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Agricultural Water Governance in the Desert: Shifting Risks in Central Arizona

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ABSTRACT: In Arizona, the policy debates over the Colorado River Basin Drought Contingency Plans exposed long-running tensions surrounding how we use and value scarce water resources in a desert. These negotiations also highlighted generations-old disputes between indigenous communities' water rights and Anglo settlers. This paper explores how irrigators respond to, and participate in, the crafting of institutional arrangements while at the same time experiencing increased exposure to climatic and hydrological risk. Our analysis incorporates qualitative interview data, a literature review, archival information from policy reports, and secondary data on water use and agricultural production. Building on the fieldwork with farmers and water experts that we completed before the drought contingency planning efforts began, we describe the status quo and then explore potential future contexts based on shifting incentives and on the constraints that arise during periods of Colorado River water shortages. Through an understanding of the socio-hydrological system, we examine the region's agricultural water use, water governance, indigenous water rights and co-governance, and the potential future of agriculture in the region. Our study illustrates how the historic and current institutions have been maintaining agricultural vibrancy but also creating new risks associated with increased dependence on the Colorado River.

KEYWORDS: Irrigated agriculture, drought, governance, climate change, Colorado River, Arizona

INTRODUCTION

Recognising the stressed status of the almighty and all-important Colorado River, in 2007 the Department of the Interior established Interim Guidelines for Lower Basin Shortages and the Coordinated Operations of Lake Powell and Lake Mead with a threshold that would trigger a declaration of shortage and mandatory cuts (US Department of the Interior, 2007). A shortage based on these Interim Guidelines has not been declared, but it is anticipated that this is likely to occur by 2024 (US Department of the Interior and Bureau of Reclamation, 2019). In May 2019, in anticipation of a shortage declaration, the Lower Colorado Basin states – Arizona, California and Nevada – adopted a Drought Contingency Plan (DCP) with a new 'Tier Zero' trigger for cuts that was set at approximately 332 metres above sea level (masl), as measured at Lake Mead. The DCP was developed in order to increase water conservation and raise Lake Mead water levels; the aim was to reduce the likelihood of shortages and of the more substantive cuts based on the 2007 Interim Guidelines (Sullivan et al., 2019). In August 2019, the Bureau of Reclamation projected that Lake Mead levels would fall below the DCP Tier Zero trigger threshold (ibid). While the actual water level at the end of 2019 was above the Tier Zero trigger, the Tier Zero shortage went into effect based on the August 2019 forecast; Colorado River water supplies to Central Arizona were thus reduced (Cullom, 2020). The Tier Zero cuts affected the availability of Colorado River water to irrigated agriculture and intensified debate both in and outside the farm sector about the future of Arizona agriculture. The competing narratives on the shortage expose long-running tensions surrounding how we use and value scarce water resources in the western United States.

The water governance challenges in Arizona and the rest of the arid, western US (Kuhn and Fleck, 2019; Zetland, 2009) are similar to those of many stressed socio-hydrological systems, including in Australia (Grafton et al., 2020), Spain (Varela-Ortega et al., 2016), and South Africa (Bosch and Gupta, 2020); all these systems are faced with the challenges of overlapping institutions, overallocated water systems, and reduced surface water flows due to climate change. The Arizona case also highlights tensions associated with indigenous water rights and settler communities; these tensions include the sovereignty, equity and justice issues that are also found throughout the world (Grafton et al., 2020, Sarna-Wojcicki et al., 2019; Wilson, 2020). Our analysis provides insight into how agricultural irrigators respond to historical and current sociopolitical infrastructure and actively participate in its formation. Following an approach similar to that of Tellman et al. (2018), we examine how perceived risks shift in response to the interaction between historically dominant water use and cropping patterns, and climate change; we look at the resultant water supply issues, at how decision-making is affected, and at the potential motivation for institutional change. We highlight how water conservation proposals – such as best management practices (BMPs) – perversely increase consumption, and we consider the ways in which, without new institutional changes, the current drought contingency planning efforts are likely to lead to groundwater overdraft. At a global level, these insights are relevant to understanding the challenges for irrigated agriculture and the governance of water-stressed systems.

LITERATURE REVIEW

We use a socio-hydrological system framework which situates irrigators' decisions within an environment that contains both socio-hydrological risk and institutions that shape choice sets (York et al., 2019; Eakin et al., 2017). Institutions are part of the sociopolitical infrastructure; their relationships with other natural infrastructure such as land, and with social, knowledge and hard infrastructures such as canals, wells and reservoirs create the incentives and constraints that shape farmers' irrigation decisions (Eakin et al., 2016). Farmers' choices are further structured through their 'mental models', or ways of thinking, and through their narratives about change and the future (Bausch et al., 2015). Mental models and narratives about water management and governance shape, and are shaped by, policy models (Eakin et al., 2019; Molle, 2008), scientific information (Bremer et al., 2020), and local and indigenous knowledge (Grafton et al., 2020).

In Central Arizona, the climatic-hydrological system has experienced extended drought for several decades (Udall and Overpeck, 2017). These dramatic conditions, often mediated by underlying institutions and infrastructure, affect farmers' perceptions of socio-hydrological risks (Eakin et al., 2016). Extended drought and shifting weather patterns lead to new information regarding potential outcomes; this information feeds back through the system and affects the mental models of the actors regarding perceptions of risk and potential modes of action; shifts in the dominant narratives can sometimes occur (Bausch et al., 2015). The essential feature of feedback systems is that over time they give rise to persistent structures (Anderies et al., 2019). These patterns, persistent on a decadal time scale which is relevant to human perception, this can create inertia and impede more fundamental change. Infrequently, rapid changes such as significant policy shifts or extreme weather conditions can generate swift change in mental models, action situations, and the environment; policy entrepreneurs are sometimes able to usher in new institutions and motivate collective action during these periods of change (Mintrom and Vergari, 1996). Adaptation is a critical issue in most socio-hydrological systems that are facing climate change (Sivapalan et al., 2012); there is, however, a gap in use-inspired research on this issue that may faciliate these changes (Sivapalan et al., 2014). There is also a need to develop the kind of information about the socio-hydrological system that would enable thoughtful participatory discussions with diverse stakeholders (Damkjaer and Taylor, 2017).

Throughout the arid and increasingly water-scarce regions of the world, debate over continued water-intensive agricultural practices is intensifying. In Australia's Murray-Darling Basin during the recent Millennial Drought (2001-2009), water markets emerged which reduced agricultural water consumption; agriculture persisted, but with a reduction in low-value water-intensive crops and increased use of imported feed to maintain dairy practices (Kirby et al., 2014). Grafton et al. (2020) argue that the perceived success of these changes was "post-truth" due to a failure to recognise and incorporate indigenous rights and knowledge and a scientific understanding of the system. In Spain, informal water exchanges have long existed and were codified in 2001, leading to transfers away from low-value agricultural production (Palomo-Hierro et al., 2015). Giannoccaro et al. (2013) noted the low volume of trading; through surveys of farmers' perceptions, they concluded that the relative lack of transfers could be attributed to farmers' unfamiliarity with the new water markets and their unwillingness to participate except under financial duress.

In the Arizona case, intersectoral water transfers and surface water markets exist, albeit in a very different form. Arizona has a groundwater banking system whereby enrolled farmers use surface water or effluent to reduce groundwater overdraft and recharge aquifers (Jacobs and Holway, 2004). Irrigation districts historically have entered long-term contracts for surface water and are able to purchase Central Arizona Project (CAP) water through a spot market, but there are long-running conflicts over indigenous water rights (Bark and Jacobs, 2009). Drought planning in Arizona has focused on decision-support systems (Jacobs et al., 2005) and on the inclusion of this information to support adaptation, especially in cities (Gober et al., 2016). Farmers, however, also need to respond to changing climate and temperature (Berardy and Chester, 2017). As the region faces a mega-drought, response and adaptation is not merely a question of decision-support and information, but also requires an understanding of how institutions drive irrigators' choices and how farmers drive institutional change.

METHODS

We developed an interpretative research paradigm for our in-depth case study; multiple sources of data were used, including interviews, policy documents, and literature (Hemingway, 1990; Schwandt, 1994;

Creswell, 2009). Interviewees were selected using a purposive sampling strategy (Patton and Patton, 1990; Miles et al., 2014) to achieve maximum variation among respondents, based on sector and stakeholder domain. Over two years (2011 to 2013), we conducted semi-structured interviews with 32 stakeholders involved in agricultural production, with water policy experts, and with climate experts who worked with the farm community (Table 1). This data informs our understanding of the existing socio-hydrological system. We complemented our qualitative interviews with an archival analysis of secondary literature, policy documents, and media accounts of historical and proposed policy changes.

Table 1. Summary of interview participants.

Participant description	Number of individuals interviewed
Cooperative extension agents	3
Agricultural finance experts (US Department of Agriculture agents, commodity marketing service providers, credit providers)	4
Farmers (alfalfa, cotton and dairy)	4
Farmer representatives (lobbyists, representatives from farmers organisations)	4
Irrigation district managers	5
Researchers (agricultural statisticians, agronomists, climatologists, historians, regional planners)	7
Other water experts (consultants, lawyers, regulators)	5

CENTRAL ARIZONA AGRICULTURE

Water-intensive irrigated agriculture persists in the rapidly urbanising, arid central region of Arizona; 223,099 hectares (ha) are under production and over US$2 billion[1] in direct commodity sales accounts for 53.7% of the state's agricultural production (Table 2). Cotton, hay and durum wheat have historically dominated this region. Maricopa and Pinal Counties are hubs for dairy production, which drives the demand for hay as an input and as a means for nutrient management for manure (Martin et al., 2006) (Table 2).

Table 2. Characteristics of agricultural production in Central Arizona.

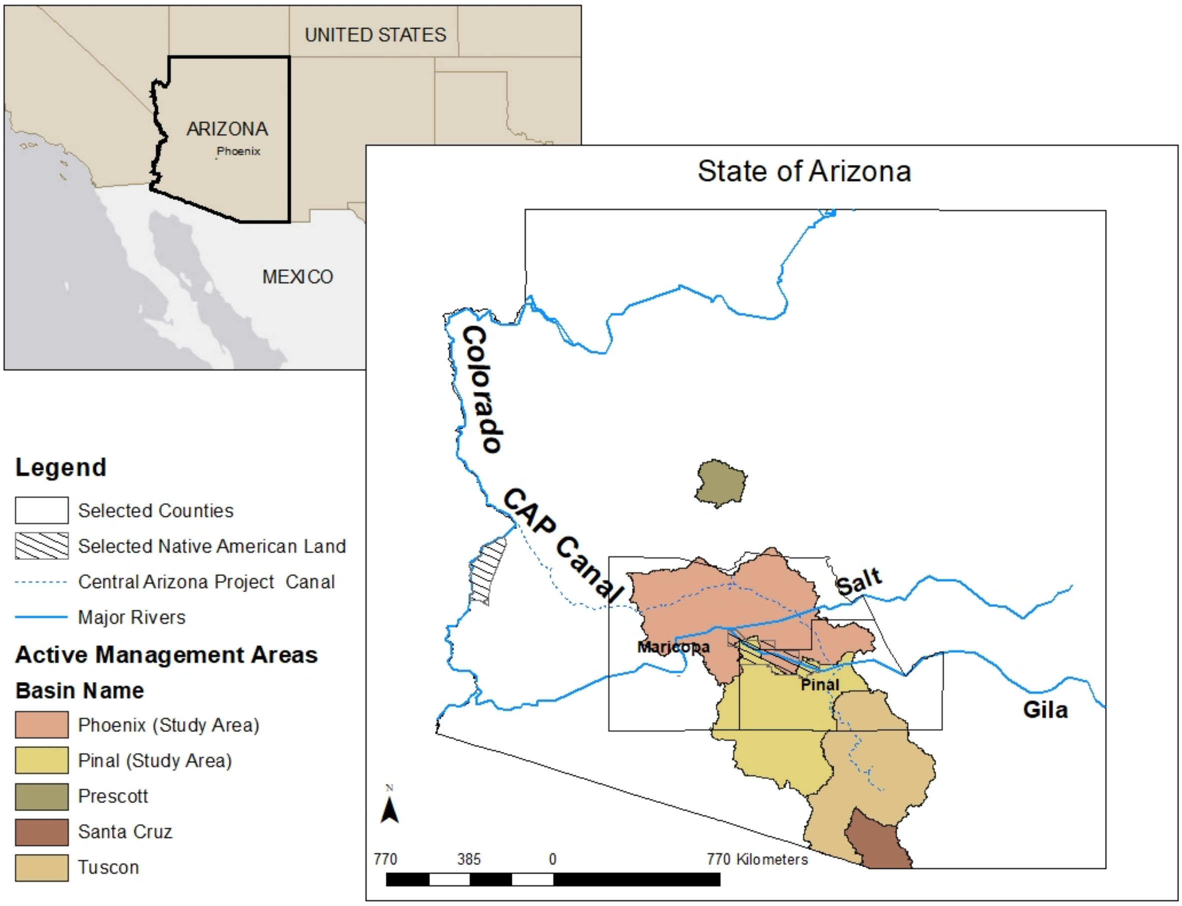
	Maricopa County	Pinal County
Land in farms	191,672 ha	425,737 ha
Top three crops	Forage, including hay and haylage (41,329 ha), cotton (11,174 ha), vegetables (9183 ha)	Cotton (35,595 ha), hay and haylage (31,359 ha), wheat (10,501 ha)
Dairy cows	121,778	66,319
Total commodity sales (10^9 US$)	1.209	0.862
% of Arizona's total agricultural value	31.4%	22.4%

Source: National Agricultural Statistics Service (NASS, 2017). Note: ha = hectares.

[1] All dollar amounts are in US dollars.

Agriculture's contribution to the local economy includes direct, indirect and induced multiplier effects. In 2015, the estimated overall contribution of agriculture to the economy of Maricopa County was $1.95 billion (Duval et al., 2018); in 2016, agriculture contributed an estimated $1.1 billion to Pinal County's economy (Bickel et al., 2018). Sustaining crops in the deserts of Central Arizona requires extensive irrigation; this comes from three primary sources: groundwater, surface water from the Salt and Gila Rivers, and Colorado River water that is delivered through the Central Arizona Project (Figure 1).

Figure 1. Map of the Central Arizona study area.



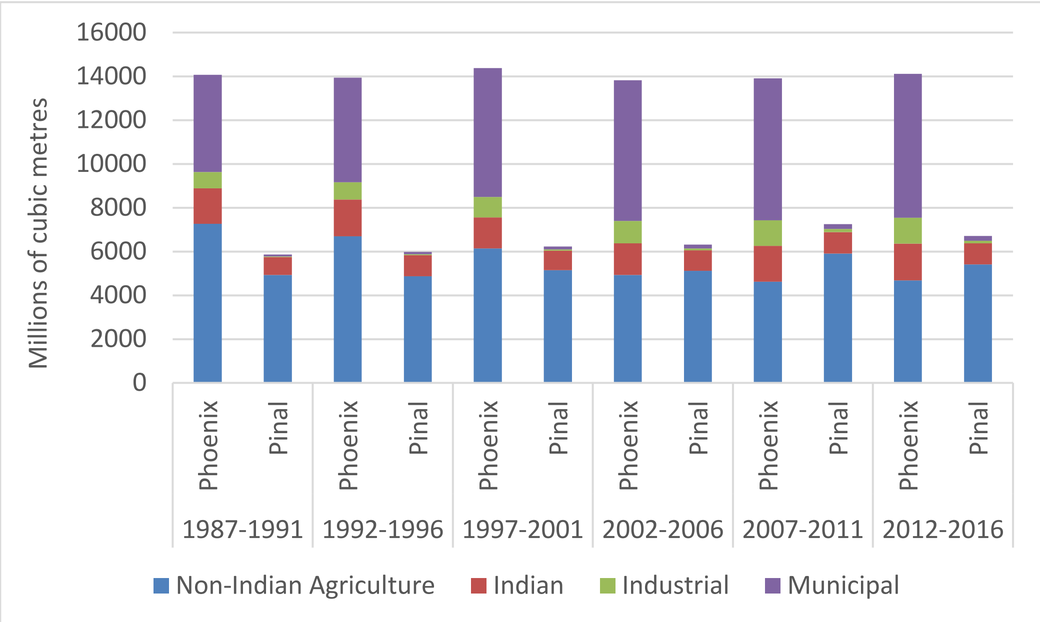
Source: ESRI and CAP Canal (2019); ESRI et al. (2011); ESRI and kjones_azgfd (2019); ESRI and jperezez48_asu (2020); ESRI and intern_ft (2019); ESRI and OTSGS (2015).

Since 1980, Active Management Areas (AMAs), established through the *Groundwater Management Act* (GMA), have limited water use for agricultural irrigation and restricted the expansion of irrigated agriculture. In our study area, Maricopa County is mostly overlaid by the Phoenix AMA, and Pinal County by the Pinal AMA; our study focuses on agriculture in these management areas (Figure 1), which are in a region that is under increased stress due to the changing availability of Colorado River water. (Rural desert lands without irrigated agriculture fall outside of AMAs and are not included in our analysis.)

The *Groundwater Management Act* established quantified rights that were based on historic irrigation use within AMAs. An Irrigation Grandfathered Right (IGFR) certificate was given to farms with acreage that was irrigated entirely or partially with groundwater in any year between 1975 and 1980. The total annual number of irrigable acres was established according to the highest number of irrigated acres in any single year during the 1975 to 1980 period (Megdal et al., 2008). Water duties refer to the amount of water (from all sources) per irrigable acre per year (Frisvold et al., 2007). Farms may substitute groundwater for surface water or vice versa, depending on their decreed and appropriative rights to surface water or through their irrigation district's contracts with the Central Arizona Project for Colorado River water; the total amount of water from all sources, however, may not exceed their duty. The IGFR certificate and associated water duties may not be transferred off-site to other agricultural lands outside the farm unit, but they are transferable with the farm when sold (Ashley and Smith, 1999); they may also be 'extinguished' in order to generate credits for assured water supply for other uses when the parcel is developed (ADWR, 2020a). Farmers may bank unusued water duties for use in a future year, which is referred to as having 'flex credits'; flex credits may be used to legally exceed an annual water duty or can be sold to other farms within an irrigation district or water subbasin.[2]

Under the *Groundwater Management Act*, the state of Arizona monitors water use according to four different sectors: 1) indigenous water use, labelled 'Indian', which includes agricultural, municipal and industrial uses on Indian lands, 2) non-Indian agriculture, which is defined as agricultural activity on non-Indian lands, 3) industrial uses, and 4) municipal uses. Municipal and industrial uses are often combined into a single category, 'M&I', and are defined as uses on non-Indian lands. Water demand has decreased for agriculture and has increased for municipal use in Phoenix (although demand across all four sectors has remained steady); in Pinal, agriculture remains the dominant use (Figure 2).

Figure 2. Central Arizona water demand by sector, 1987 to 2016.

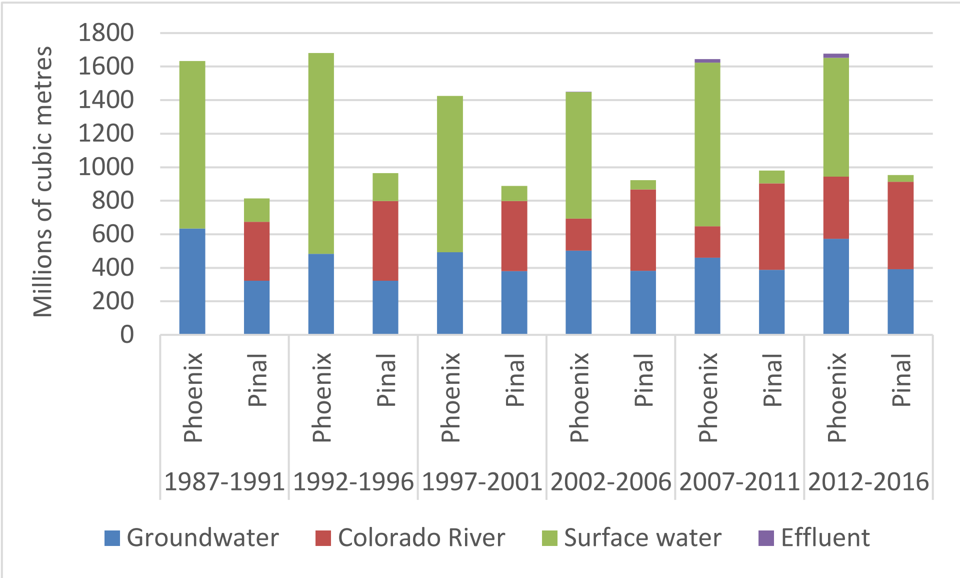


Source: Arizona Department of Water Resources (ADWR, 2020b).

Completion of the Central Arizona Project enabled access to the Colorado River, shifting the sources of water supply for farming, especially in Pinal (Figure 3).

[2] The use of flex credits is limited to the amount banked by the farmer two years prior to the Arizona Revised Statutes § 45-467[O].

Figure 3. Central Arizona non-Indian agricultural water sources, 1987 to 2016.

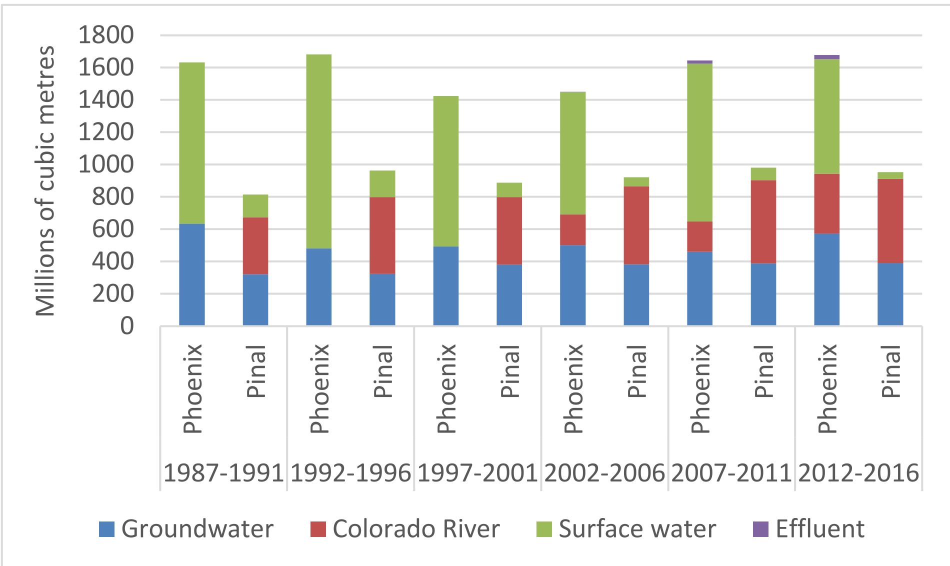


Source: Arizona Department of Water Resources (ADWR, 2020b).

In both Phoenix and Pinal, groundwater remains the primary source of water for irrigated agriculture, although the mix of sources has shifted over time to become increasingly reliant on the Colorado.

The majority of Indian-sector water demand is for agricultural water use; between 1985 and 2015, agricultural use of water averaged 99.6% in the Phoenix AMA and 96.4% in the Pinal AMA (ADWR, 2020b). Indigenous communities in the Phoenix and Pinal AMAs rely on a mix of water sources; in Pinal the source most used by Indian communities is the Colorado River and in Phoenix the main source is 'other surface water'; the second-most important source in both areas is groundwater (Figure 4).

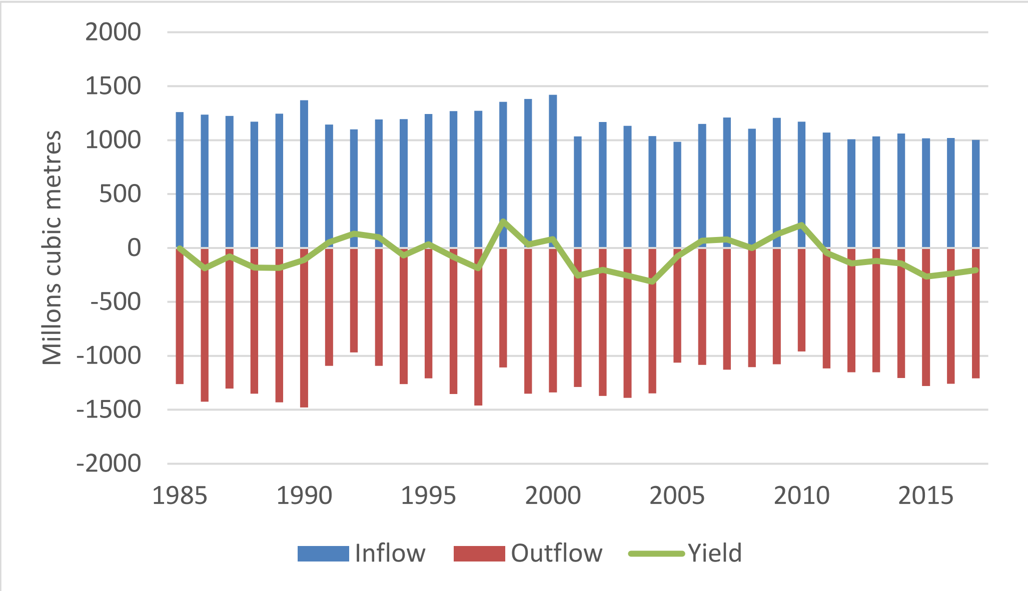
Figure 4. Central Arizona Indian water sources, 1987 to 2016.



Source: Arizona Department of Water Resources (ADWR, 2020b).

Water duties are based on water demand; return flows and incidental recharge do not affect the volume of allowable water use at the farm level that is set by the GMA; these return flows and recharges, however, are critical for the state's water conservation goals and are monitored to ensure that downstream users' decreed water rights are met (Glennon and Pearce, 2007). The incidental recharging of the aquifer that is associated with non-Indian agriculture and with (mainly agricultural) Indian water use is quite sizable (Figure 4). Recharge has decreased since 1987, but between 2012 and 2016 13% percent of total water demand in Phoenix and 25% in Pinal became recharged groundwater inflow. Safe yield is defined as a long-term balance of annual groundwater inflow versus outflow. This groundwater policy approach was considered innovative at the time of its adoption (Maguire, 2007) and still is one of the primary conservation goals of the Phoenix AMA. One of the mechanisms for achieving safe yield has been the conversion of irrigated agricultural land to residential use and the extinguishment of irrigated agriculture water duties during the development process (White, 2013; Bausch et al., 2015).

Figure 5. Phoenix Active Management Area safe yield, 1985 to 2017.

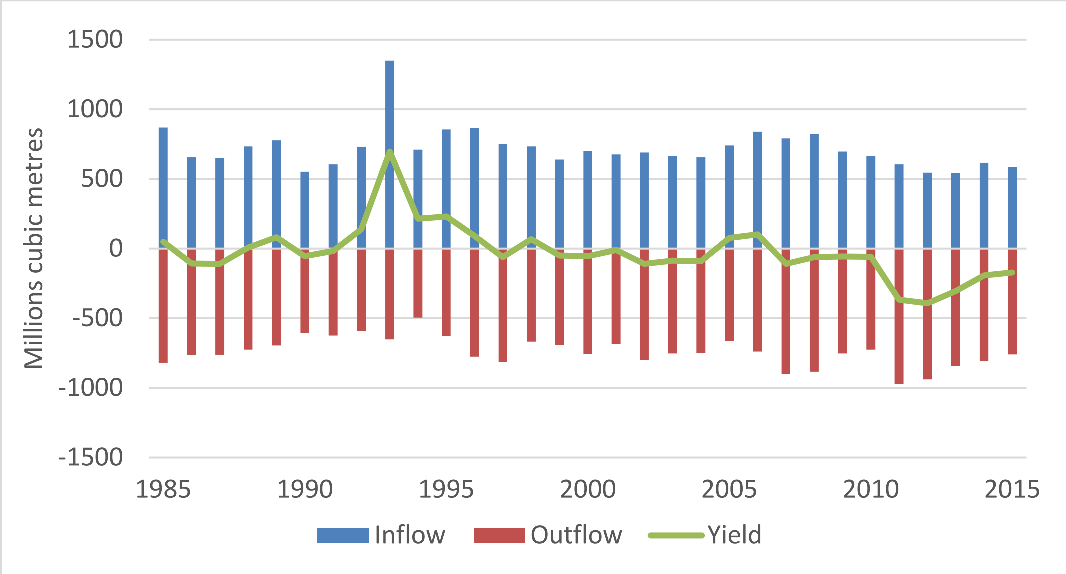


Source: Arizona Department of Water Resources (ADWR, 2020b).

In Phoenix, the GMA, the retirement of farmland, and access to Colorado River water are credited with stopping groundwater overdraft; this can be seen in Figure 5 with the yield line close to 0 (inflows equaling outflows). Recently, there is even evidence of uplift of land due to water recharge into groundwater storage facilities in Phoenix (Miller and Shirzaei, 2014).

Over the past two decades, Pinal has witnessed a slowdown of aquifer overdraft and a reduction in subsidence; even so, the management plan for the area remains focused on a controlled drawdown in order to maintain the agricultural economy (Larson and Payne, 2017). There are no specifics in Pinal's current management plan as to how long agriculture should be preserved nor how much water should remain in the aquifer for non-irrigated agricultural purposes (ADWR, 2020d).

Figure 6. Pinal Active Management Area, 1985 to 2015.



Source: Arizona Department of Water Resources (ADWR, 2020b).

The Arizona Department of Water Resources (ADWR) is currently developing the fifth management plan for each Active Management Area; it sets conservation goals such as safe yield. The Department of Water Resources leads these efforts, with public input through an AMA Groundwater Users Advisory Council and numerous public hearings. Historically, management planning has either led to institutional innovations and change or has become mired in division (Ballester and Mott Lacroix, 2016). Management plans should advance conservation goals in an incremental fashion that is tailored to the heterogeneity of each area in the state while maintaining state control of the process (Megdal et al., 2008). Within Pinal, there is an emerging sustainability debate as to whether the current goal of a strategic drawdown of the aquifer to support agriculture is desirable and equitable for the AMA as a whole (Allhands, 2020). Before addressing the future trajectory of Arizona water and agriculture, we will explore how Arizona water institutions have led to the current situation.

ARIZONA WATER GOVERNANCE

In 1864, with the passing of the Howell Code, the newly formed Territory of Arizona codified the prior appropriation doctrine, also known as "first in time, first in right"; this doctrine allowed landowners to divert surface water onto their land. Owners held exclusive rights to the diverted waters and the water rights were tied to the parcel; in times of shortage, water would be provided based on seniority of water rights (Dunbar, 1983). Prior appropriation underpins all surface water claims in the state. In the late 19th and early 20th centuries, water development in Central Arizona focused primarily on the Gila River and its stems, the Salt and Verde Rivers. These rivers were quickly (over)appropriated for agricultural use (Zarbin, 1995; August and Gammage, 2007). Newly formed irrigation districts allowed the creation of an extensive canal infrastructure system, much of which was based on an ancient Hohokam irrigation system that traversed the Phoenix valley (Larson et al., 2005). The United States Reclamation Service built the Roosevelt Dam on the Salt River in 1913; it went on to build the Coolidge Dam on the Gila in 1928, by which time it had been renamed the United States Bureau of Reclamation (USBR); these projects increased the capacity of these systems to store massive amounts of surface water, which in turn allowed a large agricultural system managed by Anglo farmers to flourish in Central Arizona.

Unlike many other western states, Arizona has not regulated ground and surface water through a conjunctive management approach, even though hydrological linkages were recognised early in the 20th century (Smith, 1936). Historically, groundwater was regulated through the English common law tradition, which granted correlative rights to landowners with parcels overlaying the aquifer, with the exception of underground channels; this was determined by the 1904 case of *Howard v. Perrin* (Rusinek, 1985). There were attempts by irrigation districts to obtain the right to regulate groundwater, but these efforts were not successful (Dunbar, 1977). A 1930 Arizona Supreme Court decision, *Maricopa County Municipal Water District No. 1 v. Southwest Cotton*, established the beneficial use doctrine for groundwater, which codified agriculture as a beneficial use (Evans, 2010).

Colorado River governance

From early statehood, the young but rapidly growing arid state of Arizona had its eyes on the hotly contested Colorado River. *Wyoming v. Colorado,* a 1922 US Supreme Court decision, determined that prior appropriation would be applied to interstate river disputes. Because of this, most Colorado Basin states signed and ratified the 1922 Colorado River Compact, which apportioned the Colorado equally between the Upper Basin (Colorado, New Mexico, Utah and Wyoming) and the Lower Basin (Arizona, California and Nevada) (MacDonnell, 2012). Because the Colorado River Compact did not directly address allocation between states, there was a growing political and economic fear in Arizona that a politically powerful and rapidly growing California would appropriate the majority of the Lower Basin allocation (Gelt, 1997). The prior appropriation doctrine requires demonstration of actual beneficial use in order to 'perfect' (establish) a water right. Seniority is determined by the timing of the establishment of the water right. Generally, rights are not reserved for future water development under prior appropriation (although indigenous water rights are different, as discussed below). Because of the need to establish water rights through usage, and the desire of Arizona to grow significantly in the future, the state of Arizona originally refused to ratify the Compact.

The state finally did ratify the Compact in 1944, only after it became clear that it would be necessary to do so in order to secure the Bureau of Reclamation funding that was needed to construct the infrastructure that would deliver Colorado River water to Central Arizona (Gelt, 1997). Even after ratification, Arizona continued to fight with its archrival California over the Lower Basin's apportionment of Colorado River water. Arizona focused on developing future use while California focused on protecting established uses. The dispute led to the 1963 US Supreme Court case of *Arizona v. California* (US Supreme Court, 1963), hereafter referred to as *Arizona*. This monumental decision was a major victory for Arizona, establishing the rights to 3.45 billion cubic metres (Bm$^{3)}$) from the Colorado without needing to first establish use. Within Arizona, the rights to Colorado River water are established through three means: a perfected right that is recognised by the US Supreme Court and listed in a judicial decree; a contract through the Bureau of Reclamation under Section 5 of the 1928 *Boulder Canyon Act*, (as, for example, the contract to the Central Arizona Water Conservation District, which is the entity that provides Central Arizona Project water); and a subcontract through a Section 5 contractor (such as a contract from the Central Arizona Water Conservation District to an irrigation district) (Glennon and Pearce, 2007).

Indian water rights and Arizona

Over the past 50 years, some of the most contentious legal water battles in the western United States have surrounded indigenous water rights. Indigenous water settlements and the Colorado River are inextricably linked in Arizona. *Winters v. United States* 1908 (hereafter referred to as *Winters*) determined that tribes' reservation treaties implicitly included rights to water "sufficient to fulfil the need of the reservation as a homeland". Within the prior appropriation system, the priority of a tribe's *Winters* rights is based on the original reservation treaty date or on 'time immemorial' for tribal nations on aboriginal homelands (Larson and Payne, 2017). Importantly, *Winters* rights are treated as federally reserved water rights (due to tribes' trust relationship with the federal government), which means that they cannot be forfeited by non-use. In Arizona, *Winters* rights, if quantified, typically supersede almost all non-Indian rights in a given basin because most treaties predated major settlement and water use by settlers or because indigenous communities live on their aboriginal homelands (Larson and Payne, 2017; Colby et al., 2005; Sanchez et al., 2020).

Tribes rely on cooperation and representation from the federal government to quantify and establish their rights; this can involve either 1) a negotiated settlement with neighbouring water users, or 2) a judicial decree in state courts. Although *Winters* has provided indigenous communities with significant water rights, some settlements have been less favourable than others, due in part to inadequate representation and to difficulty in establishing what constitutes 'sufficient' water (Getches, 1997). There has been a reluctance in many communities to adjudicate claims because of concern as to whether claims will be more favourably settled in the future; there has also been a more general resistance to the idea that the US federal government should be allowed to make these determinations for indigenous communities (Curley, 2019). We will provide an overview of existing indigenous water settlements and decreed rights with a focus on two communities, the Colorado River Indian Tribes (CRIT) and the Gila River Indian Community (GRIC); these two communities play a central role in Colorado water governance negotiations and in the future of Central Arizona's development.

On the Colorado, one of the most momentous judicial decrees is associated with the Colorado River Indian Tribes; these four distinct tribes – the Chemehuevi, Mohave, Hopi and Navajo – inhabit tribal lands that are located on the Colorado River. The 121,406 ha CRIT reservation was established in what is now Arizona and California in 1865. In the 1963 *Arizona* case, CRIT water rights were quantified, with an annual 816.8 million cubic metres (Mm^3) associated with land in Arizona and an additional 70.4 Mm^3 in California. The judicial decree allows the CRIT community to use the water for any purpose on Indian lands (Colorado River Research Group, 2016), but does not allow selling the leases off of tribal lands (Nania, 2020).

Many indigenous water rights determinations occur through settlements instead of through protracted and costly adjudication in the court system. Beginning with the *Ak-Chin Indian Water Rights Settlement Act* of 1978, Indian water rights settlements have been significant; they have resulted in substantial ramifications for all major water users, especially agriculturalists in Arizona. Because most basins are already fully appropriated, the quantification of *Winters* rights typically requires reallocation of water that is currently being diverted by other users.

Winters and *Arizona* also set the stage for water transfers, or potential transfers, via water leases from indigenous communities. Not all indigenous claims can be leased off of community lands for non-Indian agricultural, municipal or industrial uses; the right to lease the water is established through the Settlement Act and the Secretary of the Interior must approve proposed leases (Colby et al., 2005). The Colorado River Indian Tribes, with rights from a judicial decree in *Arizona*, cannot lease water off of tribal lands; in contrast, the Gila River Indian Community, with rights through the *Arizona Water Settlements Act* of 2004, may lease water off of tribal lands.

In Arizona, 740.1 Mm^3 of CAP water is allocated to tribes, which constitutes 46% of CAP's total supply (Sundust et al., 2019). In 2015, there were 825.5 Mm^3 of mainstem diversions by the CRIT and three other indigenous communities (Colorado River Research Group, 2016). Even though indigenous communities have large high-priority rights and sovereignty, tribal nations did not have a seat at the table for Colorado River Basin water governance negotiations until the drought contingency planning efforts. In 2007, for example, the Colorado River Interim Guidelines were set, but there was not a single representative from tribal nations present at the negotiations (Smith, 2020). According to Governor Stephen Roe Lewis of the Gila River Indian Community, "Tribes need to be at the table when important water decisions are being made (…). [W]e didn't get invited as a community until 2016" (Faller, 2019). The Gila River Indian Community and the Colorado River Indian Tribes had to push to be invited to the table and granted formal roles (Sundust et al., 2019).

The GRIC and CRIT communities were central to the DCP negotiations and were critical to meeting planning targets. In order to move past a stalemate, the GRIC proposed a sale of approximately 1.02 Bm^3 of water – that is, 40.9 Mm^3 per year for 25 years – to the Central Arizona Groundwater Replenishment District (CAGRD). The CAGRD is a water banking authority that enables homebuilders to satisfy Assured Water Supply rules for new homes construction (these rules require builders to demonstrate 100 years of supply). The GRIC lease to CAGRD enabled the sizable housing and economic development lobby to get behind the DCP. CRIT agreed to fallow agricultural lands on the reservation in order to reduce diversions by 61.6 Mm^3 annually, which would help maintain Lake Mead levels. CRIT Chairman Dennis Patch indicated a desire to do more to contribute to the DCP; in a press release, however, he noted the restrictions associated with their water rights, which limit their ability to lease water off of Indian lands (Colorado River Indian Tribes, 2019).

The issues of co-governance and sovereignty are exemplified by the tension surrounding the Colorado River, indigenous water rights, and agriculture. Even though the GRIC and CRIT were pivotal to the DCP, they had to fight to be at the table. During a particularly heated period, the agricultural lobby and its political supporters were frustrated when the GRIC failed to support a proposed lease of GRIC water to Pinal County agriculturalists because of a conflict associated with rights on the Gila River (Jaspers, 2019). The Speaker of the Arizona House of Representatives responded in anger that, "This is just showing their mentality to everybody who gets in their way (…). It's all 'Our way or no way'" (Fischer, 2019). The battle surrounding the proposed lease illustrates the competing mental models of Anglo agriculturalists, their supporters such as Speaker Bowers, and indigenous communities.

Moving beyond the DCP, these competing models shape the contentious debates surrounding the Colorado River and indigenous water rights. Farmers perceive unadjudicated indigenous claims as a risk to future agricultural and water rights. The most substantial unadjudicated claims are associated with the Navajo Nation; at stake is an estimated 308.4 Mm^3 of water in Arizona (Nania, 2020). A recent manifestation of the simmering conflict between indigenous communities and the state of Arizona occurred at a meeting that was ostensibly about resolving ongoing tribal claims; long-running tensions were stoked when several tribal representatives were not allowed to speak (James, 2020). There is also controversy over these negotiated processes within tribal nations: co-governance of water with states and the federal government requires an admission by indigenous communities that they have lost sovereignty, but many indigenous communities have actively resisted federal attempts to govern tribal nations (Curley, 2019). Wilson (2020) argues that co-governing water resources with colonial or settler governments often leads to disenfranchisement for indigenous communities, including beyond the American context. In our case as well, the attempts of indigenous communities to assert agency and maintain sovereignty are evident. These efforts result in competing narratives – and sometimes political conflicts – between indigenous communities and settler agricultural communities.

Competition with indigenous communities over water was a common theme in our interviews with non-Indian agriculturalists. A cotton farmer (Interview no. 0811) asserted that, "There isn't an Indian tribe in Arizona that isn't trying to stick their straw into the Colorado River". The frames of distrust or competition were ever-present in our fieldwork. Approximately 48% of our respondents referred to indigenous water rights issues as being substantive; these included the issues of Indian CAP water allocations (26% of respondents) and Indian water leases for non-Indian uses (13% of respondents). For many indigenous communities, on the other hand, there are substantial concerns about water rights, co-governance and sovereignty. The mental models of Anglo agriculturalists can frame indigenous claims as being either an opportunity or a risk to the future of agriculture. Moving agricultural production from non-Indian to Indian lands is a likely future scenario that we explore in Section 6.

The Central Arizona Project and irrigated agriculture

Most people anticipated that farmers would shift from groundwater to Colorado River water when the Central Arizona Project was completed. The utilisation of Section 5 subcontracts with the Central Arizona Water Conservation District (CAWCD), however, was substantially lower than anticipated because farmers had access to low-cost groundwater or other surface water sources. The estimated cost of CAP water was \$0.096/m^3 while groundwater and water from other surface water sources cost approximately \$0.008-0.029/m^3 (Fuller, 1998). In the late 1980s, as CAP water started to flow into the region, nine irrigation districts filed for bankruptcy protection due to the so-called 'take-or-pay' provision of CAP contracts; this was a provision which required agricultural users to pay a fixed rate on all water available to them in a given year even when not used (Fuller, 1998; Baker, 1995; Wilson, 1997). Because of the lack of municipal and industrial demand, there was a greater than anticipated amount of water available to the agricultural sector; this left irrigation districts responsible for approximately 75% of the operating, maintenance and replacement (OMR) costs, which came to about \$22.5 million (Central Arizona Project, 2016a). Without significant reform, the future of the Central Arizona Project was in question.

To increase non-Indian agricultural use, the CAWCD waived the take-or-pay provision and created what was called a target pricing scheme. This scheme created a lower priority set of pools, the original cost of which was \$0.055/m^3 for pool 1, \$0.042 for pool 2, and \$0.030 for pool 3; each pool became available after the higher cost pool was exhausted (Fuller, 1998). The volume of these pools totalled at least 493.4 Mm^3 annually (Central Arizona Project, 2016a). In exchange, the non-Indian agricultural sector forfeited the Section 5 subcontracts that granted them a right to a percentage of future CAP water; approximately 90% of the agricultural water rights were waived as a result (Fuller, 1998). Irrigation districts that waived their Section 5 subcontract rights were able to purchase water through the target pricing scheme, but they no longer held a Section 5 subcontract water right (Central Arizona Project, 2016a).

Glennon (1995) argued that CAP underutilisation could be shifted to fulfil *Winters* rights. This approach was adopted by Congress in 2004, in the form of the *Arizona Water Settlements Act* and by the Arizona Legislature with the *Arizona Water Settlement Agreement.* The Arizona Water Settlement Agreement permanently shifted CAP water allocations associated with some of the remaining irrigation district subcontracts to indigenous communities; in this way, *Winters* rights were met and the target pricing scheme was replaced with a new 'ag pool' whose prices were equal to the energy costs of transferring water (Central Arizona Project, 2004). The water available from the ag pool would be reduced over time and would cease to exist by 2030. In addition to energy prices for the entire ag pool, the *Arizona Water Settlements Act* enabled any irrigation district using CAP water to "[get] out from under the *Reclamation Reform Act*" (Irrigation expert, Interview no. 0726). Federally subsidised water deliveries were restricted to farms that were under 388.5 ha. Irrigation districts could deliver water to all their customers, even those with large landholdings, at reduced rates; thus, by being part of the 2004 agreements, large irrigators were able to access CAP water at discounted prices (US Bureau of Reclamation, n.d.).

Repayments to the federal government by non-Indian users of CAP water (for agricultural, municipal and industrial uses) were reduced in proportion to the percentage of water delivered to Indian communities; increased use of CAP water by Indian communities therefore was to the financial benefit of non-Indian CAP water users. This reduced repayment cost is because of the Indian communities' trust relationship with the federal government; according to this, operating and maintenance costs cannot be charged to the system or the Indian communities, but rather are borne by the federal government itself (Fuller, 1998). The 1902 *National Reclamation Act* limits repayments for agriculture-related infrastructure, so the CAWCD was able to reduce its costs by incentivising agricultural use of water. Thus by shifting CAP use to non-Indian agriculture and indigenous communities, the CAP costs borne by municipal and industrial users were reduced, while costs borne primarily outside Arizona by the federal government were increased.

In 2009, the CAWCD created a new incentive for eligible irrigators to participate in a groundwater savings programme, whereby enrolled farmers were encouraged to use CAP water instead of groundwater to satisfy part or all of their water demand. The 2009 incentive programme was also widely supported because of a constant concern that California cities would become dependent on Arizona's unused CAP water.

> Municipalities like Los Angeles (…), as a rule, have the lowest priority rights to the Colorado River supplies; they get the remnants. So they were the ones who were really growing on Arizona's unused apportionment. There was a grave concern that at some point, given their political power, either they would go to Congress to revamp things or would potentially go to the Supreme Court and argue with their cohort-in-arms, the state of Nevada (…). The cities agreed to subsidize the price of CAP water to the farmers (…). The idea from the cities' standpoint is that it is an investment for us; we'll pay the difference on the cost of pumping groundwater versus the delivery cost of CAP water, and in return, we'll get storage credits. We'll basically own groundwater rights, plus this non-Indian Ag Pool will become available at some point in the future; so we're preserving Arizona's entitlement. We'll capture this non-Indian ag priority water that the farmers have rights to today; certainly, if urbanization goes the way it is planned, it will become available. It's better to pay upfront for that supply and ensure that this water supply is available than lose it to California and Nevada (Water Lawyer, Interview No. 0727A).

The 2004 agreements freed up more water to fulfil *Winters* settlements, and the 2009 incentives encouraged full use of the agricultural pool, shifting farmers from groundwater to CAP water (Central Arizona Project, 2016b). Neither programme imposed any changes on on-farm production. During our fieldwork, farmers and districts recognised that a shift back to groundwater would occur once the ag pool was no longer available; their irrigated grandfathered rights would allow farmers to resume or increase groundwater pumping instead of using surface water such as CAP.

Groundwater Management Act

Concern about irrigated agriculture and water availability is not new to the region. By the 1930s, there was widespread recognition that Arizona groundwater was rapidly depleting due to irrigated agriculture (Smith, 1936). Arizonans viewed access to Colorado River water as being key to reducing groundwater overdraft while maintaining a vibrant agricultural economy; funding from Congress to transport Colorado River water to Central Arizona was contingent on groundwater regulation (Dunbar, 1977). A water lawyer (Interview no. 0727B) argued that

> [i]rrigated agriculture on groundwater was expanding so rapidly in the 1970s, there was significant drawdown, and it was a perfect example of the tragedy of the commons, where if it was allowed to continue to expand – and it was very profitable, so it was going to expand – we'd find ourselves with no water resource left.

There was evidence of dropping groundwater levels and subsidence throughout Arizona prior to the 1980 signing of the *Groundwater Management Act*; since then, however, this trend has reversed or slowed throughout Central Arizona (Konikow, 2013). The *Groundwater Management Act* established quantified rights to groundwater based on historic irrigation use within AMAs; it was a major achievement in terms of water sustainability, but also increased tension between the agricultural and other sectors, especially growing cities.

> The *Groundwater Management Act* was a very big event in agricultural history because, prior to that act being passed, if you owned land you could drill a well, you could pump whatever water you wanted from it and put it on your land. The Act basically capped the number of acres in farming in all of the Active

> Management Areas (…). So there cannot be any more farms, but there can be more houses (Cotton farmer, Interview no. 0804).

The GMA initially stipulated that irrigation efficiency requirements were intended to increase over time, reducing the associated water duties (Glennon, 1991). Irrigation efficiency is measured as the ratio of beneficial water use to total water used (Lahmers and Eden, 2018). A state water policymaker discussed the conflict associated with negotiating more efficient standards:

> Back when the groundwater code was created, what the agricultural community had to do was pretty drastic (…). Originally, it was pretty tough, I would have to say (…). Farmers wanted 75 [percent efficiency]; we were saying 85, so 80 sounded like the best place to come into the middle (State water expert, Interview no. 1118).

As stated by an interviewed water expert (Interview no. 0801):

> The ag community started off by arguing that "It's not achievable, it just is not achievable". Eventually, they realized that argument wasn't getting them anywhere, so what they came back with was "Well, you could achieve it, but it's not economically feasible. We couldn't stay in business. We think it's 70 or 75 percent". And these arguments just went on and on and on.

The agricultural sector actively resisted a ratcheting up of efficiency requirements beyond the 80% efficiency codified in 1980; they argued that they had already adopted significant efficiency measures such as, for example, field levelling and lining canals, and that further increases in efficiency would be difficult to achieve without high costs. Efficiency standards were never changed and have not had a large impact on water use since 1980 (Jacobs and Holway, 2004). Efficiency standards do not distinguish recoverable recharge into the aquifer and return flows from losses such as evapotranspiration and unrecoverable recharge (Clemmens et al., 2008); according to a state water expert (Interview no. 1118) the failure to differentiate between these flows in the GMA efficiency standards is a source of long-running frustration. The GMA capped the amount of non-Indian agricultural land in Central Arizona and established a baseline for irrigated water usage from all sources on that acreage.

Flex credits

Flex credits are unused water duties saved from previous years. Farmers may use banked or purchased flex credits to draw water in excess of their annual water duty. Flex credit accounts primarily benefit large, comparatively water-intensive operations that are assigned a large water duty under the GMA. While many in the agricultural sector felt they had given up an important private entitlement to water with the GMA, some interviewees who were consulted in this study asserted that the water duty allocated to most farmers was adequate, if not generous (see also Needham and Wilson, 2005). Fleck (2013) reports that flex credit balances in Phoenix irrigation districts remained steady from 1992 to 2011 at approximately 1.8 Bm^3, while in the same period flex credit balances in Pinal increased from about 4.3 to over 6.1 Bm^3. To put these numbers in context, the Phoenix flex credits banked in 2011 were approximately half of the state's entire Colorado River water allocation of 3.45 Bm^3, while the Pinal 2011 balance was almost double the state's Colorado River allocation.

Irrigators report water use to the Arizona Department of Water Resources (ADWR), which maintains records of available flex credits, and sellers file flex credit transactions with the ADWR. Information about available flex credits is then communicated to irrigation districts through ADWR reports, or often via word of mouth; as of recently, however, an ADWR website enables farmers to search for available flex credits by district.[3]

[3] The website was launched after our fieldwork (ADWR, 2020c): www.azwater.gov/querycenter/query.aspx?rptsessionid=B6FB7185F2BB8B6BE040000A16006832

Flex credits enable farmers to use more than their annual water duty; based on our interviews, however, few farmers use, buy, or sell these credits. Interviews in 2011, at the start of our study period, coincided with the tail end of a feverish period of commodity production, so we heard of several flex credit transactions; farmers indicated, however, that these transactions were unusual and that, in most years, flex credits had little impact on water use. They were created to help farmers manage risk but, in reality, they are seldom used.

Best management practices

Farms that had already implemented conservation measures before 1980 were assigned a smaller water duty and thus were less likely to have surplus water to bank through flex credits. The agricultural sector lobbied for an alternative, and the Best Management Practices (BMP) Program was adopted in 2002 (Arizona Revised Statutes § 45-566.02[B]). BMP relieved farmers of the limitations of their assigned water duty if they could demonstrate that they had implemented a series of prescribed technologies and techniques designed to promote water efficiency (Megdal et al., 2008).

Enrolees were required to demonstrate that they had: 1) equipped their land with improved irrigation systems such as drip or centre pivot irrigation and/or laser-levelled fields; 2) installed improved water conveyance systems such as concrete-lined ditches or closed conduits on at least 50% of the farm; 3) instituted approved irrigation management practices that were improved annually, including laser touchups to ensure that fields were level, or were using contour farming to increase infiltration; and 4) were using approved agronomic practices, including crop rotation, on at least 20% of their farm acreage, were mulching at least 20% of their acreage, and/or were testing the soil and water of at least 50% of their acreage (ADWR, 2020e).

Interviewees in our study reported that the BMP Program was particularly advantageous for farmers. According to one cotton farmer (Interview no. 0811):

> It used to be that you could transfer flex credits within an irrigation district, and I had someone approach me one time (…). But with the BMP Program, who needs it? I don't know how many farms are signed up in the BMP Program. I know this one is. I've got a friend of mine that signed up for it a year or two ago, got the landlords to sign off on it. They finally figured it out; some of them were paranoid they were signing away their water rights. That's what they were afraid of.

As of 2020, for irrigation districts with reports that are publicly available through the ADWR, approximately 10% of IGFR holders in the Phoenix AMA had enrolled in the BMP Program, while almost a quarter in Pinal had enrolled (ADWR, 2020c). "BMP is a good alternative for farmers that wanted to switch crops (…) but were constrained by their water duty" (Cotton farmer, Interview No. 0804).

The BMP Program enables farmers to plant water-intensive crops that they would have difficulty growing if they complied with the water duty (Kilby and Wilson, 2013). The use of the BMP Program is frequently associated with the expansion of dairies onto land that previously had other types of production. As one irrigation expert (Interview no. 0726) commented:

> In 2007, dairies moved into their district [dairies displaced by urban expansion] and brought a different cropping pattern: alfalfa, corn silage, milo, etc. Many of the growers providing these crops are on the BMP Program, so they are using water wisely, but still using a lot of water.

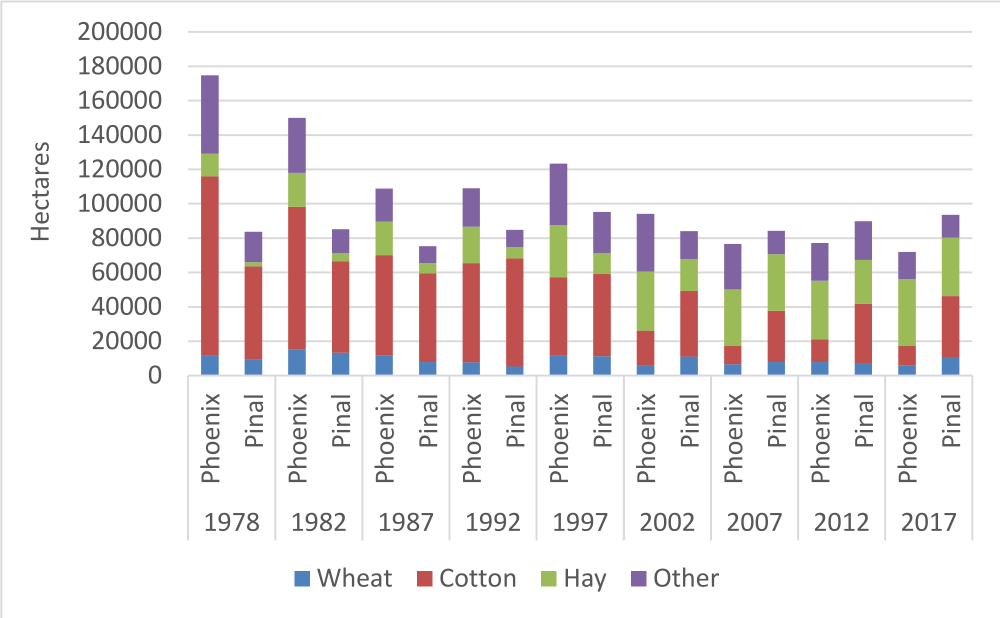
Rather than adjust on-farm practices to accommodate constraints imposed by water duties, the programme allowed the removal of limitations within the confines of accepted technological standards and practices. According to a state water expert (Interview no. 1118):

> We're usually seeing folks that are going into that program because, "Hey, we're doing this already, there's nothing that we really have to do" (…) We haven't seen too many folks that had to do any drastic changes to their programs to get into the [BMP] program.

Evidence of changing agricultural practices

Overall, the set of water policies enabled water-intensive agricultural practices to persist in Central Arizona. Due to changing economic conditions, the irrigated agricultural footprint decreased dramatically in Phoenix (Kane and York, 2017), while in Pinal, the footprint largely remains the same.

Figure 7. Irrigated cropland in Central Arizona.



Source: National Agricultural Statistics Service (NASS, 2007, 2012, 2017); US Department of Agriculture (USDA, 2017).

Water-intensive hay, mostly alfalfa, has become an increasingly important crop in the region (Figure 7). This expansion of hay growing is partially related to dairy production, which has increased almost fourfold since 1978 (NASS, 2017; USDA, 2017). Our participants described a growing alfalfa export market that has resulted from several factors: inexpensive shipping in containers returning to Asia from the port of Los Angeles, after delivering products for American consumption; increased international demand for dairy products, which has resulted in an increased need for forage throughout the globe; and restrictions on water-intensive alfalfa production in other countries, especially the Middle East. The perspectives of these participants are supported in the literature, which reflects a dramatic increase in hay exports from the western United States over the past two decades (Matthews et al., 2016).

Incentives for CAP water, flex credits, the BMP Program, and efficiency standards all illustrate a pattern of agency within the farm community in terms of farmers' ability to negotiate the institutional arrangements that enable them to mediate the risks associated with intersectoral competition, as well as the perceived political, economic, and hydrological risks. Notably, risks generated by a changing climate were mostly absent in the mental models motivating institutional change. Changes in agricultural practices were largely confined to shifts towards more water-intensive dairy and hay production, which were partially facilitated by the BMP Program. Farmland conversion reduced agricultural water consumption in Phoenix and helped maintain safe yields. In Pinal, the persistence of agriculture has been supported through these institutions; groundwater overdraft has decreased, but with the Tier Zero shortage, farmers will shift back to groundwater to satisfy their irrigation grandfathered rights.

THE FUTURE

In the previous section, we focused on how Arizona institutions affected irrigators' water decision-making and how farmers pushed back and shaped institutions to ensure that they were crafted in ways that sustained agriculture's continued viability; however, the future of irrigated agriculture in Central Arizona and in other predominately snow-fed agricultural systems throughout the world will be bleak without major transformations (Qin et al., 2020). It is acknowledged that, even without climatic change and megadroughts, the Colorado River is dangerously overallocated (Meko et al., 2007; Karl et al., 2009), yet even Arizona – the most junior state – has typically received its entire annual water allocation (Wildeman and Forde, 2012; Udall and Overpeck, 2017). Up until Tier Zero, farmers largely were buffered; their focus was on defending their water rights against competing water users, be they states (California), sectors (urban), or indigenous communities (*Winters* rights). Former Secretary of the Interior Bruce Babbitt (Babbitt, 2020) has recently advocated for a new Irrigation Reserve Program that would be modelled after the Conservation Reserve Program; such a programme would advance water conservation goals by fallowing farmland and equitably compensating farmers. In other parts of Arizona, collaboration with environmental groups has been another means of sustaining farming or ranching in synergistic ways (Schoon et al., 2017; Postel, 2017), though farmers in our study perceived many conservation and environmental groups as adversaries and have not pursued these potential collaborations.

The threat is now more existential to the entire region; perhaps more accurately, the region will finally be facing the direct consequences of climate change through reduced Central Arizona Project water deliveries. Many of the institutional arrangements that have been fought over and carefully crafted are counterproductive to the sustainability of the region; therefore, instead of working to maintain the status quo, the agricultural sector and the state more broadly, will need to collaboratively change the sociopolitical infrastructure.

Drought Contingency Plan

Under the 2007 Colorado River Interim Guidelines, a Tier 1 threshold of approximately 327.7 m at Lake Mead triggers a shortage. In 2016, Lake Mead breached this threshold, which led to drought contingency planning that was aimed at providing institutions that would support water conservation in order to lessen the impact of shortages (Sullivan et al., 2019). In May 2019, the Colorado Basin states signed the Drought Contingency Plan; a Tier Zero threshold was established in the Lower Basin that was focused on the maintenance of long-term storage within Lake Mead in order to reduce the likelihood of future shortages. In August 2019, the Bureau of Reclamation declared that the first DCP Tier Zero threshold was anticipated in 2020 (US Bureau of Reclamation, 2019). Ultimately, Lake Mead water levels rebounded slightly, but a Tier Zero shortage remained in effect, reducing CAP water allocation by 236 Mm^3 or 12% of CAP's allocation; this in turn reduced the agricultural pool by 15% (Cullom, 2020).

In Arizona, the brunt of Tier Zero cuts was felt by the agricultural sector, especially within Pinal County. As described earlier, during the 2018/19 Legislative Session that was concurrent with DCP discussions, there was a joint proposal of the agricultural lobby, local policymakers and some Arizona legislators to purchase CAP water from the Gila River Indian Community (GRIC) for Pinal County farmers (US Department of the Interior and Bureau of Reclamation, 2019). The hotly debated proposal was ultimately withdrawn due to lack of support within the GRIC for a provision related to agriculture in southwestern Arizona (James, 2019a) and concerns about the sustainability implications of supporting Pinal agriculture (Sundust et al., 2019). To lessen the impact of the DCP on Pinal agriculture, the state provided a $20 million Pinal Groundwater Infrastructure Fund to develop groundwater infrastructure and increase efficiency in the Pinal AMA (Jaspers, 2019); many wells were no longer operational there because farmers had shifted to CAP water. Infrastructure improvements or new wells are necessary if groundwater is to be pumped up in quantities sufficient to meet Pinal farmers' water demand during Colorado River shortages.

As agricultural water use in Central Arizona shifts back to groundwater, there will be a renewed drawdown of the aquifer. Overdraft of groundwater due to a shrinking Colorado River water supply is an issue that the entire Colorado Basin is facing (Castle et al., 2014). While many in policy positions tout Arizona's success in reducing groundwater overdraft, Hirt et al. (2017) argue that the state's policy position for a strategic drawdown of aquifers and use of Colorado River water masks an unsustainable system that must be transformed.

Indigenous water and agriculture

An alternative future vision of agriculture is a shift onto indigenous community lands or waters. Many of our interviewees foresaw that agricultural production would increasingly shift to indigenous community lands with higher priority CAP water, or, to a lesser extent, non-Indian agricultural lands with water leases from indigenous communities. There are numerous challenges to accessing leased water from indigenous community land, as leases must be approved by the community and the Secretary of the Interior (Nyberg, 2015). These leases are also much more expensive than existing agricultural water costs; specifically, because many leases are used for development, such as leases to municipal providers to support new home construction, it is unlikely that irrigators will be able to afford to lease indigenous communities' CAP water without state subsidies, given current operating costs and revenues.

Some non-Indian farmers lease land from indigenous communities, which typically enables them to access water through the communities. Two of the biggest indigenous communities in our study area are the Gila India River Community, where 12,111 ha of cropland is harvested by 18 non-Indian operators and 37 Indian operators, and the Salt River Pima-Maricopa Indian Community, where over 9821 ha of cropland are harvested by five non-Indian operators and three Indian operators (NASS, 2019). One respondent commented that he is able to access Salt River Project water through leasing Indian community land, which is significantly cheaper than leasing non-Indian land and using CAP water (Cotton farmer, Interview no. 1105). Likewise, an irrigation expert (Interview no. 1101.2) indicated that he anticipates that agricultural use will increasingly move to indigenous communities because of their large, and currently underutilised, CAP water allocations. At the same time, the cost of altering land use on reservations can be high due to bureaucratic hurdles and ownership fractionation issues that arise on individually owned land that is held in trust with the federal government (Anderson and Lueck, 1992; Leonard et al., 2020).

The omnipresent concern of indigenous communities about non-Indian agricultural water leases (such as the failed GRIC lease to aid Pinal farmers) is an understandable worry; it is associated with sovereignty and self-determination, and with the long-running tension – if not open conflict – between the Anglo agricultural sector and indigenous communities. As Governor Lewis of the Gila River Indian Community stated,

> We have fought to regain our water settlement, our water rights. That historic struggle has really shaped our community, to where we do not take for granted any drop of our water, what we call in our language, the O'odham language, *shudag* – water is life (James, 2018).

Over the past two years, the GRIC has remained committed to the DCP; they have provided the state with the water leases that are necessary to push the planning process forward but have notably excluded non-Indian agriculture. As the water crisis worsens in Arizona, there is likely to also be an intensification of the issues surrounding Anglo settler/indigenous co-governance of water resources and water sovereignty.

Sustainable Central Arizona agriculture

The current debates over the DCP highlight the way in which long-standing tensions and perspectives can challenge the efforts of co-governance. Changing the mental models that undergird these negotiations requires an expansion of ideas about the role of agriculture, the types of farming, and the potential mutual benefits of continued Central Arizona agriculture. Non-agricultural interests have questioned the desirability of continued agricultural production in the deserts of Central Arizona, especially if that agriculture shifts back to being dependant on groundwater (see, for example, James, 2019b). There is an opportunity to explore the potential services and functions (Lovell, 2010) and even the environmental benefits (Postel, 2017) of continued farming. A shift towards a food-water-energy nexus model (White et al., 2017) would incorporate considerations of crop and dairy production, but could also include heat island mitigation and could recognise the advantages of a flexible system that encourages fallowing during periods of water shortage.

In our interviews, most respondents argued that farmers were conserving water but that the crops and practices were inherently water intensive. We spoke to farmers who were experimenting with no-till practices to reduce evapotranspiration and surface temperatures or who had installed drip irrigation for alfalfa, cotton and other crops. Extension agents, farmers and irrigation experts spoke about opportunities for improvement at the margins; more substantive adaptations, however, were mostly absent from our conversations. These may become required given the current socio-hydrological state and should be the subject of future research.

Strategies for continued agriculture include less water-intensive crops or increased high-value food production such as vegetables (Bae and Dall'erba, 2018); agriculturalists in our study, however, stressed some of the challenges associated with water quality, processing infrastructure, and financing. An overarching concern in decisions about changing practices was capital. Many farmers leased land whose owners were intent on selling for development in future years; these farmers were wary of bearing high capital-improvement costs when there was a likely future of urban conversion. Farmers expressed a commitment to contributing to the food system by, for example, expanding plantings of wheat. Wheat has a lower per-hectare water demand than cotton or alfalfa (Frisvold, 2015) and the region's durum wheat is known for its high quality and is often exported to Italy for pasta production (McGinley, 2002). Several farmers talked about an attempt that had been made to launch a processing facility in Pinal for local pasta production; the intent had been to capture added value in production, but this had failed due to lack of investment. Vegetable production continues in Central Arizona, but respondents mentioned numerous hurdles such as few cold-storage and processing facilities in the region.

Food production was not the only function that farmers discussed; with rising temperatures, there were opportunities in metropolitan Phoenix to reconsider the benefits of heat mitigation and greenspace projects (Aggarwal et al., 2012; Metson et al., 2012). As one respondent commented, "[N]obody wants to live in an area where there's no agricultural use – you don't want to have just houses wall to wall" (State water expert, Interview no. 118).

This concern was echoed in other comments regarding the liveability or desirability of the region without agriculture.

> I've always taken the position (in public forums) that the demise of agriculture is not the panacea for the western water problems. Be careful what you ask for because if you implement policies that are intended to drive agriculture out of business, you will probably succeed – maybe at some high cost, but succeed nonetheless – and then you've got an economy of a state missing a very vibrant historic component, and a certain aspect of quality of life that we enjoy by having farms still within our metropolitan area (Water lawyer, Interview no. 0727B).

While on a per-hectare basis, agriculture uses far more water than would be consumed under residential use (Megdal and Shipman, 2010), once the land is fully converted to urban use, water consumption is 'hardened' and relatively inflexible on an interannual basis. In contrast, there is the potential to temporarily halt agricultural production, compensating farmers for lost income in a mixed urban and agricultural system. In the Imperial Valley, California, for example, farmers have been called upon to sell their water resources to meet urban needs in the face of scarce supply; the water market institutions that have emerged to enable this exchange illustrate how agricultural water use can be considered somewhat flexible in the face of interannual variability in water supplies. The Imperial Valley case, however, is not without controversy (see, for example, Booker and Young, 1994; Haddad, 2000; Maganda, 2005). Farmers in our study were interested in similar models; they were, however, also concerned about whether institutions could be created that would fairly and adequately compensate farmers for fallowing fields during periods of drought.

As a water lawyer stated (Interview no. 0727), "Every time we see issues out there that need to be dealt with, I think we always conclude that you can't really get the impetus to make the tough choices until there's a crisis". Prompted in part by the Colorado River Tier Zero shortage, discussions about the future of Arizona agriculture are underway through AMA planning, as well as informally throughout the state. Mental models, including beliefs about the system structures and dynamics, are embedded in institutional arrangements that persist over time; these have become part of the hard infrastructure that contributes to system rigidity. Changing this political infrastructure will require collective action and new narratives and understandings of the system as a whole, and policy entrepreneurs may be needed to actively facilitate these processes (Sarasvathy and Ramesh, 2019). Collaborative governance efforts, such as the DCP and the Active Management Area fifth management planning process, open up windows of opportunity for building trust and enabling collective action and adaptation of the system as a whole (Ansell and Gash, 2008). Collective action will be hindered by poorly managed processes that exclude the relevant stakeholders and fail to consider equity, and which reinforce 'old' mental models with narratives of competition and divisive politics (Singleton, 2002).

CONCLUSION

It is clear that the region will be facing tough choices in the future; only recently, however, the more normative question of what should agriculture's future role be under changing climatic conditions has become central to the policy debate. Obstacles to alternative paths for agriculture arise out of long-running conflicts between the agricultural and indigenous communities regarding water rights and the reluctance of the Anglo agricultural community to adapt to a changing socio-hydrological system. Central to the future sustainability of the region is the inclusion of all sectors, most notably indigenous rights holders. Short-term solutions, such as the BMP Program and incentives for the agricultural use of CAP, have in many ways limited opportunities for adaptation (Tellman et al., 2018). To sustainably manage the system, longer time horizons will require significant shifts in the mental models and narratives of farmers and in the system as a whole. Farmers were encouraged to forfeit long-standing CAP Section 5 subcontracts, which was a short-term win-win for the region; it allowed farmers to access cheap CAP water, reduced groundwater overdraft, provided a source of Colorado River water for indigenous water rights settlements, and reduced bankruptcy risk for irrigation districts. In the process, it also maintained Arizona CAP usage which thwarted potential use and appropriation by California. Overall, a picture emerges of a relatively consistent water-intensive agricultural practice sustained by Arizona water policy. There has been some adoption of water conservation measures and a shift away from groundwater use throughout the region, though the Tier Zero shortage is upending many of the water conservation gains.

Water governance affects water use through the effect of institutions on day-to-day decision-making (Molle et al., 2018). Still, all too often in water conservation there is a narrow focus on decision-support and an insufficient examination of how overlapping institutions mediate and generate risks for decision-makers. In the context of increasingly intense public and political debate surrounding agricultural water use in the western United States, this study highlights the limits of short-term policy solutions that maintain the status quo; it also stressed the need to develop new narratives and mental models, to include indigenous communities in water governance, and to adopt new institutions that support a more sustainable socio-hydrological system.

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