of Reclamation (USBR) used downscaled global climate models and hydrologic models for the region that project a 3.3 °C rise in basin-wide temperature and a 12.4% decrease in the average annual flow of the river by the year 2080. Using the central literature values for temperature and precipitation sensitivity mentioned above, a ~5% *increase* in precipitation would be required to have this projection agree, which is at the upper end of range mentioned above, suggesting that this is a conservative estimate (Reclamation 2012).

The Demand chapter of the 2012 USBR report cited above projects that actual consumptive use in the year 2060 along the entire river, including deliveries to Mexico, evaporation, and other losses, will increase to between 17.7 and 20.1 maf per year, well above 14.3 maf per year that the Supply chapter of that report projects will be available above Imperial Dam near Yuma (Reclamation 2012). In short, business as usual will deplete the reservoir and result in cutbacks.

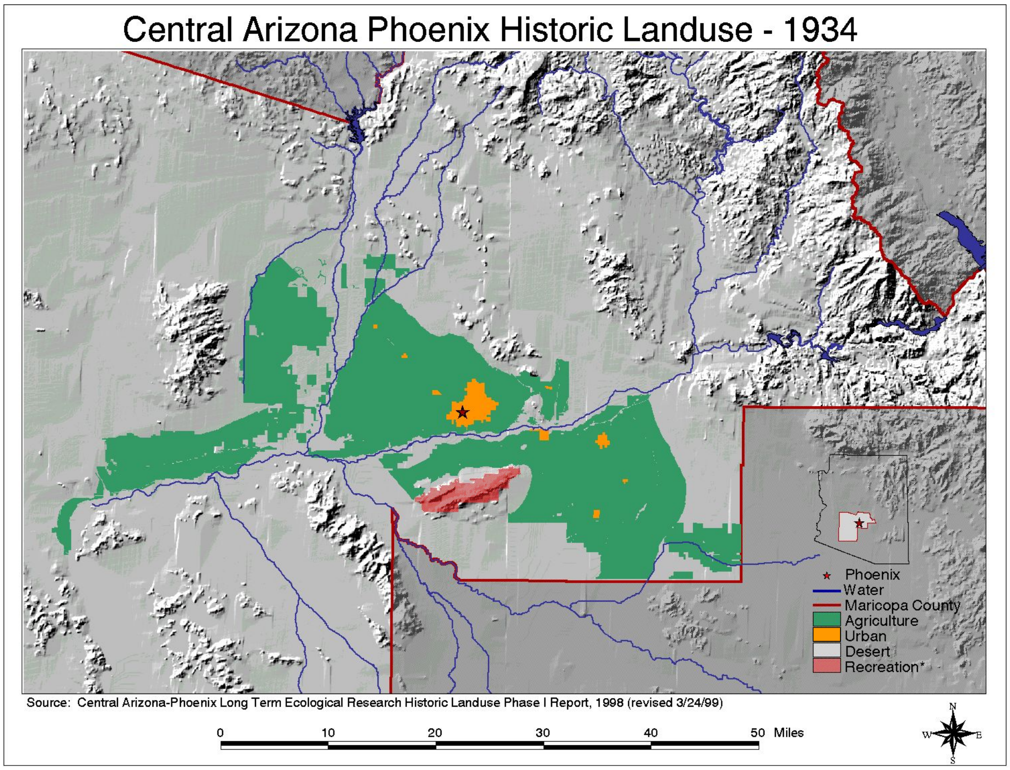
Groundwater:

Groundwater is water stored in aquifers underneath the County and the Community. After a long downward percolation and natural purification process, water that once accumulated on the surface reaches the water table and can stay there for a very long time. Aquifers are not underground rivers or lakes but water occupying space in-between unconsolidated minerals. Farmers can stick a well pump (like a 'straw') down into the minerals and suck up the water to use on their fields. This has allowed for the development of the arid Phoenix metro area to progress rapidly, but not without consequences (Figure 5).

Water levels below the contemporary Phoenix metro area have declined by 25-325 feet over the 20th century with the most severe declines occurring in the Glendale and Queen Creek areas (ADWR 1999). Extracting groundwater at the scale and rate of the region's farmers alters the natural hydrology of the region dramatically (Rascona 2005; ADWR 2010 p7-11). The direction of subsurface flow has changed from its natural patterns. Cones of depression form around the well pump and draw in surrounding groundwater, changing the direction of the water's flow towards the well pumps of the largest users. In some areas, so much water has been extracted that the lowered water table has caused the land above it to sink several feet causing damage to infrastructure (ADWR 2010 p7-11). This is called land subsidence and has been widely documented in the region (MAG 2019). This altering of the subsurface hydrology also has an effect on natural streamflow and critical riparian habitats. Groundwater is a major factor in maintaining a healthy riparian area in the Sonoran Desert. Due to the excessive pumping, groundwater no longer supports these habitats to the same extent and no longer seeps into the streams at certain times and locations. Residents, municipalities, and farmers have also had to deal with a falling water table. When near-by intensive water users draw down the local water table, it can fall below their neighbors well and render them useless.

Recognizing how this incentivized a 'race to the bottom', stakeholders came together to pass the 1980 Arizona Groundwater Management Act, a state law that regulates the use of groundwater in newly created 'Active management Areas'. The Phoenix Active Management Area (PHX AMA) overlays the metro-area of the County and includes part of the Community. Several important and lasting regulations have changed the way that water is used in the region. Most farmers are required to report their water usage to the ADWR and describe what it was used for. If the well is used for agriculture in the PHX AMA, then additional regulations apply.

The 1980 Arizona Groundwater Management Act's (GMA) most important regulation for County farmers can be summarized as follows. Groundwater pumping on a parcel of land greater than 2 acres in size for agricultural irrigation purposes is *illegal* within the Phoenix Active Management Area *unless* the land has an irrigation grandfathered right (IGR). An IGR must have been legally obtained by proving productive irrigation use during the 1975-1980 time period and must not have been taken out of use since. If taken out of use, that right is extinguished permanently. IGRs, for but a few exceptions, are tied to the specific piece of land on which they were granted. No new IGRs can be created. Therefore, irrigated agriculture in the PHX AMA can only use less and less groundwater going forward. In the case of areas outside the reach of CAP, SRP, and reclaimed water, this means that irrigated agriculture *in general* within the PHX AMA can only decline in



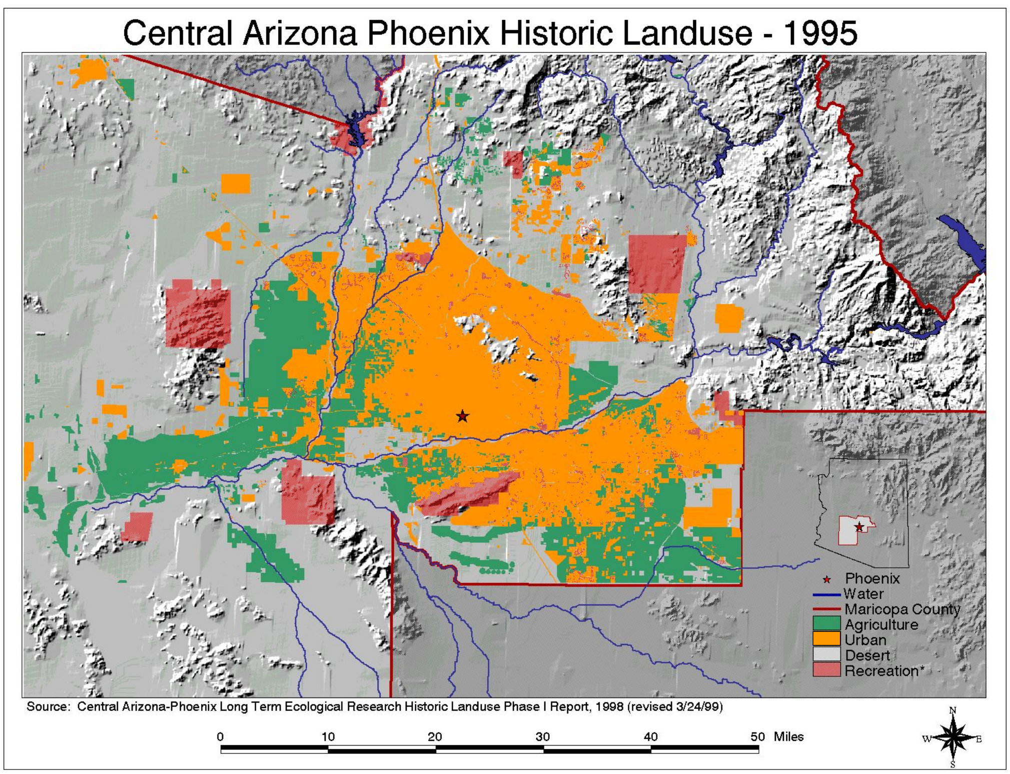


Figure 5. **Top**: Land use map of the Phoenix metro area in 1934. Orange is urban land uses while green is agricultural land uses (irrigated cropland and pasture). Note the small urban core. **Bottom**: Land use map of the Phoenix metro area in 1995. Note the urbanization of farmland (which totals 370,000 acres converted from 1912-2017 representing ~55% of all the irrigated land that was ever created; Knowles-Yánez et al. 1999; USDA 2017; USDA 2019)

the future. Farmers are required to report their water usage and pay fees to the ADWR accordingly (A.R.S. Title 45 Chapter 2).

As legislated, agriculture in the PHX AMA now uses much less groundwater (Figure 6). This has primarily not been because of a substitution of groundwater for renewable water. It has mostly been due to taking land out of production which, as described above, permanently reduces the number of remaining IGR acres. The GMA is achieving its objectives, specifically the PHX AMA is on track to meet the goal of 'Safe Yield' by 2025 (ADWR 2014).

Groundwater overdraft was the major impetus for passing the GMA. Overdraft is when more water is taken out of the aquifer than is put back in on a year to year basis. It is a subbasin wide problem as described above that affects not only the perpetrator, but their neighbors. Historically, agriculture was the largest contributor to overdraft. This report has estimated the size of that contribution.

The Arizona Department of Water Resources uses a figure of one-quarter to one-third of all water that falls on or is spread on agricultural fields is recharged to the aquifer below. The actual figure varies considerably by season, soil type, and crop type. Nevertheless, the ADWR, under this assumption estimates that roughly one-third of the contemporary agricultural groundwater use is 'mined' or overdrafted (ADWR 2018). Thus, farmers, as a whole, accrue a debt to the aquifer every year because they extract *1.5x as much groundwater as they replenish*. This debt is partially repaid each year by municipalities and governmental associations recharging groundwater in an effort to raise or maintain a stable water table. This can be thought of as one of the many state subsidies that the agriculture sector receives.

However, the GMA has a fee structure in place that requires farmers to pay a withdrawal fee, some of which may pay for the recharge (A.R.S. Title 45, Chapter 2). By considering the portfolio of water used by farmers and using the conservative one-third recharge figure mentioned above as an assumption, this report estimates that cumulatively, during the period from 1985-2017 County farmers overdrafted 5.2 million acre feet of groundwater, an amount equivalent to 15 years of agricultural groundwater use at 2017 levels**.** Using a model calibrated with the modern data, the cumulative historical groundwater debt exacted by farmers from 1900-2017 was estimated to be 9.5 million acre feet of groundwater, or 28 years of agricultural groundwater use at 2017 levels (see Appendix 4 for details).

Furthermore, it is evident that, all else being equal, farms in the County use more water per acre than they used to due to the increased temperature that the Phoenix Metro Area has experienced over the past century (NOAA 2019; Figure A3). The Phoenix Metro Area's annual average temperature has risen by 6.5 °F from 1895-2018 (NOAA 2019). The majority of this rise has been due to the urban heat island effect as Gila Bend's (a more rural municipality) annual average temperature has risen by just 2.5 °F from 1903-2013, mostly due to climate change (NOAA 2019). It can be expected then, that as the temperature in the County continues to rise (Figure A3), more water will be required to irrigate the same crops and that the efficiency with which that water recharges to the aquifer will diminish.

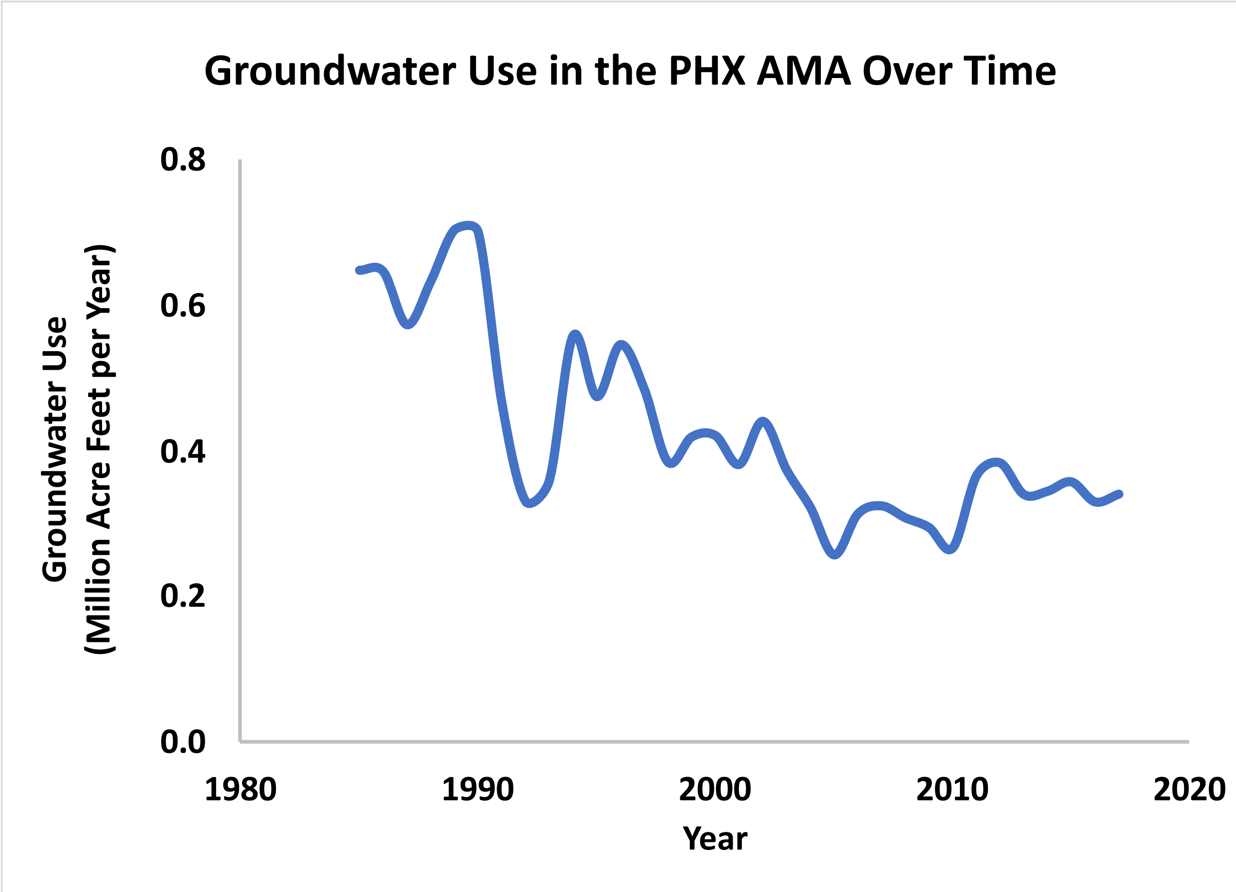


Figure 6. Groundwater use for agricultural irrigation in the PHX AMA (Phoenix Active Management Area) over time (ADWR 2018).

The Gila River Indian Community:

Introduction

As a historically agricultural community, the Akimel O'otham and the Pee Posh, who now make up the Gila River Indian Community, the Salt River Pima Maricopa Indian Community, and the Ak Chin Indian Community relied on local surface water to sustain their society and reproduce their food system in the Sonoran Desert near modern day Phoenix, Arizona. This section will focus on the Gila River Indian Community (herein 'the Community'), their food system's history, their water and land challenges, and their opportunities and movement towards a self-determined food system.

A History of the Community's Food System

First encounters by the Spanish in the late 17th century tell of a politically autonomous, agriculturally based, and self-sufficient society intimately connected with their river and their environment. At that moment in time the Akimel O'otham were fully food sovereign, being able to exercise substantial agency as a community over their food system (Nyéléni 2007). It is important to note that they were able to do so while maintaining a biodiverse ecosystem with sustained marshes, groves, meadows of native grasses, beavers and their dams, native animal and bird populations, thick tree canopy shading the banks and narrow stretches of the river which kept the water cool for abundant native fish, and a water table high enough to reach the deep tap roots of mesquite trees which formed thick bosques (PMIP 2018).

Foods eaten by the Akimel O'otham included fish, maize, tepary beans, squash, mesquite beans and pods, lima beans, grain amaranth and grain chenopod. From this time to the late 19th century the Akimel O'otham joined with their new community partners, the Pee Posh, to cultivate vast acres of wheat, introduced by the Spanish. The contemporary U.S. border crossed the Community in 1854 with the U.S. making the Gadsden Purchase. By 1859 a reservation was set up for the Community. By 1873 the Community had to fend off men sent by U.S. President Ulysses Grant who were to discuss removal to Oklahoma with the Community (PMIP 2018).

Thus began the Community's relationship with American empire and its colonizers. They came from the east and began diverting the Gila River just above the Community to the point that crops failed for Community farms year after year. Lack of water drove starvation and forced migration to the Salt River north of the Community, thus creating the contemporary Salt River Pima Maricopa Indian Community (Rogers & Edmiston 2013). They deadly famine lasted decades and forced the Community to turn to the exploitation of their natural resources and enter the then territorial Arizona economy and garner the monetary means to purchase foreign food.

Community members spurred the growth of a young Phoenix with a supply of fuel wood cut from their mesquite bosques. Within 12 years they had cut over 100,000 acres to avoid starvation (PMIP 2018). Sentiments at this time express the desire for a return to a self-sufficient Community. One member was quoted in 1895 as saying;

> Until the past few years we have always had plenty of water to irrigate our farms, and never knew what want was. We always had grain stored up for a full year's supply. We were happy and contented. Since the white men came and built the big canals and acequias we have no water for our crops. The Government refuses to give us food and we do not ask for it; we only ask for water, for we prefer to earn our living if we can. (PMIP 2018 Water Settlement Chapter 4 page 3)

This sentiment carried through to tribal leadership who began a century's long task of advocacy and litigation through the web of a still evolving U.S. legal system.

Water Litigation and Settlement

Beginning with supreme court case *United States v. Winters* in 1907, tribes were guaranteed enough water to fulfill the purpose of the reservation which has been interpreted liberally to include enough for all practically irrigable acreage, the tribe's history, their economy, and culture (United States v. Winters in 1907; Arizona v. California, 1963; Lewis 2005). This decision and the Globe Equity 59 decision gave some 'paper-water rights' to the Community but further litigation dragged on for decades in quantifying, protecting and receiving funds to eventually receive 'wet-water' (for a full review, see Rogers and Edmiston 2013). Following a 1992 contract with the Secretary of the Interior to receive Central Arizona Project (CAP) water, what is now known as the Pima Maricopa Irrigation District was formed.

Importantly, this agency was formed using the Indian Self-Determination and Education Assistance Act of 1975 which meant that the tribally staffed and controlled agency would have substantial control over the projects while obtaining funding from the federal government. In 2004, after decades of negotiations with numerous parties, President George W. Bush signed the Arizona Water Settlements Act which quantified the Community's water rights from a variety of sources to total 653,500 acre feet per year as well as $200 million to construct the necessary delivery infrastructure (AWSA 2004). This globally-significant and landmark settlement is rightly canonized with the historic *Mabo v. Queensland* (1992) case in Australia and the Native Title Act (1993) that followed, which similarly recognized the priority and legitimacy of indigenous rights to their land and water (Tsatsaros et al. 2018). However, like the Australian case, the Gila River Indian Community still faces significant barriers to realizing the objectives of these hard-won rights (Feller 2007).

Much of the settlement water (ca. 50%) comes from the Central Arizona Project which is over allocated and in decline due to climate change as described above (Christensen et al 2004). Additionally, the impending shortage declaration will cut back a portion (ca. 16%) of the Community's CAP water. Since breaking ground in 1998, the Community has been continually at work developing a state of the art delivery system for the use of their water.

Box 2:
Health Implications of Water Deprivation
and a Comparable Community

In 1900, one case of diabetes was documented in the Community (Hrdlicka 1908). In 1937 there were 21 cases (Joslin 1940). After less than 100 years, the Community now has among the highest reported age and sex adjusted prevalence of type 2 diabetes in the world at 38% (Shultz et al. 2006). The Community also has among the highest reported sex adjusted prevalence of obesity in the world at 69% (Shultz et al. 2006). 47% of Community members live on incomes below the federal poverty line and 35% of adults have not graduated high school (ADHS 2018). The unemployment rate stood at 27% in 2017 (ADHS 2018). This Community will contrast with any. However, a related O'otham community high in the mountains of Sonora Mexico that split from the U.S. O'otham 700-1000 years ago provides a test case for environmental and social determinants of health (Esparza-Romero et al. 2015).

The food system of the Mexican O'otham resembles the food system of the Akimel O'otham's before colonization. Protected in the high Sierra Madres, the Mexican O'otham did not have an outside vehicle access road, piped water, or central electricity until the 1990s (Shultz et al. 2006; Esparza-Romero et al. 2015). In the Mexican O'otham's diet, meat and animal products are rare, and corn and beans are staples. Nearly 70% of Mexican O'otham have a family garden and most have a larger plot away from home where they cultivate the staples of their diet. Nearly everyone eats food from the local land and gardens, and all ages participate in food production (Begay et al 2011).

Hard physical labor in the fields is common among men (40 hours per week) whereas long hours of light labor is common among women (74 hours; Ravussin et al. 1994). Another study used a standardized method to say that Mexican O'otham exert 27.5 hours of physical activity per week while the U.S. Akimel O'otham exert only 7.6 hours per week, a 3.6-fold difference. Consequently, sex-adjusted obesity prevalence among the Mexican O'otham is low at 13% of adults and the age and sex-adjusted prevalence of type 2 diabetes is 6.9% (Shultz et al. 2006).

They plant and harvest fruit trees, corn, beans, squash, potatoes, onions, garlic, chili, tomatoes, herbs and greens in addition to wild edibles. Planting patterns have persisted in this ejido-style subsistence society. Land surrounding the community is held and worked *in common* and governed by locally elected representatives. As a testament to the social capital of the community, the sharing of garden proceeds is common and, following deforestation by the local lumber mill, the community engaged in a reforestation effort (planting trees) that will explicitly only benefit future generations (Begay et al. 2011). In short, their traditional food system is still robust and serving them well; they have substantial food sovereignty (Nyéléni 2007.

Current Land Challenges in the Community

Following the General Allotment Act of 1887, which forced the American style private property regime on the Community, 26% of the Community's land was divided up amongst nearly 5000 members. Each member received a 10 acre irrigable plot and a 10 acre non-irrigable plot such that 67% of the irrigable land today is held in allotment status. With that, greater than 95% of agricultural lease acreage is from allotted lands. The land fractionation process created by General Allotment endlessly splits inherited land generation after generation which significantly encumbers Community members using or leasing the land. The Pima Agency, which oversees leases as the signatory for the Secretary of the Interior, reports that 121,136 individual allotment shares are owned by tribal members and nearly two-thirds of these are for less than $1/5^{th}$ of an acre (allotments are not owned by Community members in fee simple, the federal government maintains ownership in trust for the allottees). Leasing these lands requires that a majority of the allottees agree to it, that the growers fill out myriad forms *and* go through the National Environmental Policy Act process, and, if that were not enough obstacles, growers must often acquire loans for start-up capital that are hard to come by and often have extensive demands because <u>allotted land cannot be used as collateral</u> (i.e. they are not owned in fee simple by the allottees; DeJong 2014).

Community Food System Vision

Through the Pima Maricopa Irrigation District, the Community has put forth a bold vision of their future food system. They wish to again become the breadbasket of Arizona and restore their agricultural heritage and create a vibrant farm economy. They wish to produce large quantities of commercial products such as animal feed, cotton, cattle, and dairy and sell them on world markets. This is a vision of a food system where commodities are sold to support the profits of farmers and potentially the Community. At the same time, they wish to reinvigorate their traditional foods and environment through the establishment of a regional seedbank and several riparian habitat areas which are used by community members for fish and craft materials like devils claw and arrow-weed. Finally, they wish to grow traditional foods such as tepary beans and corn in order to reduce diabetes rates (PMIP 2018).

Current Food Sovereignty Initiatives

In line with their vision, District 7 of the Community has a riparian restoration easement which has resulted in the successful locating and raising of bald eagles as well as the establishment of native cottonwood and mesquite (GRTV 2015). Additionally, the Community now participates in groundwater replenishment which simultaneously creates substantial vegetation and habitat for local birds which the Community is now turning into a recreation and trails site (GRTV 2016a). Another initiative is the Community Garden Project which is grant-funded by two diabetes prevention programs, the Gila River Health Care Life Center and the Tribal Health Department's Genesis Program. Two employees maintain a ¼ acre in-ground demonstration garden where the primary goal is to get members to come and learn how to garden so that they can become self-sufficient in growing healthy food and taking control of diabetes. The project has also distributed nearly one hundred ready-to-plant raised beds to community members along with potting soil and technical assistance (GRTV 2016b).

Another food sovereignty initiative is the District 3 Sacaton O'otham Language Class which organized a baithaj harvest (saguaro fruit) in 2016. Youth O'otham and their elders were brought together to learn about the environment, their traditional heritage, their harvest ceremonies, and all the while, their language (Gila River News 2016). It is important to juxtapose these initiatives with the most current data from the United States Census of Agriculture which describes the majority of the Community's irrigated farmland being planted in commercial commodities by farmers who do not self-identify as "American Indian or Alaskan Native" (see Figure 7 below; USDA 2012).

Discussion

The future of food sovereignty in the Community is uncertain. The vision statement cited above was set for the year 2020. As of 2019 it seems that many of their goals have not been met. The most recent diabetes and obesity data available are from 2003 so health effects cannot be analyzed here. DeJong (2014) suggests that agricultural land in recent years has not increased. Allotment is still in effect, though, the Indian Land Consolidation Act may have alleviated the situation slightly. The Community is not yet "the breadbasket of Arizona" nor do they grow traditional crops in large quantities.

Going forward, DeJong (2014) has suggested that the Community may want to consider an agricultural development agency to help new member growers overcome the numerous obstacles to beginning a farm as described above. Continued progress on the water infrastructure promises a secure future in agriculture but ensuring that Community members are the ones doing the growing and that traditional crops are being consumed locally remains a distant challenge that demands transformative solutions to yet unresolved problems such as the high unemployment, low educational attainment, high disease rates, as well as the substantial risks involved in a commercial venture in a monetized capitalistic economy. New and old forms of collective action are necessary to regain food sovereignty (Figueroa 2015). In this sense, regaining language, traditional knowledge, and cultural practices may allow for the youth Community members to emerge unencumbered in a new political moment more suitable to progressive change or to advance a revolution to decolonize their food system and retake their food sovereignty (Corntassel 2012; Grey and Patel 2015).

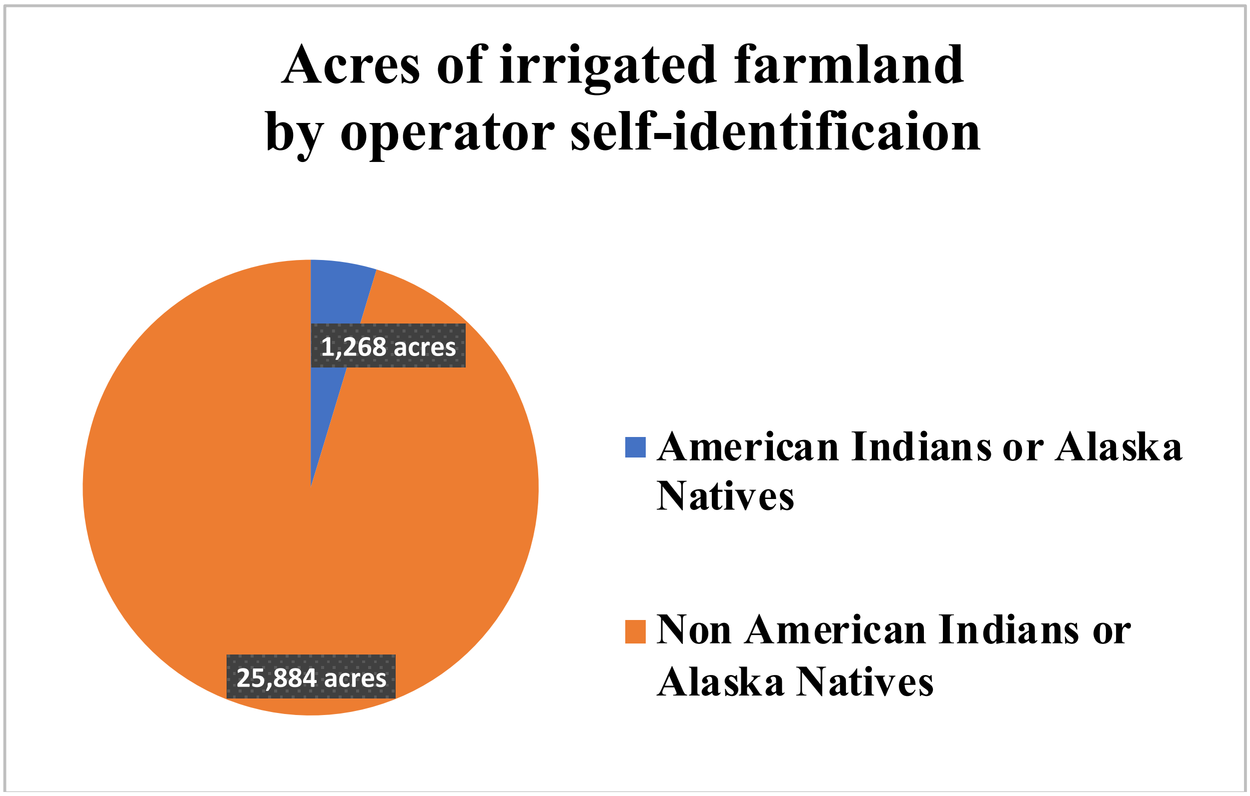


Figure 7. The distribution of irrigated farmland acreage by principle operator self-identification. Of the 27,152 acres irrigated, only 5% are principally operated by a(n) "American Indian or Native Alaskan". The principal crops grown are forages and cotton (USDA 2012).

Synthesis and Discussion: Intervention Points and Comparable Food System Anecdotes

Local food in the Sonoran Desert remains a distant mirage for most County residents and Community members. Both the Colorado River priority system and the Arizona Groundwater Management Act were legislated such that Maricopa County would not be able to support a viable local food system of any significant scale if the urban population continued to grow as it did in the

20th century. Both of these pieces of legislation were prudent reactions to the magnitude, pace, and style of urban development in the region. The ever-sprawling suburban model of development in the County and the continual growth in its population forced higher-levels of government to step in and make certain that drinking water for those people would be ensured. The lack of appropriate governance at the municipal level to enforce water-smart, desert-adapted development ultimately did the County in for any prospects of having a local food system. Both the paving over of farmland and the transfer of agricultural water rights to municipal water rights all but ensured that commercial-scale agriculture in the region would decline. It must be assumed that planners and elected officials over the past century foresaw the effects of such development styles and made the conscious choice that the County's food system would become import dependent and supplied through regional and global industrial trading systems.

Box 3:
The Justice Brothers Ranch

The Justice family has been in Arizona since 1885 and in Maricopa County since the turn of the century. The Justice Brothers Ranch was founded in 1928 and over the years has grown cotton, alfalfa, and wheat, though now they primarily raise cattle for slaughter, forage crops, and citrus. The farm has about 200 acres but leases another 200 acres putting the Justice Brothers Ranch in the top 10% of farms in Maricopa County by size. Selwyn Justice, age 30, is the fourth-generation to work this ranch and has seen first-hand the quick-paced urban development approaching his family's farm.

As a member of the McMicken Irrigation District, Selwyn is accustomed to cooperating with his neighbors and the ADWR to access groundwater. This irrigation district, like many others across the valley, employs a one landowner, one vote system for electing their board. The ranch used to have one active agricultural groundwater well, but minor seismic activity crushed the well casing, rendering it useless. However, due to the good relationships and good infrastructure within the district, the ranch now buys water from a neighbor.

Most of the citrus from the ranch is sold and consumed locally. It is sold together with other local growers at farmers markets as well as at their own U-Pick operation. However, the ranch hasn't always used these channels and has had to respond and adapt to the urbanization of many other citrus orchards. When asked about how these pressures affect his plans for the future, Selwyn said, "I'd like to stay here forever, but our processing has gone away. We used to be a Sunkist grower, then we sold to a middle man between us and local consumers. Now we operate with a direct-to-consumer U-Pick operation." This story, of development removing local food assets, resonates for many in the valley that remember the citrus orchard presence and the picking, processing, and packing jobs that came with them. The ranch's meat sales too are moving from an intermediary model to a direct-to-consumer model with the idea of doing their own on-site processing in the future.

When considering if the ranch is at risk from the quickly expanding development, Selwyn notes that the land is in a fly-zone for Luke Airforce Base and as such, there is a residential building moratorium. However, their neighbor recently sold their land to an industrial developer. When lamenting the style of development he has witnessed and the lack of infill and high density housing, Selwyn said, "As long as I have to share the valley with this kind of development, I'm frustrated." As a family farm that has been around since the dawn of Arizona statehood, the Justice Brothers Ranch has seen the urban core grow out to them year after year and seen countless farms lost to it.

Selwyn's daughter is 6 years old and his goal is to afford her the same opportunity he had on the ranch through at least high school. When contemplating the way that the region's market in land has failed to preserve valley farms over the past few decades, Selwyn concluded, "The idea of using houses as an investment opportunity as opposed to shelter, there's something wrong with that. A house is supposed to be a home not a speculative investment."

- Interview with author on 2/25/19.

More than half of all the cropland ever created in the County has been converted to urban development (~55%; Knowles-Yánez et al. 1999; USDA 2017; USDA 2019). With this hemorrhaging of farmland over the past 80 years and the way that the tightly controlled and regulated water environment is structured to operate, the most pragmatic mode of action for building a local food system is (1) protecting the remaining acres the County has left from further development and retirement and (2) working to convert those acres to the production of food for local consumption.

In a best-case scenario, where all of the remaining farmland is converted to producing food for local consumption and the County population remains at its current level, it was estimated that **up to 10% of County residents could be sustained year-round on a typical American diet** (See Appendix 2 for calculations, methods, and details). Briefly, models of the amount of land and water the typical American diet requires were adapted to Sonoran Desert growing conditions and then evaluated using the County's currently available amount of water and land for agriculture. This yielded estimates of how many people consuming the typical American diet could be sustained by County agricultural resources.

Other scenarios, such as only the production and consumption of only fruits and vegetables were evaluated. Using the 2010 United States Department of Agriculture Dietary Guidelines for Americans recommended amount of fruit and vegetable consumption and how they would be grown in the Sonoran Desert, it was estimated that the entire County's population could meet their recommended fruit and vegetable intake, year-round, from local production alone (Appendix 2). The remainder of this report will discuss the barriers and potential pathways to achieving these best-case scenarios.

Halting Farmland Loss

Any meaningful attempt at halting the loss of farmland in the County to urban development requires deeply seeded ideas to be challenged. For the past century, the development pattern of Maricopa County has been remarkably consistent with the average amount of land required for each additional person remaining constant through that time (Jenerette and Wu 2001). Indeed, the majority of agricultural land that was converted to urban uses became residential housing (Keys et al 2007). This is a favorable transition from a water perspective because it results in less water used per acre overall (ibid). Jenerette and Wu (2001) as well as Maricopa Association of Governments (2019a) have predicted that, if current population growth trends and land use development patterns continue, agricultural land will virtually disappear in the coming decades (potentially as early as 2038). In the past and in the future, net domestic migration has been and will continue to be the primary cause of population growth in Maricopa County (U.S. Census Bureau 2019; Arizona Office of Economic Opportunity 2018). Net domestic migration is easier to control than natural increases (i.e. births minus deaths). However, a more effective and less intrusive mode of curbing the loss of farmland is to regulate urban development in favor of infill, renovations, and high-density buildings. This can be done in direct partnership with existing farms.

For example, Wayne County, Pennsylvania has preserved 3,333 acres of farmland on 35 farms by purchasing the development rights of that land. This means that they have an agricultural conservation easement put in place on that land in perpetuity that only allows the land to be used for agriculture and restricts development of any other sort (Wayne County Agricultural Development Board 2011). Farmers who have a strong connection to the land and wish to preserve farming as a way of life for their children and for their community will enter into these legally binding agreements. In another example, Hadley, Massachusetts zones agricultural and urban core land uses such that one acre of farmland within the agricultural zone is granted development rights to 2,000 square feet of additional floor space for urban core buildings that can be sold to those wishing to build in the urban core zones (Township of Hadley, 2016). Other creative means of preserving farmland and incentivizing infill should be evaluated.

Transitioning Existing Farmland

Significant barriers exist for transitioning the already existing County farmland to a production regime that produces food for local consumption. Most notably, the amount of food produced and consumed locally is not quantified by any sources known to the author. However, the 2017 USDA Census of Agriculture now enumerates two special categories of total commodity sales that can serve as proxies for locally and regionally consumed foods produced by County farmers. The first totals all edible food for human consumption sold directly to consumers through farmers markets, farm stands, U-Pick operations, and CSAs (Community Supported Agriculture; USDA 2017a). In 2017, 164 farms sold $16,809,000 worth of food through these direct to consumer market channels (there is a large margin of error in this estimate; USDA 2017). The nature of these direct market channels allows for the reasonable assumption that these locally produced foods are also being consumed locally. To put this in perspective, this figure represents 1.4% (between 0.0% and 3.2% with 95% confidence) of all the farm sales for the County in 2017. Put another way this figure represents $3.90 per County resident per year or 0.14% of the average American's annual food budget (USDA 2017a).

The other useful measure is the value of edible food for human consumption sold directly to retail markets, institutions, and food hubs such as supermarkets, restaurants, schools, hospitals, workplace cafeterias, prisons, and food banks. In 2017, 44 County farms sold $126,358,000 worth of food through these channels which, by their nature, allow for the assumption that the food was consumed regionally (USDA 2017). In perspective, this figure represents 10.5% (between 4.8% and 17.3% with 95% confidence) of all the farm sales for the County in 2017. Put another way this figure represents $29.39 per County resident per year or 1.08% of the average American's annual food budget (USDA 2017a). These two estimates show that locally consumed food represents a small portion of the food that County Farmers produce *and* a very small proportion of the food that County residents consume.

The barriers to organizing production towards local food for local consumption are too numerous to detail here. However, several potential mechanisms that are not otherwise visible were illuminated through the research process and will be described here. First, it became clear that there has been a 'ruling class' of cash-crop farmers that have dominated production since such numbers have started being kept (1925) and right up to the present. Since that time about 50 farms have controlled two-thirds of the County's agricultural land (USDA 1925-2017). These farms are larger than 2000 acres each. While this pattern was unique to the County during the 20th century, it is no longer. Indeed, the entire United States now has a similar distribution of agricultural land and equipment (Peterson & Brooks 1993). County cropland, specifically, also shows this pattern. These large farms predominantly grow water intensive crops such as alfalfa and cotton, meaning that the majority of the County's agricultural water is used by about 50 farms (see Appendix 4). This high-concentration cash crop model has not, in its decades long existence, yielded a thriving local food system in the County.

Box 4:
The Cuban Example

In 1959, farmland ownership in Cuba was concentrated much like it is today in Maricopa County. That is, Maricopa County farmland distribution today is much like that of Cuba 60 years ago. In 1959, 8% of all farmers controlled 70% of the farmland in Cuba (Sinclair and Thompson 2001). For Maricopa County in 2017, 3% of all farmers controlled 73% of the County's farmland (USDA 2017). Following the 1959 revolution, Cuba redistributed farmland from foreign and domestic *latifundios* (large cash-crop farms) to state run *latifundios* such that, by the beginning of 1990's, more than 80% of the farmland was held by the state sector in *enormous* parcels (32,000 to 76,000 acres on average; Chan and Roach 2011). These farms focused on three cash-crops for export: tobacco, coffee, and sugarcane which covered more than half of the country's agricultural area (Funes-Monzote 2008). This model of large cash-crops sold for export is similar to that of modern-day Maricopa County (which focuses on alfalfa and cotton). Then, in 1991 the Soviet Union, Cuba's main trading partner (and supplier of agricultural inputs) collapsed.

During Cuba's "Special Period" of the 1990's following the collapse of their main trading partner and while they were still under the burden of the longstanding trade embargo imposed by the United States, renewed intensity in Cuban agriculture was required to meet the food demand that previously was met with imports. This was accomplished in large part by breaking up the concentrated cash-crop farms and distributing the land to small farmers who produced food for local consumption. In 1993, most of the state farms were devolved into a new form of socialist production called Basic Units of Cooperative Production (UBPCs) which became the largest productive sector of the agricultural economy (Chan and Roach 2011; Sinclair and Thompson 2001). These cooperatives are worker owned and worker managed where members decide what to produce, how to produce it, who to sell it to, and what to do with the profits. Most employ a salary that is tied to individual productivity as well as a share of the overall profits which is tied to the productivity of the whole. The UBPCs, other cooperative models in the country, as well as small individual and family-owned farms, are models of production that have led to the successful transition towards locally-oriented, sustainable and healthy food production in Cuba (Altieri and Funes-Monzote 2012).

In addition to the rural reforms mentioned above, urban and peri-urban agriculture has flourished to such a degree that farmers in and around cities across the country have been able to produce *the majority* of the fruit, vegetables, and leafy greens that the country requires (Altieri and Funes-Monzote 2012; Wright 2008; Sinclair and Thompson 2001; Willot 2013; Chan and Roach 2011). Additional merits of this system include farmer incomes that surpass the national average. Furthermore, Cuban agriculture is characterized by high levels of social capital that facilitate the sharing of farm equipment, seeds, fertilizers and other inputs, and normalize the provisioning of 10-30% of their crops to schools, hospitals, and childcare centers (See Willot 2013 p 51).

Cuba ensured the success of their reforms by outlawing the private sale of farmland. There, farmers could only sell to the state or deed the land to a relative. Thus, Cuba preempted the tendency for concentration that runs rampant in a more-free market of land (Chan and Roach 2011; Sinclair and Thompson 2001). This style of agrarian reform is currently unconstitutional and illegal in Arizona (see Section 2 Article 17 of Arizona's Constitution and Title 12 Chapter 8 Article 2.1 of the Arizona Revised Statutes). Municipalities and the state should work to amend/overturn these legal barriers to redistribution. However, innovative and legal solutions can be pursued in the meantime (e.g. Sustainable Iowa Land Trust).

By their nature, large cash-crop farmers that grow fiber (cotton) and feed (alfalfa) crops disallow the production of food for local consumption and have done so in the County for decades. The principle barrier identified here is that the large cash-crop farmers get to decide what is planted on the majority of Maricopa County's crop acres, and they do not plant food for local consumption. This ability to be unaccountable to local democratic forces is conferred by the concentration of the means of production and is a well-known failure of private property and modern capitalism. That is, large farmers that produce cash-crops for impersonal (and often distant) commodity markets can not only (1) ignore and insulate themselves from local communities (which require a robust and meaningful relationship with their farmers to have a thriving food system), but (2) they can also bend state and local politics to further entrench their position of power, as they have done in the County before with the passage of Arizona's Agricultural Employment Relations Law in the early 1970's (see Arizona Revised Statutes Title 23, Chapter 8, Article 5; **Box 5**; as well as Dean and Reynolds 2006; and Gutierrez 2012).

Box 5:
Cesar Chavez in Maricopa County

In 1972, Cesar Chavez and the United Farm Workers (UFW) came to Maricopa County to organize farmworkers against Arizona's Agricultural Employment Relations Law. He reportedly lost 30 pounds during a 24 day fast in protest of this law. When it was passed, the UFW gathered the necessary signatures (>100,000) to institute the first recall of an Arizona Governor in history, though this process languished in the courts before it could take effect (Dean and Reynolds 2006). This law criminalizes many of the effective organizing tactics employed by farmworkers and their unions including storefront boycotting and union organizing on the farm while protecting the "management rights" of farmers to determine how much farmworkers get paid, which crops to plant, who does what work, and what to do with the profits, among others. These measures all but ensure that a corrosively unequal power structure will persist between farmers, farmworkers, and local communities. Indeed, it is this inequality that forced County farmworkers to sleep beneath the citrus trees in makeshift housing made of orange crates where they were paid less than the federal minimum wage (Kovacs 2019; Dale and Casey 2016; Morin 1977). These sorts of abuses continue in the County right up to the present. In 2017, farmworkers picking watermelons, onions, and potatoes at an El Mirage farm were forced to live in makeshift housing made of converted school buses and semi-trailers during the hot (>110°F) summer months (Vandell and Gomez-Rodriguez 2017).

Anti-trust legislation has traditionally broken up monopolies in the U.S. that co-opt a sector of the economy. However, instead of the federal government applying these laws to farms, they have *encouraged* concentration through explicit agricultural policy. The famous "Get Big or Get Out" policy of the Secretary of Agriculture, Earl Butz, accelerated the consolidation of farms into bigger and bigger holdings.

This report concludes the following: (1) If farmland continues to be lost as it is, then there will soon be no viable farms to produce local food in significant quantities. (2) If the high-concentration cash-crop model of agricultural production has not yielded even a modest local food system in Maricopa County over the past century, then it can be expected that it will not in the future and a change is in order. (3) If a few big farms use the majority of the County's land and water to make their profits and are not helping to build a vibrant local food system that is healthy, equitable, sustainable, and thriving, then a newly organized system of production is necessary.

Successful models of how to make such a transition on a large scale have been documented (see **Box 4** above). Adaptations of such models to the County's circumstances could be fruitful. A future where substantial segments of the County's diet are supplied by County farms is still possible, but highly unlikely unless the loss of farmland is halted soon and transformative changes in the organization of production and distribution are realized.

Appendix 1
Crop water requirements in the Phoenix Active Management Area

Crop	Irrigation Requirement (acre-feet per acre)	Crop	Irrigation Requirement (acre-feet per acre)	Crop	Irrigation Requirement (acre-feet per acre)
Grain Crops		**Vegetable Crops**		**Vine Crops**	
Barley	2.1	Beets	2.5	Cantaloupe	2.2
Oats	1.8	Broccoli	2.6	Honeydew	2.5
Sorghum Grain	2.1	Cabbage	2.4	Watermelons	2.3
Wheat	2.2	Carrots	2.1	**Citrus**	
Corn, Grains	2.1	Cauliflower	2.6	Grapefruit	4.0
Forage Crops		Chili Peppers	3.0	Oranges, All	3.3
Alfalfa	4.7	Corn, Sweet	2.5	**Fruits**	
Alfalfa High Yield	6.2	Cucumbers	2.0	Dates	4.9
Bermuda Grass	3.6	Lettuce	3.2	Peaches	4.2
Permanent Pasture Mix	5.7	Okra	3.0	Olives	2.6
Sudan Grass	2.6	Onions, Dry	2.7	**Nuts**	
Field Crops		Potatoes	2.8	Pecans with Ground Cover	5.8
Cotton	3.4	Tomatoes	2.5	Pecans Without Ground Cover	4.5
Pinto Beans	1.3	Miscellaneous Vegetables	2.5	**Miscellaneous Crops**	
Soybeans	1.9	Summer Squash and Zucchini	2.3	Double Cropped Vegetables	3.3

Figure A1. Water use requirements for crops in the County (ADWR 1999).

Appendix 2
Methods used to calculate the potential for County agriculture to sustain County residents

Following Peters et al. 2016, estimates of how many people County farmland can support were made. Assuming that residents require 2.67 acres per capita per year (national average of the typical American diet), and there are 4.3 million residents in the County, the County would need 11.48 million acres of farmland. It follows that, since the County has 474,000 acres of farmland (USDA 2017) and 641,000 acres of Arizona State Trust Land (which can be grazed; ASLD 2016), 9.7% of County residents could be sustained on a typical diet produced within the County.

These are oversimplified calculations with many assumptions. To get a more relevant estimate, it is instructive to separate out grazing land and cropland. In the typical American diet, 69% of the required land is grazing land, and the rest is some form of cropland (Peters et al 2016). This is similar to how global farmland use portions out for the global average diet. With that, at 0.83 acres per capita per year of cropland required for the typical diet, 3.57 million acres of cropland would be needed to sustain local residents (note that cropland here includes irrigated pasture). The County has 219,000 acres of what Peters et al. defines as cropland (USDA 2017). Together this means that 6.1% of the County's cropland requirements could be met with existing land. Using values from above, the County would require 7.91 million acres of grazing land. With the 641,000 acres of state land mentioned above, the County could meet 8.1% of its grazing land requirement. This is likely an overestimate as this County's grazing land, being a desert with less than 10 inches of rain per year, is less productive than the typical grazing land used in Peters et al. (2016).

To use another method that is relevant to our arid climate, estimates of productive capacity can be made with water requirements. Following Jalava et al. 2014, water requirements of the typical American diet were combined with known values of available irrigation water in the PHX AMA (Phoenix Active Management Area), and crop-by-crop water use figures (provided by the ADWR 3rd Management Plan for the PHX AMA; ADWR 1999) to estimate how many residents could be sustained on that diet through local production. Jalava et al. estimate that the typical American diet requires 1.21 acre feet per capita of water per year. This includes green (rainfall) and blue (irrigation) water. For County estimates, the full 1.21 acre feet per capita per year is used because the desert rainfall (i.e. green water) is much less than the rainfall on farmland used in this study. Additionally, this is likely an under estimate of how much water is required because the County has some of the highest evapotranspiration rates in the country. However, using 1.21 acre feet per capita and the County's population, 5.2 million acre feet (maf) of water would be required. The most recent figure from the ADWR said that the PHX AMA used 0.73 maf of water for agriculture in 2009. This means that with available water, 14% of the County's population could be sustained on a local diet. However, as stated above, water use is much more intensive in the Sonoran Desert.

To set bounds on how much of an overestimate this is, the two datasets use above were combined for further analysis. It was calculated that 1.22 acre feet of water was consumed per acre of cropland per year (non-animal product blue water + non-animal product green water / 0.43 acres per capita per year of non-feed/forage cropland). This figure, 1.22 acre feet of water per acre per year on cropland is below the range of typical crop water use figures in the PHX AMA. Figures from the ADWR's 3rd Management Plan for the PHX AMA suggest that the typical crop requires 2-5 acre feet per acre per year (average of 3.2; ADWR 1999). Thus, using this method to account for increased evapotranspiration in the desert, a more accurate estimate of how many residents could be sustained locally on the 0.73 maf of water available for agriculture range from 3.4-8.5% (average of 5.3%). That is to say, using the water intensity of diet as a metric for how much water the County requires for food production, adapting it to an arid climate, and bounding it by the amount of water the PHX AMA has available for agriculture, up to 8.5% of the County's residents could be sustained by local food production.

Note that the two estimates are close to each other, though they use different methods. Using land alone gives an estimate of 6.1% of the County's residents while using water and land gives an estimate of 5.3%. For the purpose of this report, the conclusion drawn from this analysis is this: **Maricopa County has the potential to feed up to 10% of its residents with food produced within the County.**

Alternatively, production and consumption of only fruits and vegetables was estimated. Using the 2010 United States Department of Agriculture Dietary Guidelines for Americans and following Peters et al. (2016), 0.0481 acres per person per year would be required to produce the recommended amounts of fruits and vegetables. Multiplied by the 4.3 million residents of the County, total amount of land required equals 207,000 acres of cropland. The County has 219,000 acres of what Peters et al. (2016) defines as cropland (USDA 2017). Thus, about 95% of the County's recommended fruit and vegetable requirements could be produced within the County. However, the full 100% is within the margin of error so the conclusion drawn for this report is this: **Maricopa County currently has the potential to supply all of its residents with their USDA recommended amounts of fruits and vegetables from County farmland.**

Assumptions and Limitations: It was assumed that County farmers could reproduce typical yields used in these studies. It is unclear how much of the Arizona State Trust Land within the County is actually grazed. Federal grazing land within the County is also uncertain. Thus, the full amount of Arizona State Trust Land was used to compensate for both the overestimate of state grazing land and the exclusion of federal grazing land. For instance, some of the State Trust land is used for mining and some is protected for wildlife and/or recreation, while some Bureau of Land Management and Tonto National Forest land is likely used for grazing. It is a limitation of this analysis to paper over these uncertainties, but the estimates are acceptable for the purposes of this report.

The role of diet must be stressed here. Both estimates use average diets for Americans. Both studies referenced tested the effects of different diets on the amount of resources required. Jalava et al. 2014 found that shifting the typical American diet to a healthy vegan diet of recommended proportion and quality would reduce total water consumption by 35%. Similarly, Peters et al. 2016 found that shifting the typical American diet to a healthy vegan diet would reduce total land demand by 88%. That is to say, Maricopa County could potentially sustain more than 2.6 times as many residents (i.e. 19.8% of the County's population) in comparison to the above estimates, on existing land, if residents adopted this diet while sparing all their required grazing land for ecological regeneration.

Appendix 3
Inequality and the means of agricultural production in the County:

In 2017, the top 3% of farmers (that's roughly 50 farmers) controlled two-thirds of all the agricultural land in the county on farms larger than 2000 acres each (see Figure A1 below; USDA 2017). This is not a new pattern. In 1925, the top 1% of county farmers (roughly 40 farmers) held two-thirds of all the farmland on farms larger than 1000 acres (USDA 1925). This distribution has remained entrenched every year since the USDA began counting it in the County. This pattern used to be unique to the County but is no longer as the entire United States now has a similar distribution of agricultural land and equipment (Peterson & Brooks 1993).

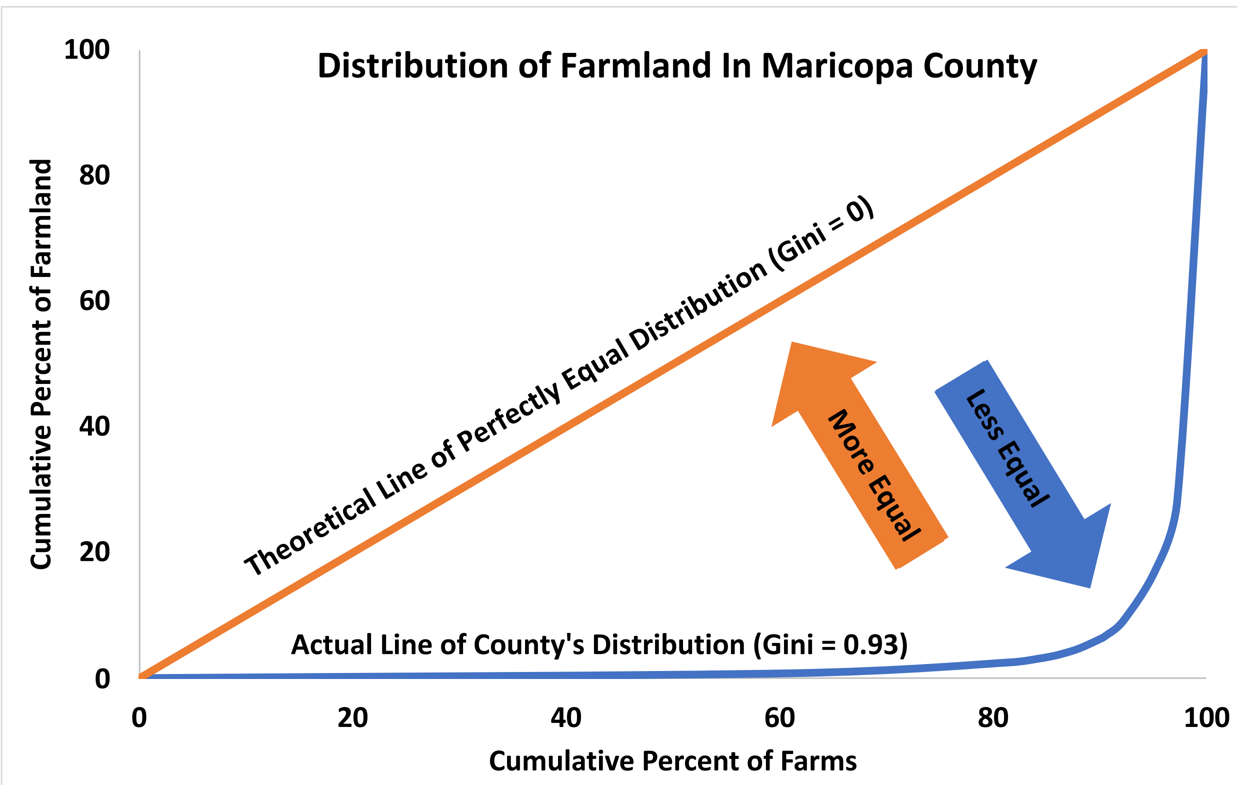


Figure A1. A Lorenz Curve showing the distribution of farmland amongst farmers in Maricopa County in 2017. The orange line represents a hypothetical scenario where every farm is the same size (perfect equality; Gini coefficient of 0) and a right triangle would represent a scenario where one farm owned all the farmland (perfect inequality; Gini coefficient of 1). The blue line shows how Maricopa County's distribution is skewed towards inequality as indicated by the large Gini coefficient of 0.93 (USDA 2017).

This same pattern is evident in the distribution of all agricultural goods in the County from vegetable production, to farm labor, to cattle, and others (USDA 2017). No deliberate redistribution system exists as it does with, for example, personal income, where taxes redistribute the wealth earned by individuals that year to the community. Due to this dearth of redistributive policies in agriculture, extreme concentration towards the top is the tendency. Concentration of land and other resources has many consequences for a society and local food systems.

Appendix 4
Methods for estimating agricultural overdraft in the County:

Overdraft is defined as taking more water from an aquifer than is replaced on a year to year basis. A farmer could overdraft by taking out 3 acre feet of water from the County's aquifer and only replacing 2 acre feet in a given year. The main way that farmers replace water is actually incidental to their operations. When they apply water to the soil, a portion of that water seeps into the groundwater and makes its way down to the aquifer (which takes ~20 years in the County). This portion is highly variable and depends mostly on temperature, soil texture, and crop type. All else being equal, the amount of incidental recharge is lower (1) during the hot summer months, (2) with high clay soils, and (3) with crops that transpire a lot of water or have a lot of bare soil exposed between the rows. The ADWR uses a figure of one-quarter to one-third of all water that falls on or is spread on agricultural fields is recharged to the aquifer below. The ADWR, with this assumption, estimates that roughly one-third of the County-aggregated contemporary agricultural groundwater use is overdrafted (i.e. 'mined'; ADWR 2018). Thus, farmers, as a whole, accrue a debt to the aquifer every year because they extract *1.5x as much groundwater as they replenish*.

To estimate the amount of groundwater overdraft that County farmers as a whole are directly responsible for, the ADWR's water use data was combined with the USDA's Census of Agriculture data (ADWR 2018; USDA 1900-2017). The ADWR dataset only goes back to 1985 but provides reliable relationships that were used to parameterize a model of water use on the irrigated acres enumerated by the USDA Census of Agriculture back to 1900. Specifically, the ADWR data set was used to show that the average water use per acre is ~4 acre feet per acre per year and that ~33% of the water applied to the soil is recharged. Furthermore the 1982 County USDA Census of Agriculture data provided estimates of the proportion of County acres that are irrigated with groundwater vs. surface water. It was estimated that 53.77% of irrigated acres in the County in 1982 used 'On Farm Wells' with the remaining 46.23% of irrigated acres using 'On Farm or Off Farm Surface Water'. This aligns with the ADWR dataset which estimate that, in 1985, 51.18% of agricultural water in the PHX AMA was sourced from groundwater. These two estimates are crucial because they represent the water portfolio available to farms before CAP and reclaimed water came into existence. Lastly, the USDA Census of Agriculture data for irrigated land only goes back to 1945, however, harvested cropland goes back to 1900. For the years 1900-1940 harvested cropland was used instead of irrigated land as they have shown to be related in the County during the years 1945-2017 by a near 1:1 linear relationship (irrigated land = 1.045*harvested cropland;R^2 = 0.88).

By considering the portfolio of water used by farmers and using the conservative one-third recharge figure mentioned above as an assumption, this report estimates that cumulatively, during the period from 1985-2017 County farmers overdrafted 5.2 million acre feet of groundwater, an amount equivalent to 15 years of agricultural groundwater use at 2017 levels**.** Using a model calibrated with the modern data, the cumulative historical groundwater debt exacted by farmers from 1900-2017 was estimated to be 9.3 million acre feet of groundwater, or 27 years of agricultural groundwater use at 2017 levels.

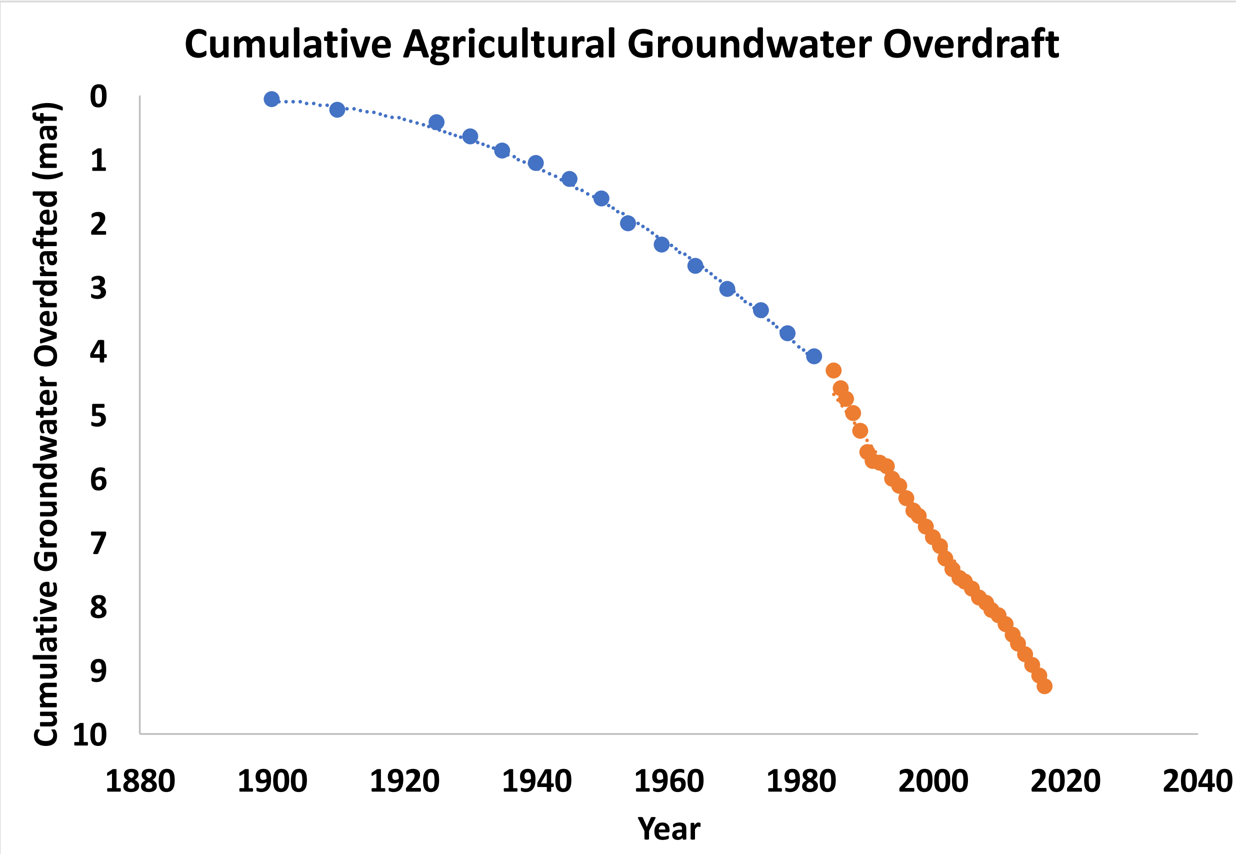


Figure A2. Cumulative agricultural groundwater overdraft form County farmers from 1900-2017. The orange dots and line are data taken from the ADWR dataset while the blue dots and line are the modeled overdraft of the USDA data parameterized with the ADWR data (ADWR 2018; USDA 2018).

In Figure A2 it is noted that groundwater overdraft is not declining at the rate predicted by the loss of cropland detailed in this report. In fact, the ADWR dataset computes that the incidental recharge rate has been declining linearly from 33% of surface-applied water in 1985 to 23% of surface-applied water in 2017. Some of this decrease is likely related to the increased evapotranspiration induced by the increased temperature the Phoenix Metro Area has experienced over that time (NOAA 2019; Figure A3). The Phoenix Metro Area's annual average temperature has risen by 6.5 °F from 1895-2018 (NOAA 2019). The majority of this rise has been due to the urban heat island effect as Gila Bend's (a more rural municipality) annual average temperature has risen by just 2.5 °F from 1903-2013, mostly due to climate change (NOAA 2019). It can be expected then, that as the temperature in the County continues to rise (Figure A3), more water will be required to irrigate the same crops and that the efficiency with which that water recharges to the aquifer will diminish.

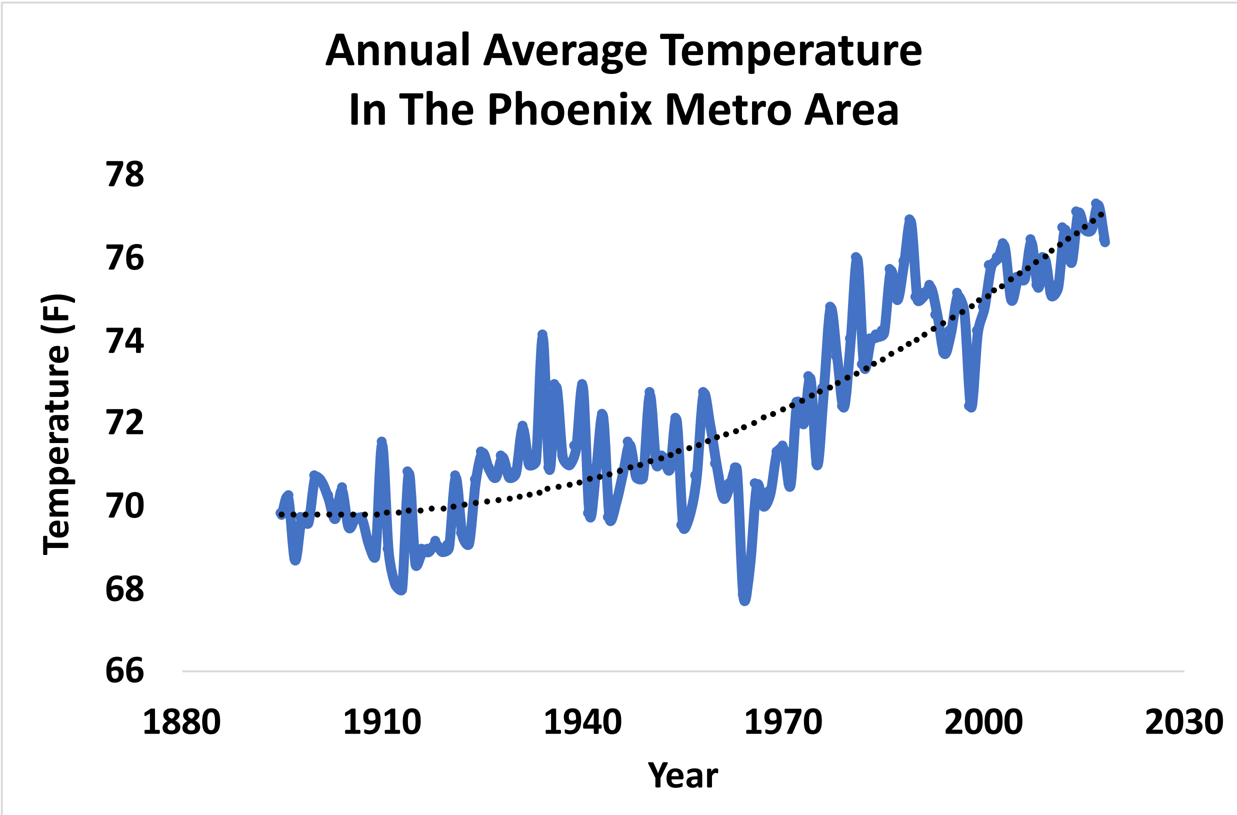


Figure A3. Annual average temperature for the Phoenix Metro Area from 1895-2018. Note the 6.5 °F rise since the late 19th Century. Most of this rise can be attributed to the urban heat island effect while some can be attributed to regional effects of global climate change (NOAA 2019).

References:

ADWR. 2018. Arizona Department of Water Resources. Phoenix Active Management Area Annual Water Use Data Historic Template and Summary 1985-2017. Retrieved from https://new.azwater.gov/ama/ama-data

ADWR. 2014. Arizona Department of Water Resources: Geographic Information Systems. Arizona Irrigation Districts Map and Groundwater Level Changes in Arizona Years 1993-2013 Map.

ADWR. 2010. Arizona Department of Water Resources: Arizona Water Atlas.

ADWR. 1999. Arizona Department of Water Resources: Phoenix Active Management Area 3rd Management Plan.

Altieri, M. and Funes-Monzote, F. 2012. The paradox of Cuban Agriculture. Monthly Review January 2012, 23-33.

Arend C, Beckwith D, and Stitzer L. 2017. Arizona's Water Future: Colorado River Shortage, Innovative Solutions, and Living Well with Less. Wester Resource Advocates.

Arizona State Land Department. 2016. Annual Report.

Arizona v. California. (1963). 373 U.S. 546.

ADHS (Arizona Department of Health Services). 2017. Gila River Indian Community Primary Care Area Statistical Profile. Bureau of Women's and Children's Health.

Arizona Office of Economic Opportunity. 2018. Population Projections for Maricopa County: Medium Series 2018-2055.

Arizona Water Settlements Act (AWSA) of 2004, Public Law 108-360, 118 Stat. 347

A.R.S. Arizona Revised Statutes: Title 45 Chapter 2 - Groundwater Code.

Barnett, T. P., & Pierce, D. W. (2008). When will Lake Mead go dry? Water Resources Research, 44 (3), 1–10. http://doi.org/10.1029/2007WR006704

Begay et al. 2011. An Exploration of Gardens in Maycoba, Mexico: Change in the Environment of a Population Genetically Prone to Diabetes. The International Journal of Health, Wellness and Society Volume 1, Issue 3.

CAP (Central Arizona Project) 2019. Colorado River Shortage. Retrieved from, https://www.cap-az.com/departments/planning/colorado-river-programs/shortage

Central Arizona Water Conservation District. (2017). “Comprehensive Annual Financial Report For the Fiscal Year Ended December 21s 2016.” Retrieved from https://www.cap-az.com/documents/departments/finance/2016-Comprehensive-Annual-Financial-Report-CAFR.pdf

Chan, M. and Roach, E. 2011. Unfinished puzzle. Cuban agriculture: The challenges, lessons, and opportunities. Food First Books.

Christensen, N. S., Wood, A. W., Voisin, N., Lettenmaier, D P., and Palmer, R. N. (2004). “The Effects of Climate Change on the Hydrology and Water Resources of the Colorado River Basin.” Climatic Change, 62(1-3): 337-363.

Colby, B. G., & Jacobs, K. L. (2007). Arizona Water Policy: Management Innovations in an Urbanizing, Arid Region. Resources for the Future.

Corntassel, J. 2012. Re-envisioning resurgence: Indigenous pathways to decolonization and sustainable self-determination. Decolonization: Indigeneity, Education & Society Vol. 1, No. 1, 2012, pp. 86.101

Dale, M and Casey, M. 2016. Arrowhead Ranch Past: Arizona Undocumented Workers Went On Strike 39 Years Ago. October 3rd, 2016. KJZZ.

Dean D, and Reynolds J. 2006. Hispanic Historic Property Survey: Final Report, Community Expansion and the Struggle For Change, 1957-1975. City of Phoenix Historic Preservation Office.

DeJong D. 2014. Navigating the Maze: The Gila River Indian Community Water Settlement Act of 2004 and Administrative Challenges. American Indian Quarterly. Winter. vol. 38, no. 1

Ellis A, Hawkins T, Balling Jr. RC, Gober P. 2008. Estimating future runoff levels for a semi-arid fluvial system in central Arizona, USA. Climate Research. Vol. 35: 227-239.

Esparza-Romero et al. 2015. Environmentally Driven Increases in Type 2 Diabetes and Obesity in Pima Indians and Non-Pimas in Mexico Over a 15-Year Period: The Maycoba Project. Diabetes Care 2015; 38: 2075–2082. doi 10.2337/dc15-0089

Feller, Joseph M., The Adjudication that Ate Arizona Water Law (2007). Arizona Law Review, Vol. 49, p. 405, 2007. Available at SSRN: https://ssrn.com/abstract=1467835

Figueroa, M. (2015). Food sovereignty in everyday life: Toward a people-centered approach to food systems. Globalizations, 12(4), 498-512. doi:10.1080/14747731.2015.1005966

Funes-Monzote, F. 2008. Farming like we’re here to stay: The mixed farming alternative for Cuba. PhD Dissertation from Wageningen University, The Netherlands.

Gila River Television News (GRTV). 2015. “District 7 Wetlands Report.” Retrieved from http://www.gricnews.org/index.php/pdf-archives

Gila River Television News (GRTV). 2016a. “Our Sun:dag – Water Rights in Motion.” Retrieved from http://www.gricnews.org/index.php/pdf-archives

Gila River Television News (GRTV). 2016b. “Community Garden Project.” Retrieved from http://www.gricnews.org/index.php/pdf-archives

Gila River News. 2016. “Baithaj Harvest with District 3 O'otham Language Class” Published July 11th. http://www.gricnews.org/index.php/pdf-archives

Grey, S. and Patel, R. 2015. Food sovereignty as decolonization: some contributions from Indigenous movements to food system and development politics. Agriculture and Human Values. 32: 431–444. doi 10.1007/s10460-014-9548-9

Gutierrez, G. 2012. Interview # OH-395. Gustavo Gutierrez. July 12, 2012. Tempe Historical Museum: Oral History Project.

Hrdlicka, A. Bureau of American Ethnology. Washington, D.C.: Smithsonian Institution; 1908.

Interior, D. of. (2018). Open Water Data Initiative: Colorado River Basin. Retrieved from https://www.doi.gov/water/owdi.cr.drought/en/#Lifeline

Jalava, M., Kummu, M., Porkka, M., Siebert, S., and Varis, O. 2014. Diet Change: A solution to reduce water use? Environmental Research Letters. Supplementary data retrieved from, https://iopscience.iop.org/article/10.1088/1748-9326/9/7/074016/data

Jenerette, G and Wu, J. 2001. Analysis and simulation of land-use change in the central Arizona - Phoenix region, USA. Landscape Ecology 16: 611-626.

Joslin, E. P. 1940. The universality of diabetes: A survey of diabetic morbidity in Arizona the Frank Billings lecture. J Am Med Assoc. 1940; 115(24):2033–8.10.1001/jama.1940.02810500001001

Keys, E. Wentz, E. and Redman, C. 2007. The Spatial Structure of Land Use from 1970-2000 in the Phoenix, Arizona, Metropolitan Area. The Professional Geographer 59(1), 131-147.

Knowles-Yánez, K., C. Moritz, J. Fry, C. L. Redman, M. Bucchin, and P. H. McCartney. 1999. Historic Land Use: Phase I Report on Generalized Land Use. Central Arizona -Phoenix Long-Term Ecological Research Contribution No. 1, Center for Environmental Studies, Arizona State University, Tempe.

Kovacs, K. 2019. The History of Investigative Reporters and Editors: Chapter 1 - Desert Rats, Phoenix October 1976. Retrieved from https://www.ire.org/about/history

Lewis, Rodney B. 2005. “Gila River Indian Community Water Settlement.” Hard Times on the Colorado River: Drought, Growth and the Future of the Compact (Summer Conference, June 8-10). h p://scholar.law.colorado.edu/hard-times-on-colorado-river/6

MAG. 2019. Maricopa Association of Governments. Maricopa County Planning and Development Department. PlanNet GIS Maps retrieved from https://gis.maricopa.gov/PND/PlanNet/index.html

MAG. 2019a. Maricopa Association of Governments. Land Use Explore: Future Land Use Projections. Retrieved from http://geo.azmag.gov/maps/landuse/

Morin, R. 1977. Illegal Aliens Have Been Striking in Arizona Citrus Groves. Washington Post. October 27th, 1977.

NOAA (National Ocean and Atmospheric Administration) . (2019). Phoenix, Arizona Online Weather Data. National Weather Service Forecast Office. Data accessed from NOWData at https://w2.weather.gov/climate/

Nyéléni. 2007. Nyéléni Forum for Food Sovereignty: Declaration of the Forum for Food Sovereignty. Selingué, Mali, 23-27 February.

Peters, C.J., Picardy, J., Darrouzet-Nardi, A.F., Wilkins, J.L., Griffin, T.S. and Fick, G.W., 2016. Carrying capacity of U.S. agricultural land: Ten diet scenarios. Elem Sci Anth, 4, p.000116. doi http://doi.org/10.12952/journal.elementa.000116

Peterson, N. and Brooks, N. 1993. The Changing Concentration of U.S. Agricultural Production During the 20th Century: 14th Annual Report to the Congress on the Status of the Family Farm. Agriculture and Rural Economy Division, Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin No. 671.

PMIP (Pima Maricopa Irrigation Project). 2018. History of the Gila River Water Settlement Act of 2004. Retrieved from http://www.gilariver.com/settlement.htm

Rascona. 2005. Maps showing groundwater conditions in the Phoenix Active Management Area. Hydrologic Map Series Report No. 35, Maricopa, Pinal and Yavapai counties, Arizona, Nov. 2002 – Feb. 2003, Arizona Department of Water Resources.

Ravussin, E., Valencia, M., Esparza, J., Bennett, P., and Schulz, L. 1994. Effects of a traditional lifestyle on obesity in Pima Indians. Diabetes Care, 17, 9 September, 1067-1074.

Reclamation, B. of. (2012). Colorado River Basin Water Supply and Demand Study. Technical Report B – Supply and Technical Report C - Demand.

Reclamation, B. of. (2018). Lake Mead at Hoover Dam, Elevation (Feet). Retrieved from https://www.usbr.gov/lc/region/g4000/hourly/mead-elv.html

Reclamation, B. of. (2018a). Annual Operating Plan for Colorado River Reservoirs 2018. Retrieved from, https://www.usbr.gov/lc/region/g4000/aop/AOP18.pdf

Reclamation, B. of. (2018b). Upper Colorado Region: Historical Data. Retrieved from https://www.usbr.gov/rsvrWater/HistoricalApp.html

Reclamation, B. of. (2018c). Upper Colorado Region: Glen Canyon Dam. Retrieved from https://www.usbr.gov/uc/water/crsp/cs/gcd.html

Reclamation, B. of. 2019. Colorado Basin River Forecast Center: 24 Month Study, May 1st, 2019.

Rogers, D. & Edmiston, S. 2013. The Gila River Indian Community Water Rights Settlement and its impact on water resource management, Water International, 38:3, 250-262, DOI: 10.1080/02508060.2013.793571

Schulz, L. O., Bennett, P. H., Ravussin, E., Kidd, J. R., Kidd, K. K., Esparza, J., Valencia, M. E. 2006. Effects of traditional and western environments on prevalence of type 2 diabetes in Pima Indians in Mexico and the U.S. Diabetes Care, Volume 29, Number 8, August. pp. 1866-1871.

Sinclair, M. and Thompson, M. 2001. Cuba, going against the grain: Agricultural crisis and transformation. Oxfam American Report.

SRP. 2019. Salt River Project: Elections. Retrieved from https://www.srpnet.com/elections/

SRP. 2019a. Salt River Project: Dams. Retrieved from https://www.srpnet.com/water/dams/default.aspx

Township of Hadley (Massachusetts). 2016. Zoning Bylaw. Section XVII, Farmland Preservation Bylaw. Retrieved on 2/13/19 from, https://ecode360.com/13511544

Tsatsaros, J.H.; Wellman, J.L.; Bohnet, I.C.; Brodie, J.E.; Valentine, P. 2018. Indigenous Water Governance in Australia: Comparisons with the United States and Canada. Water 2018, 10, 1639.

Udall, B. and J. Overpeck. 2017. The twenty-first century Colorado River hot drought and implications for the future, Water Resources Research, 53, 2404– 2418, doi:10.1002/2016WR019638.

U.S. Census Bureau. 2019. Estimates of the Components of Resident Population Change: April 1, 2010 to July 1, 2018 for Maricopa County.

USDA. 2017. United States Department of Agriculture. 2017: Census of Agriculture for Maricopa County.

USDA. 2017a. United States Department of Agriculture: Economic Research Service. Food spending and share of income spent on food across U.S. households in 2017.

USDA. 1900-2017. United States Department of Agriculture: Census of Agriculture for Maricopa County, years 1900, 1910, 1925, 1930, 1935, 1940, 1945, 1950, 1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987, 1992, 1997, 2002, 2007, 2012, and 2017.

USDA. 2019. National Agricultural Statistics Service: Cropland Data Layer for Maricopa County. Retrieved from, https://nassgeodata.gmu.edu/CropScape/

USDA. 2012. United States Department of Agriculture 2012 Census of Agriculture: American Indian Reservations. Volume 2. Subject Series. Part 5 AC-12-S-5.

United States v. Winters. (1908). 207 U.S. 564.

USGS (United States Geologic Survey). (2016). "More than Half of Streamflow in the Upper Colorado River Basin Originates as Groundwater." Retrieved from https://www.usgs.gov/news/more-half-streamflow-upper-colorado-river-basin-originates-groundwater

Vandell, P., and Gomez-Rodriguez, L. 2017. Feds find 'simply inhumane' living conditions for workers at Arizona farm. June 9, 2017. The Republic.

Vano, J., Udall, B., Cayan, D., Overpeck, J., Brekke, L., Das, T., Hartmann, H., Hidalgo, H., Hoerling, M., Mccabe, G., Morino, K., Webb, R., Werner, K., and Lettenmaier, D. 2014. Understanding uncertainties in future Colorado River streamflow. American Meteorological Society. January, 59-78.

Wayne County Agricultural Development Board. 2011. Wayne County (Pennsylvania) Agricultural and Farmland Protection Plan. Retrieved from, https://www.waynepreservation.com

Willott, L. 2013. Food sovereignty in Cuba: A case study of the social support for agroecological farming with a focus on gender through participatory photography. Master of Arts Thesis from the University of Victoria.

Wright, J. 2008. Sustainable agriculture and food security in an era of oil scarcity: Lessons from Cuba. Routledge.