Agricultural Water Use and the 1980 Groundwater Management Act: Institutional Change and Water Conservation in South-Central Arizona, USA

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Summary

Present day human societies face many challenges in effectively managing resources that exhibit characteristics of "common-pool resources" (CPR), of which groundwater is a critical example. CPRs consist of natural or man-made resource systems from which it is difficult to exclude resources users, and where one person's use impacts another's. Scholars also incorporate CPRs into the broader study of social-ecological systems (SESs), placing emphasis on the role of proper and improper institutions in pushing SESs towards sustainability or collapse. Institutions are the rules-in-use that shape human action. The seminal 1980 Groundwater Management Act (GMA) in Arizona, USA is an institution designed to curb groundwater overdraft through a combination of conservation strategies, augmentation and supply development, and reduction in agricultural water use through strict prohibition of its expansion in designated areas. Today, with urbanization pressures and the halting of agricultural expansion, agriculture uses less water on the whole than in 1980. However, in spite of the conservation and efficiency regulations imposed on agriculture by the GMA, on a per-acre basis, agriculture's water consumption is stable. Employing an analytical framework used to evaluate the contribution of institutions to the maintenance of SESs, I examine: a) the original institutional design and process of institutional change within the GMA, b) how institutional change affects resource users' response to signals of water scarcity, and c) how to increase water conservation on farms. Results from the institutional analysis indicate there was insufficient time to incorporate farmers' existing knowledge about water efficiency into the Act. Thus, after 1980, farmers lobbied for adjustments to the regulations of the GMA in order to increase their water use flexibility. To elicit recommendations on how to increase water conservation and irrigation efficiency on farms, I collected primary data through interviews with farmers and water policy experts in south-central Arizona. Suggestions from interviewees include: the need for a greater understanding of the temporary nature of central Arizona agriculture in providing incentives to boost water conservation (e.g. renting land instead of owning land), the promotion of currently available incentives to invest in water conservation, and increased farmer education about water-saving practices.

Background

Prior to the passage of the pivotal 1980 Groundwater Management Act, groundwater in Arizona was governed by the doctrine of reasonable use, whereby a landowner had the right to pump as much groundwater from underneath his or her property as could be put to use (Schlager 1995). This institutional arrangement worked well for nearly a century, but with urban population growth and the steady consumption of groundwater by the industrial and agricultural sectors in the south-central part of the state, negative environmental and economic impacts emerged (Connall 1982). Arizona experienced rampant groundwater overdraft throughout the populous south-central part of the state during the middle part of the 20th century.

To fix the problems associated with groundwater overdraft, such as subsidence, land fissuring, and aquifer compaction (Bouwer 1977), as well as to maintain federal funding for the Bureau of Reclamation project called the Central Arizona Project (CAP), the state of Arizona passed the Groundwater Management Act (GMA) in 1980. The GMA intended to curb groundwater overdraft in designated Active Management Areas (AMAs) (Arizona Department of Water Resources [ADWR] 2004). The Arizona Department of Water Resources (ADWR) is the state agency charged with implementing and enforcing the GMA.

Institutional Analysis

Upon agreement that an institution is needed to regulate an unsustainable CPR regime, rules are established that severely constrain the "authorized actions available to [the resource users]" (Ostrom, 1990, p. 43). The next section outlines the institutional structure of the GMA. To minimize the conflict over and depletion of groundwater in Arizona, the ADWR restricts and monitors the possible actions of groundwater users with certain provisions (outlined below) in the GMA. Using the latest framework for analyzing sustainability of SESs (Ostrom, 2009), the following tables highlight the second-level variables within Ostrom's (2009) framework **included** in the GMA. Subsequent tables outline which second-level variables are **excluded** from the GMA. A brief discussion of the results follows.

***Figure 1.* Core subsystems of Social-Ecological Systems (Ostrom 2009, p. 420).**

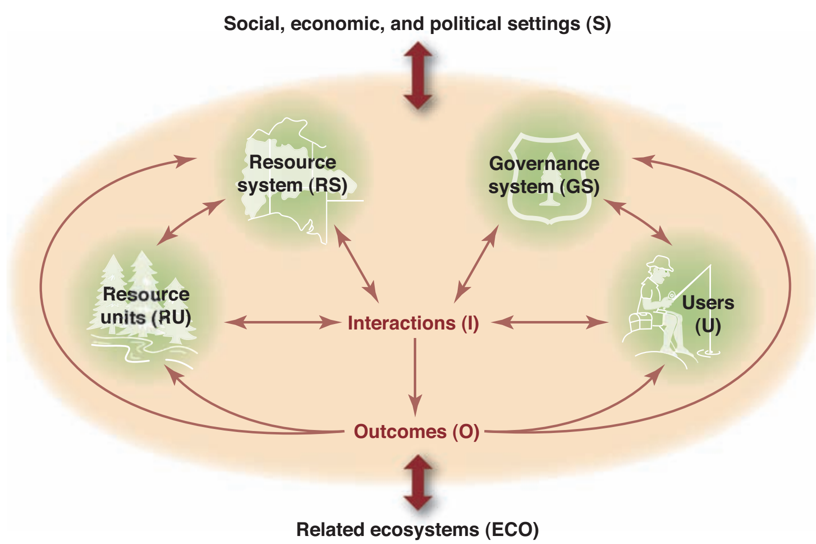

***Figure 2.* Examples of second-level variables under first-level core subsystems in a framework for analyzing social-ecological systems. (Ostrom 2009, p. 421)**

Social, economic, and political settings (S)

S1 Economic development. S2 Demographic trends. S3 Political stability.
S4 Government resource policies. S5 Market incentives. S6 Media organization.

Resource systems (RS)

RS1 Sector (e.g., water, forests, pasture, fish)
RS2 Clarity of system boundaries
RS3 Size of resource system*
RS4 Human-constructed facilities
RS5 Productivity of system*
RS6 Equilibrium properties
RS7 Predictability of system dynamics*
RS8 Storage characteristics
RS9 Location

Resource units (RU)

RU1 Resource unit mobility*
RU2 Growth or replacement rate
RU3 Interaction among resource units
RU4 Economic value
RU5 Number of units
RU6 Distinctive markings
RU7 Spatial and temporal distribution

Governance systems (GS)

GS1 Government organizations
GS2 Nongovernment organizations
GS3 Network structure
GS4 Property-rights systems
GS5 Operational rules
GS6 Collective-choice rules*
GS7 Constitutional rules
GS8 Monitoring and sanctioning processes

Users (U)

U1 Number of users*
U2 Socioeconomic attributes of users
U3 History of use
U4 Location
U5 Leadership/entrepreneurship*
U6 Norms/social capital*
U7 Knowledge of SES/mental models*
U8 Importance of resource*
U9 Technology used

***Table 1.* Second-level variables (bolded and underlined) included in GMA within corresponding Ostrom (2009) first-level core subsystem**

RESOURCE SYSTEM (RS)	GOVERNANCE SYSTEMS (GS)
<u>RS1 Sector (groundwater)</u>	**<u>GS1 Government organizations</u>**
<u>RS2 Clarity of system boundaries</u>	GS2 Nongovernment organizations
<u>RS3 Size of resource system</u>	GS3 Network structure
RS4 Human-constructed facilities	**<u>GS4 Property-rights systems</u>**
RS5 Productivity of system	**<u>GS5 Operational rules</u>**
RS6 Equilibrium properties	**<u>GS6 Collective-choice rules</u>**
RS7 Predictability of system dynamics	GS7 Constitutional rules
RS8 Storage characteristics	**<u>GS8 Monitoring and sanctioning processes</u>**
RS9 Location	
RESOURCE UNITS (RU)	**USERS (U)**
RU1 Resource unit mobility	U1 Number of users
<u>RU2 Growth or replacement rate</u>	U2 Socioeconomic attributes of users
RU3 Interaction among resource units	**<u>U3 History of use</u>**
<u>RU4 Economic value</u>	**<u>U4 Location</u>**
<u>RU5 Number of units</u>	U5 Leadership/entrepreneurship
RU6 Distinctive markings	U6 Norms/social capital
<u>RU7 Spatial and temporal distribution</u>	U7 Knowledge of SES/mental models
	U8 Importance of resource
	U9 Technology used

Table 2. **Ostrom (2009) second-level variables included in original GMA**

Ostrom (2009) variable	Groundwater Management Act
• RS1 Sector • RS2 Clarity of system boundaries • RS3 Size of resource system • GS6 Collective-choice rule	Designation of Active Management Areas (AMAs) determines the boundaries of the regulated system as defined in the GMA. GMA only regulates groundwater, no jurisdiction over surface water. AMAs determined according to hydrologically connected groundwater basins experiencing serious overdraft problems prior to 1980 (ADWR, 2004). Thus, AMAs both an ecological and institutional boundary. Outside the AMAs, these rules do not apply.
• RU5 Number of units • GS4 Property-rights systems • GS5 Operational rules • U3 History of use • U4 Location	The establishment of a program of groundwater rights and permits. Agricultural groundwater rights called Irrigated Grandfathered Rights (IGFRs) and confer the right to irrigate with a set amount of groundwater on specific plots of land irrigated with groundwater between 1975 and 1980 (Needham & Wilson, 2005). One must continue to farm on original land for the water allocation to be supplied and utilized, because water and land stay tied together (Megdal et al., 2008).
• RU4 Economic value	If the use of the land switches from agricultural to urban, for example, only three acre-feet of water per acre can be transferred to the new use, not the entire IGFR water allotment (Burton, 1990).
• RU2 Growth or replacement rate • RU7 Spatial and temporal distribution	Development of a program requiring urban developers to demonstrate a 100-year assured water supply for new growth (ADWR, 2004).
• RU5 Number of units • GS5 Operational rules	Farmers required to increase water efficiency every ten years, with the intention that farms would use less water in 2025 than in 1980 (ADWR, 2003a).
• RS2 Clarity of system boundaries • GS5 Operational rules	A provision prohibiting irrigation of new agricultural lands within AMAs (ADWR, 2004).
• GS8 Monitoring and sanctioning processes	A requirement to meter/measure water pumped from all large wells (ADWR, 2004).
• GS8 Monitoring and sanctioning processes	A program for annual water withdrawal and use reporting. These reports may be audited to ensure water-user compliance with the provisions of the Groundwater Code and management plans. Penalties may be assessed for non-compliance (ADWR, 2004).
• GS1 Government organizations	The establishment of the Arizona Department of Water Resources (ADWR) as the monitoring entity (Hirt et al., 2008)

Table 3. **Ostrom (2009) second-level variables excluded from original GMA**

Ostrom (2009) variable NOT TAKEN INTO ACCOUNT	Groundwater Management Act
• U5 Leadership / entrepreneurship	Assigned water allotments to farmers based on use from 1975-1980. Those who used more water were awarded a larger allotment than those who had been irrigating efficiently.
• U7 Knowledge of SES	Previous groundwater doctrine overturned quickly, making it difficult to incorporate the proper incentive structure to reward farmers for irrigating efficiently (as one way of coping with resource scarcity).
• U7 Knowledge of SES	Assumed reaching 85% irrigation efficiency standard in Third Management Plan was economically feasible for farmers.
• U6 Norms / social capital • U8 Importance of resource	Assumed agricultural acreage and water use would decline quickly. Significant amount remains.
• U9 Technology used	Placed emphasis on reducing agricultural acreage (scale effect) as main way to conserve groundwater. Not as much emphasis on aiding farmers with water technology effects that could reduce per-acre consumption.

Discussion

From these tables it is evident that the subsystem "Users" has the fewest variables included or considered in the GMA. Scholars studying other social-ecological system cases around the world have noted that when users and other stakeholders are given a strong voice and real responsibility, users of natural resources, such as irrigation farmers, may enhance the economic and ecological performance of the SES (Shivakoti & Ostrom, 2002). When institutions are crafted without consideration of the variables Ostrom (2009) suggests as important for sustainability, conflict in resource management can arise. In the case of the GMA, farmers, excluded for the most part in the drafting of the legislation, did not find the rules favorable and thus lobbied for and won several concessions that would grant them greater flexibility in their water use. I argue that by not considering the variables outlined in Table 2, farmers did not "buy in" to the new regulations at the onset of the GMA and thus fought to change the rules in the years and decades following 1980. When outsiders seek to improve the performance of an SES, in this case, reduce overdraft by regulating farmers' groundwater use, acknowledging and planning for the possible (sometimes perverse) incentives generated by new institutions as they interact with the existing social norms and physical world is critical if compliance with the established institutions and long-term performance of the SES is to be reached (Shivakoti & Ostrom, 2002).

The amendments gained by farmers increased their water use flexibility in the short-term. This flexibility can also be viewed as increased short-term robustness to shocks such as climate extremes (e.g. high temperature, low rainfall) and market fluctuations (e.g. ability to plant a more water intensive crop if the agricultural market demands it). Nevertheless, the amendments generate a trade-off: farmers gain flexibility in their water use, but do not change the amount of water they use per-acre, even though one of the original intents of the Act was to increase water conservation by the sector

(Needham and Wilson 2005). The three main institutional amendments to the agricultural water use rules are called: flex credits, the Best Management Practices conservation program, and the reduced irrigation efficiency standard.

Scholars studying other social-ecological systems around the world have noted that when users and other stakeholders are given a strong voice and real responsibility, users of natural resources, such as irrigation farmers, may enhance the economic and ecological performance of the SES (Shivakoti and Ostrom 2002). Some experts interviewed for this study suggested that the lawmakers who constructed the initial GMA rules knew little of the on-the-ground nuances related to farming, especially in the desert. "[The GMA] was written by people that ... didn't really understand what was going on down on the farm" (Water-agriculture expert #5, personal communication, March 4, 2010). A farmer adds:

> There are a lot of assumptions that government people make that have low or no reality. You [can] talk hypothetically [about] the amount of water the plant need[s] but when you actually deliver that water in a production situation it is a lot different because the plant can't take up all the water you send to it. (Farmer #6, personal communication, February 26, 2010)

Without a close examination of the various factors influencing agricultural water use included in the initial development of the GMA, the result was a mismatch between costs and benefits—at least as perceived by the agricultural resource users of south-central Arizona. Farmers were no longer permitted to expand their farms' irrigated acreage. They were expected to become more efficient with their water use, and with that efficiency, experience reductions in the water allotted to their farms. The resource once extracted as a private property right was suddenly defined as the communal property of the state of Arizona to be divvied up based on a farmers' historic use. A water expert suggests the stark reality farmers suddenly faced:

> I think it was shock at first for farmers that on June 11, 1980 you could use as much water and irrigate any land that you wanted. Then June 12, 1980 comes in and its like, "I can only irrigate this much, and how much water do I have to use? Who is going to tell me what to do?" (Water-agriculture expert #8, personal communication, March 10, 2010)

This mismatch meant an adjustment to certain provisions in the original Act to provide farmers the necessary flexibility to respond to changes in climate and the agricultural market. Anderies et al. (2004) highlight that institutions associated with successful SESs often provide a "rough proportionality between the benefits a resource user obtains and his or her contributions to the public infrastructure" (p. 12). An institution that does so is considered fair in most social systems (Issac et al. 1999). When institutions are constructed and considered fair, they reduce the chance that resource users will try to challenge, avoid, or disrupt the policies of the public infrastructure providers (Anderies et al. 2004). To the agricultural sector of south-central Arizona, the GMA did not appear fair:

> [It was] an upheaval in the agriculture industry because we developed our water ourselves. The wells that we drilled we owned. We bought and paid for them, and took the risks when we drilled them. Sometimes you get dust, sometimes you get water. And here were some people ... suggesting that we were going to lose control of those wells and the water that came from them, and that the water

belonged to the state of Arizona instead of to me and my peers. It was brutal. (Farmer #1, personal communication, February 3, 2010)

According to Ostrom (1990), "Participants prefer a set of rules that will give them the most advantageous outcome. Although all will prefer a new institution that [enables] them to coordinate ... activities, ... a fundamental disagreement [may] arise among participants regarding which institution to choose" (p. 42).

Although farmers need water use flexibility, it is also noteworthy that if farmers implemented greater water conservation techniques, they may be better prepared in times of scarcity, because they need less water to achieve the same satisfactory outcome on their farm. Thus, if farmers are prepared to use water as efficiently as possible, their adaptive capacity to water scarcity shocks may increase. Water-conserving technologies allow farmers to save money when water is not scarce by using whatever water is available as efficiently as possible. However, if water does become scarce, on-farm efficiency technologies enable farmers to adapt to the scarcity conditions, when they might not have been able to do so otherwise.

Unlike previous work in the literature that discusses the "weakening" of the GMA through the amendments won by agriculture as well as the municipalities (Hirt et al. 2008), I explore the process of institutional change to illustrate the legitimate concern held by farmers that the original provisions of the GMA did not provide sufficient year-to-year flexibility for water application in their agricultural operations. One result of these gains in inter-annual robustness to certain shocks is that farmers are blocked from receiving signals of water scarcity that may serve to motivate on-farm water conservation. Thus, farmers are not induced to implement water-conserving strategies to the extent originally predicted with the establishment of the GMA. With the institutional arrangements inhibiting the flow of information to farmers signaling impending or actual scarcity, farmers have less incentive to implement water conservation strategies on the farm. And given the importance of proper incentives in determining the success of an SES (Ostrom and Shivakoti 2002), it is important to know what farmers and water and agriculture experts think could be done to boost water conservation on farms in south-central Arizona.

Promoting Agricultural Water Conservation

Agricultural water conservation not only benefits the groundwater basins, it can also increase the capacity a farmer has to adapt in scarcity situations. Increasing per-acre water conservation in agriculture remains an elusive yet important component in managing Arizona's groundwater resources sustainably, and one that can be implemented at the farm-level. Defined as the reduction of water use through enhanced efficiency (Gleick 2002), conservation is critical to the future of Arizona as both groundwater and surface water supplies are predicted to become scarcer through long-term drought and increased urbanization (McKinnon 2009a; McKinnon 2009b).

General, repeating themes from the primary data interviews included the sentiment that more state-level statutory negotiations and institutional amendments to curb agricultural water use are not going to be effective at achieving increased water conservation, mainly because the previously discussed institutional battles have left both the ADWR and farmers politically exhausted. Similarly, both experts and farmers suggested that achieving greater agricultural water conservation is likely to come from economic incentives that farmers choose to implement on their farms, not from increased regulation. Lastly, it was often expressed that farmers want to be as efficient with their water use as economically possible because water is an input cost and anything that reduces costs is appealing to farmers as business operators. To develop strategies to conserve water, efforts to tap into this social norm should be increased.