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Inducing Water Conservation in Agriculture: Institutional and Behavioral Drivers

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Articles in this Theme:

How Politics and Economics Affect Irrigation and Conservation
David Zilberman, Rebecca Taylor, Myung Eun Shim, and Ben Gordon

USDA Water Conservation Efforts Reflect Regional Differences
Steven Wallander

Farmer Adoption of Water Management Practices in Response to Recurrent Drought
Ariel Dinar, Arisha Ashraf, and Julie Reints

Applying Behavioral Insights to Improve Water Security
Paul Ferraro, Kent D. Messer, and Shang Wu

Irrigated agriculture accounts for a major share of total consumptive water use and of withdrawals of surface water and groundwater in the United States. This is particularly true in western states, which have experienced severe water shortages in recent years. Climate change is expected to increase variability in precipitation and reliance on irrigation to maintain crop productivity. While the shift to pressure sprinkler irrigation systems has been increasing over time, water applied using inefficient gravity systems still accounts for a large share of total water applied in the United States (U.S. Department of Agriculture, 2013). Irrigated agriculture contributes to the depletion of major U.S. aquifers and the over-watering of crops causes run-off and leaching of nutrients, which have detrimental impacts on water quality.

Water use and technology choices have historically been affected by institutions and policies that have evolved over time. Recent government efforts seeking to induce water conservation have focused on providing payments through programs such as the Environmental Quality Incentive Program (EQIP) to induce adoption of water-efficient irrigation technologies. A recent U.S. Government Accountability Office report (2017) found that the billions of dollars spent on EQIP were not well-targeted to farmers who could provide the maximum environmental benefits at least cost because they often do not consider cost-effectiveness in selecting from among applicants. The voluntary nature of such programs and lack of data on performance-based outcomes from enrollment have constrained the ability of conservation programs to target payments to farmers in ways that ensure that outcomes are additional to what would have been achieved in the absence of the program.

Recent research in behavioral economics provides important insights on ways to supplement such programs and technologies with “nudges” that can motivate conservation behavior more cost-effectively. The articles in this theme discuss the drivers of farmers’ water management choices and the role that climatic conditions, public policies and institutions, and behavioral factors play in influencing those choices.

In the first article, David Zilberman, Rebecca Taylor, Myung Eun Shim, and Benjamin Gordon provide a long-run perspective on water policy. They argue that water policies have been motivated largely by political considerations. Early in U.S. history, water policies were used as a mechanism to induce settlement in the West. In the 19th century farmers, were given water rights if they settled land and diverted water. In the early 20th century, the government invested in water-delivery projects. As water scarcity has increased, the government has introduced mechanisms to increase efficiency of water use such as, for example, allowing water trading, charging higher fees for government-supplied water, and requiring more responsible management of groundwater aquifers. These policies have led farmers to adopt water conservation technologies. More recently the emphasis is shifting to policies to achieve environmental objectives—including water quality and water allocation for environmental uses. This has led to further reliance on markets for trading water and higher water pricing. The article also suggests that the adoption of conservation technologies in California was enhanced by implicit collaboration between private irrigation developers and Cooperative Extension, which adapted crop management to new irrigation regimes.

The second article, by Steve Wallander, discusses regional variation in irrigation demand and supply across the United States and the effectiveness of federal policies to enhance conservation. He emphasizes the heterogeneity of irrigation systems in the United States, which reflects the diversity of U.S. agriculture in terms of water sources (ground vs. surface) and crops. There have been a gradual shift toward sprinkler and drip technologies, which have higher water use efficiency, and away from furrow and flood irrigation. Wallander argues this shift has occurred at least in part due to government policies like EQIP. The article describes the limitations of conservation programs such as EQIP in inducing technology-based approaches to water conservation due to difficulties in targeting payments based on performance-based measures and to farmers that would not have adopted otherwise. These technologies may also increase production, irrigated acreage, and water use rather than reducing overall water consumption. Alternative approaches including managed aquifer recharge and enhanced metering and pricing of groundwater may be more promising ways to protect groundwater.

In the third article, Ariel Dinar, Arisha Ashraf, and Julie Reints examine water management choices in two different studies of California avocado farmers (first study) and of farmers growing various crops in desert and other southern California regions (second study), both of which have faced prolonged droughts. Their findings suggest that farmers choose technology bundles that include multiple components aimed to address various tasks of irrigation soil moisture and salinity. The bundles are composed of various practices and technologies, such as weather monitoring, pruning, irrigation management, drainage management, salinity management, chemical application, and stumping (of avocado trees). The bundles vary in their degree of complexity, costs, and effectiveness, in terms of productivity and input use efficiency. Technology adoption varies in response to water availability and climatic conditions—water scarcity and perceptions about drought will lead to the adoption of more sophisticated technologies. Advanced technologies are more likely to be adopted in regions where extension is more active by farmers who are younger and more educated and obtain a larger share of their income from agricultural production. The second study also finds support for the policy of incentivizing technology bundling, as the likelihood of a grower adopting soil-moisture monitoring technology increased by almost six-fold when the grower had already adopted salinity-monitoring technologies.

The fourth article, by Paul Ferraro, Kent Messer, and Shang Wu, provides insights from behavioral economics to improve water security. The authors discuss how changes in the ways in which choices or information are presented to decision-makers can help achieve water conservation goals more effectively. Such “nudges” can, for example, induce greater participation in conservation programs by framing choices in ways that emphasize what participants would lose from not participating in the program rather than emphasizing what they would gain from participation. Such framing leverages a well-studied phenomenon among decision-makers called loss aversion preferences. Other possible simple changes to conservation program designs include altering default choices, which leverage the decision-maker tendency to stick with the status quo, and incorporating social or peer comparisons in outreach messages, which leverages decision-maker tendencies to follow social norms.

The articles in this theme emphasize the role that institutions such as Cooperative Extension, public policy initiatives (including water metering and pricing), and behavioral nudges can play in inducing the adoption of water-conserving practices in agriculture.

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How Politics and Economics Affect Irrigation and Conservation

David Zilberman, Rebecca Taylor, Myung Eun Shim, and Ben Gordon

JEL Classifications: Q25, Q28, P16
Keywords: California, Conservation, Political Economy, Water

A growing population and rising incomes have challenged agricultural supply and led to drastic increases in irrigated agriculture. Globally, irrigated acreage increased by 76% between 1970 and 2012 (Food and Agricultural Organization of the United Nations, 2014). Irrigated agriculture can produce crop yields two to four times greater than rain-fed agriculture (Renner, 2012). Parallel to the increased demand for agricultural water, demand for municipal and industrial uses of water also rose. As overall demand for consumptive use water mounts, there are growing preferences for environmental preservation, concern for depletion of groundwater reserves, and, thus, calls for limiting the supply of water available for consumptive use (Organisation for Economic Co-operation and Development, 2015; Wada et al., 2010). There is a perceived crisis in water availability and a growing need to develop solutions that will increase supply and reduce water demand.

This article argues that much of the current water situation is a reflection of institutional and political arrangements. It further develops a political economics framework that explains the existing water allocation arrangement and suggests directions for institutional reforms. Since agriculture is responsible for more than 70% of consumptive water use in most countries, the analysis will concentrate on water resource allocation in the context of agriculture, specifically explaining the dynamics behind water products and water rights systems. We also address the challenges associated with introducing and adopting water conservation methods in agriculture and why their performance varies across regions. Finally, we provide policy recommendations and conclusions.

The Emergence of Water Policies and Institutions

Research on the history of agricultural policies (Cochrane, 1979) emphasizes that government aims to design policies to achieve multiple objectives. In the context of agriculture, these include (among others) providing resources (e.g., land and water) and developing technologies to expand agricultural production and provide safe and affordable food, assuring security of the food supply given random events, protecting farmers' income, and developing mechanisms to protect the environment. Water projects were also established as a mechanism to control floods.

The weight given to different objectives may change over time, and government choices are made subject to constraints based on control and availability of resources and ability to tax and obtain credit. In the 19th century, expanding agricultural production and land base was a major priority in the United States. There was abundance of water and land, but at the same time, the government had limited financial resources. As a result, the government established a homesteading system that allowed farmers who settled frontier regions to receive land ownership as long as they remained on the land. Similarly, in the case of water resources, farmers and other water users (both as individuals and groups) were given the right to divert water for "beneficial use," and the seniority of water rights was based on time of diversion ("first in time, first in line"). These rights were maintained as long as they were used ("use it or lose it"). During the 19th century, water districts of farmers and miners established water diversion projects that were key for agricultural activities through the West. Farmers started to pump groundwater to a limited extent.

After the establishment of personal income tax in 1909, the federal government's income greatly increased, which led to the development of large infrastructure as a major policy objective. In the early 20th century, expanding agricultural capacity continued to be a major policy objective, but most of the arable continental United States was settled and utilized. Agricultural cropland reached its peak in 1919, so the government expanded research and development to increase productivity and developed major water projects through the Army Corps of Engineers and the Bureau of Reclamation, established in 1902. During the first part of the 20th century, the government financed major projects on the Columbia and Colorado rivers, in the Tennessee Valley, and in the Central Valley in California. Some of these projects were part of the government effort to provide public works in response to the Great Depression.

The decisions about water projects were heavily based on political considerations, and economists have criticized a few of the major projects, such as the Central Arizona Project, on a benefits-costs basis (Bush and Martin, 1986). Agencies like the Bureau of Reclamation and Army Corps of Engineers, as well as individual legislators, pushed for further expansion of environmental projects, and there were even proposals to divert water from the Great Lakes to Arizona and from Alaska to California (Reisner, 1993). But growing environmental awareness, as well as mounting budgetary pressures in the 1970s and increased awareness of economic inefficiencies of water projects, led to the requirement to use benefit-cost analysis to evaluate new water projects, where the criteria of evaluation (Water Resources Council, 1983) must account for environmental side effects. These criteria have been subject to criticisms and re-evaluation, but their introduction led to reduced expansion of water projects in the United States (Shabman and Stephenson, 2000). Parallel to the introduction of benefit-cost analysis to assess water projects in the United States, the use of this analysis to assess water projects around the world increased (e.g., Pearce, 1998).

The constraints on construction of new projects added incentives to increase the efficiency of utilization of water resources in agriculture. One approach is the transition toward relying on markets to allocate water resources. In many parts of the world, water allocation was based on water rights and trading these rights was prohibited. Ability to sell water at market prices would induce farmers to switch away from water-consuming crops and to adopt water conservation technologies. However, there has been significant resistance to introduction of water markets for several reasons. First, owners of water rights objected to proposals to introduce water trading by putting water rights to bid among potential users, and this led to a consideration of mechanisms of tradable permits. Second, reliance on market forces to price water may have negative equity effects, especially on poor consumers or subsistence farmers.

One approach to address this concern is tiered pricing, in which users are given a minimum amount of water at a low cost but must pay the marginal cost of water beyond a certain level of use. This approach is especially effective in allocating water within water districts and to small water users and can be designed to meet both equity and efficiency objectives for small water users (Schoengold and Zilberman, 2014). Third, there have been concerns about third-party effects (not all the applied water is used by crops, and the residues are used to serve environmental purposes) and about loss of income within regions as economic activities may move as water is traded. This led to some constraints on water trading; for example, farmers can sell only a portion of their allocation (Schoengold and Zilberman, 2005). In some western states, the environmental benefits of water were not considered a beneficial use of water resources, and federal water projects therefore distributed water rights only for industrial and agricultural use.

The Central Valley Project Improvement Act of 1993 was a political compromise that recognized environmental water use as beneficial, reallocated 10% of Central Valley Project water to environmental purposes, and at the same time approved the sale of water rights to municipalities. This reform was introduced after the drought of 1987–1991, and its introduction illustrates that water reform tends to occur after periods of crisis, major droughts or floods, when the power and influence of different groups are changing and the status quo becomes difficult to maintain (Fischhendler and Zilberman, 2005). Similarly, the large water reform in Australia that enhanced water trading occurred after the big drought of 2001–2009 (Young, 2010; Grafton and Horn, 2014). A crisis situation also leads to major public investment decisions. For example, Israel invested in recycling and reuse of water to address growing deficits (Tsur, 2015). After the 2011–2015 drought, California introduced the Sustainable Groundwater Management Act, which will require monitoring of groundwater and control against excessive pumping (Brown, 2017).

Challenges and Possibilities of Water Conservation Technologies

One important strategy that has been proposed to address water shortages is the adoption of modern water conservation technologies. However, a growing literature suggests that adopting improved irrigation technologies does not necessarily save water. Thus, understanding the conditions under which irrigation technology adoption leads to conservation is a major challenge (Perry and Steduto, 2017).

There is a large literature on the economics of modern irrigation technologies. A key distinction is between applied water and effective water. The ratio of these two measures is water-use efficiency, which is affected by irrigation technologies as well as land quality. Irrigation efficiency is higher when water is applied on heavy soils and level land, while it is low on sandy soils and steep hills. Thus, irrigation technologies often serve to improve the water-holding capacity of soils. By increasing water-use efficiency, these technologies tend to increase yield (Caswell and Zilberman, 1985) and may reduce drainage and water logging. Shani et al. (2009) suggest that technologies like drip irrigation can also improve the timing of irrigation and maintain stable soil moisture, which both contribute to increased yield and may save water. Drip irrigation is also used as an effective mechanism for fertigation and chemigation, saving chemicals as well as reducing externalities. Generally, modern irrigation technologies (like drip irrigation) are costly compared to flood irrigation, and theory suggests that technologies are likely to be adopted on high-value crops and in locations with sandy soils or steep hills, high input prices, or concerns about environmental side effects. But while adoption of these technologies is likely to increase supply of output, they will not necessarily reduce demand for water, especially when their yield effect is substantial and in regions where demand for the final product is elastic.

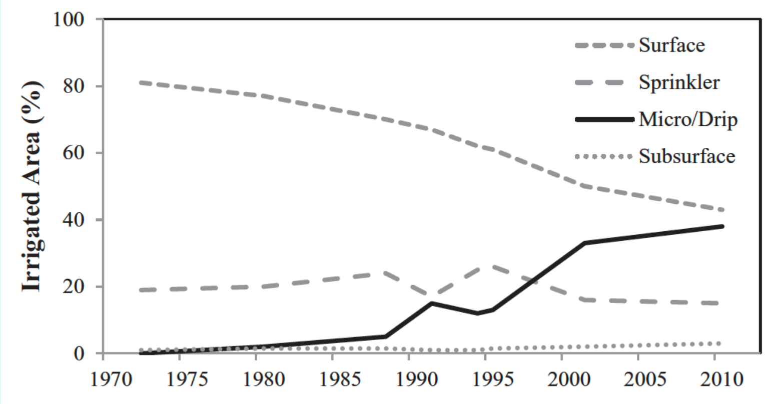
For example, Dagnino and Ward (2012) provide evidence that increased adoption of conservation led to additional water demand due to increased land cultivation as a result of improved profitability of farming. Furthermore, some suggest that adopting water irrigation can be used as a mechanism to reduce storage. Xie and Zilberman (2017) provide numerical analyses to show that water storage and modern irrigation technologies are not necessarily substitutions but instead may serve as complements in situations where water conservation technologies increase demand for water or conservation may increase the probability that water storage capacities are exhausted and thus more storage is needed. Thus, adoption of water conservation technologies is not necessarily a means to reduce water use but rather provides economic incentive to enhance water projects, and can be an effective mechanism to increase the economic performance of the agricultural sector. Of course, with a given amount of water capacity, conservation technologies can increase significantly the value of agricultural production.

Studies have found that adoption of conservation technologies like drip and sprinkler systems led to significant economic benefits in terms of increased yield as well as water savings in California, Israel, Spain, and Greece (Taylor and Zilberman, 2017). In all cases, diffusion was gradual in high-value crops and frequently occurred after periods of crisis. Successful adopters tend to have a high degree of human capital and strong support from industry. Failures and subpar performance of modern irrigation technologies in some developing countries were frequently due to lack of maintenance and support and an unreliable water supply.

The importance of timing and institutional and economic considerations in introducing conservation technologies is illustrated by the diffusion of drip irrigation in California, which was first introduced from Israel in the 1960s. The Israeli version was adopted on tree crops in Southern California, and joint public-private efforts led to the introduction of plastic tapes that were then adopted with strawberries. As Figure 1 shows, adoption rates were low until the drought of 1976–1978. The diffusion rate was still low after the drought due to uncertainty regarding quality and performance of the technology, which were—to some extent—partially addressed by establishing strong public sector activities to provide outreach and certification. The second boost to diffusion was the drought of the 1987–1991. Much of the diffusion was a result of reduction of surface water delivery by the state and increased reliance on expensive groundwater. Additionally, trading was enhanced as the state introduced “water bank,” a state-run exchange between farmers in different regions and that enabled farmers to sell water rights and provide them incentives for conservation, beginning with the 1993 passage of the Central Valley Project Improvement Act. Furthermore, political consensus on the need to conserve water in agriculture led to state investment in weather information stations (CIMIS – California Irrigation Management Information Services) and public research and extension efforts.

Cooperative Extension efforts contributed to the adoption of agricultural practices and crop varieties compatible with modern irrigation. Combined with continuous improvement in technology, these changes led to the adoption of processing tomatoes and other crops that had not previously been profitable (Taylor and Zilberman, 2017). Currently, 60% of irrigated agriculture uses drip/micro sprinklers (40%) and sprinklers (20%); surface irrigation has declined to below 50% and is mostly used on relatively low-value field crops in regions with heavy soils (Figure 1). Annual gains from yield increases and water saving associated with the adoption of drip irrigation in California are computed to be between $313 million and $1.13 billion (Taylor, Parker, and Zilberman, 2014).

Figure 1. Trends in Irrigated Area (%) by Irrigation System Category in California



Source: Tindula, Orang, and Snyder (2013).

Conclusions

Water resource management reform may increase the environmental and economic benefits of water resources. Increased demand for agricultural products may increase reliance on irrigation, but water use sustainability is likely to be achieved by effective policies that lead to reduced pollution and over-pumping, increased water trading, and the adoption of conservation technologies. However, water policies are evolving, reflecting changing political and economic circumstances. Over-investment in water projects and restriction on water trading in the past were a result of perceived water abundance and a desire to accelerate development, ignoring environmental side effects. Recognition of scarcity and environmental considerations led to reforms mostly motivated by crises. There is a growing reliance on benefit-cost analysis in assessing water projects and on water trading, but much needs to be done, including improved regulation of groundwater pumping and water pricing schemes to balance equity and efficiency considerations.

Technology—including conservation, desalination, and reuse—can address some of the challenges facing water resources. Government agencies and the private sector can enhance the implementation of effective policies by supporting public research and Extension to improve technologies and adapt them to local conditions by providing regulations to ensure product quality and by enhancing farmer actions through effective education.

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USDA Water Conservation Efforts Reflect Regional Differences

Steven Wallander

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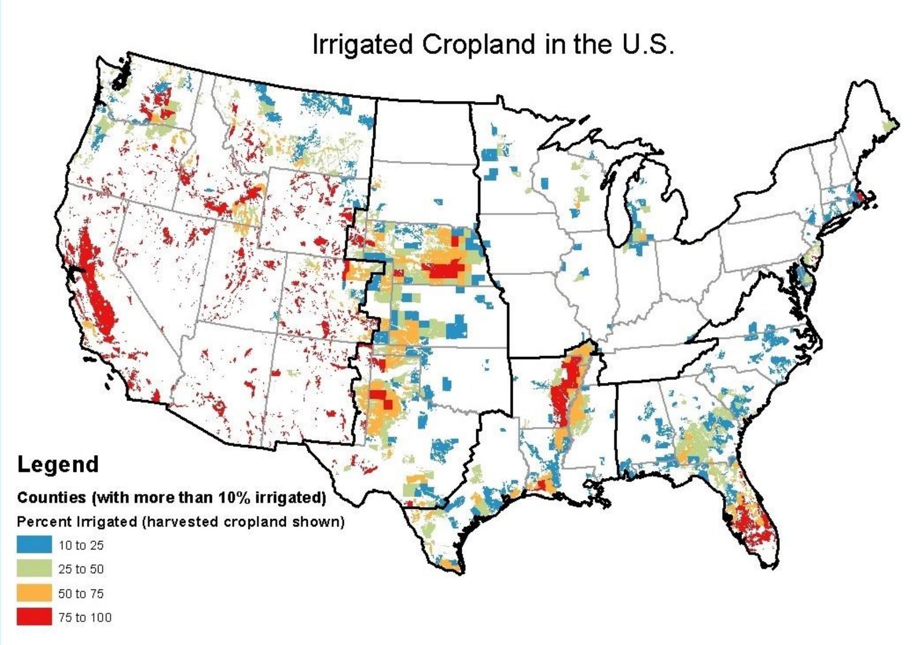
Irrigated agriculture in the United States comes in many forms: Nebraska's center-pivot-sprinkler-irrigated corn and soybean, California's drip-irrigated orchards, Arkansas's flood-irrigated rice, Florida's furrow-irrigated sugarcane, Massachusetts' cranberry bogs, and Montana's movable-sprinkler-irrigated pasture, to name just a few. Such diversity creates challenges for federal agricultural water conservation policy. One of the largest components of that policy—the U.S. Department of Agriculture's Environmental Quality Incentives Program (EQIP)—has largely addressed this challenge by promoting region-specific irrigation technology. This article examines the outcomes of the EQIP program and other important regional differences and similarities in the foundations of water conservation.

When policy-makers seek to conserve water in the agricultural sector, the purpose is generally to make more water available for other uses, perhaps municipal drinking water or environmental flows, or to increase the water available for irrigation at a future time. Since water law and water allocation decisions are typically determined at a local or state level, the federal role in water conservation has historically been to provide support. The authorizing language for EQIP exemplifies this supporting role by stating that "[t]he purposes of [EQIP]… are to promote agricultural production, forest management, and environmental quality as compatible goals, and to optimize environmental benefits, by assisting producers in complying with local, State, and national regulatory requirements concerning… surface and ground water conservation" (16 U.S. Code Part IV §3839aa).

Figure 1. Share of Harvested Acreage Irrigated

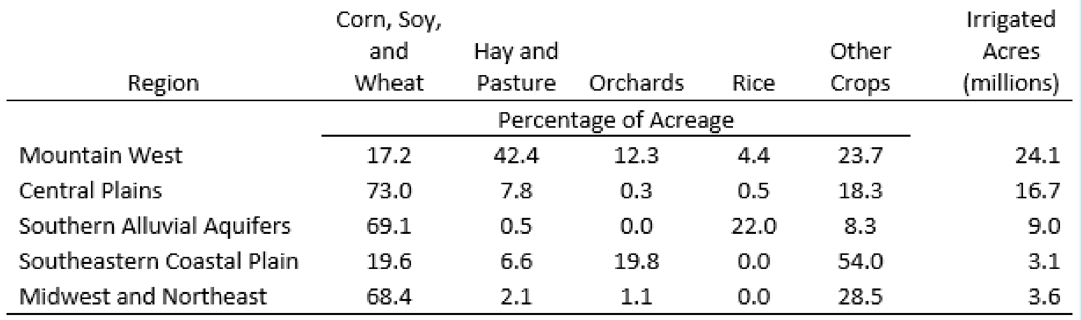


Source: Calculations based on the 2012 USDA Census of Agriculture. County boundaries are clipped to show cropland based on the 2012 National Land Cover Dataset. Regional boundaries determined by the author.

Regional Irrigation Patterns Reflect Climate, Water Availability, and Crop Choice

To capture the broad patterns in incentives for agricultural water conservation, we divide the United States into five regions: the Mountain West, the Central Plains, the Southern Alluvial Aquifers, the Southeastern Coastal Aquifers, and the Midwest/Northeast. These regions were defined to capture broad differences in water supply, crop choice, and irrigation technology. A legacy of early observations by John Wesley Powell and others is the idea that irrigation is necessary for agricultural production west of the 100th meridian and not necessary east of that line (Schlenker, Hanemann, and Fisher, 2005). While there is some truth to this generalization when focusing only on cropland, there are several areas east of the 100th meridian where irrigation is in fact quite common and there are vast areas of dryland production, especially pasture and range, in most areas to the west. County-level variation in the adoption of irrigation—as a share of total harvested cropland—shows these irrigation "hot-spots" (Figure 1). On a basic level, this simply illustrates that the supply of water from rainfall or groundwater is as important as demand for water in determining where irrigation occurs.

Table 1. Share of Irrigated Acreage by Crop Category in 2013



Region	Corn, Soy, and Wheat	Hay and Pasture	Orchards	Rice	Other Crops	Irrigated Acres (millions)
	Percentage of Acreage					
Mountain West	17.2	42.4	12.3	4.4	23.7	24.1
Central Plains	73.0	7.8	0.3	0.5	18.3	16.7
Southern Alluvial Aquifers	69.1	0.5	0.0	22.0	8.3	9.0
Southeastern Coastal Plain	19.6	6.6	19.8	0.0	54.0	3.1
Midwest and Northeast	68.4	2.1	1.1	0.0	28.5	3.6

Source: Calculations from the 2013 USDA Farm and Ranch Irrigation Survey (U.S. Department of Agriculture, 2013).

A critical driver of regional differences in demand for irrigation is variation in what crops are irrigated (Table 1). In the Mountain West, hay and pasture were the largest share of irrigated acreage in 2013, joined by orchards and a wide variety of other crops that included considerable acreage in vegetables. In the Central Plains, corn, soy, and wheat—often grown together in rotation—dominate and are joined by other crops that included cotton and sorghum. In the Southern Alluvial Aquifers, the same three dominant crops were joined primarily by rice. The Southeastern Coastal Plan spans a wide variety of other crops that included sugar cane, citrus orchards, peanut, and cotton along with some corn, soybeans, and wheat. Lastly, the Midwest and Northeast regions looked somewhat similar to the Central Plains in crop specialization—with their emphasis on corn, soy, and wheat—but the category of other crops tilted more toward vegetables and specialty crops such as cranberries.

While irrigation can facilitate the production of crops beyond their dryland range, these differences in crop specialization come in part from differences in climate and soils. Few soybeans are grown west of the Central Plains. Almost no cotton is grown north of Texas, Arkansas, and North Carolina. Climate- and soil-driven specialization have a large impact on the technology-based focus of federal water conservation policy as well as on the benefits and costs of water conservation. For example, orchards involve considerable sunk costs in orchard establishment; a large portion of the benefit of applied water, particularly during drought years, involves the preservation of capital embedded in the trees. In contrast, the extensive margin of water demand is more prevalent in many row crops, for which farmers can more easily reduce irrigated acreage. Nonetheless, crops are not located randomly, and many crops that require more water are located in areas with abundant and reliable water supplies.

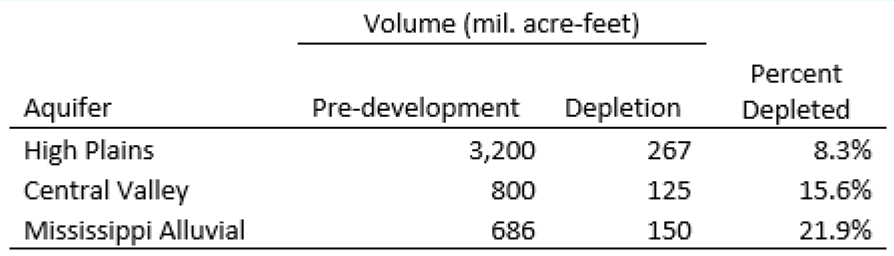
Water Supplies are a Major Driver of Regional Differences in Irrigation

As noted above, water supply is a major part of the story of irrigation. Irrigation tends to occur where there is sufficient water stored, even in areas with substantial precipitation. Given the fixed costs involved in moving to irrigated production, a critical issue for irrigators is the reliability and extent of their water source. The most basic distinction with respect to the source of water is between surface water and groundwater supplies. Surface water supplies come from capturing runoff in ponds, basins, lakes, or reservoirs. On-farm surface-water storage, typically in small ponds, is an important source of water, but from a policy perspective most surface-water-related water conservation is focused on off-farm storage in large reservoirs, which are often part of state or federal projects. Groundwater supplies come from aquifers, areas of permeable rock, sand, and gravel that contain enough water to support its extraction through wells. Many of the major irrigation areas in the United States are supported by major aquifers containing very large quantities of water, much of which has accumulated over hundreds or thousands of years.

Groundwater is the largest source of water for U.S. irrigated agriculture. Aquifers can be split into unconfined aquifers, in which the movement of water is determined primarily by gravity, and confined aquifers, in which the movement of water is determined primarily by the pressure of the overlying (confining) geologic layers. Irrigation in the High Plains region is predominately based on groundwater stored in the High Plains Aquifer, a system of several overlapping aquifers, the largest of which is the unconfined Ogallala Aquifer. In the Southern Coast Aquifers region, the presence of the unconfined Mississippi Alluvial Aquifer and the (largely) confined Mississippi Embayment allows for extensive irrigation in Arkansas, Mississippi, and—to a lesser extent—Missouri and Louisiana. In the Mountain West, many farms have access to a mix of groundwater and surface water, particularly in areas such as California's Central Valley. The Central Valley Aquifer, a system of multiple overlaid unconfined and confined aquifers, is a major source of water for much of the irrigation in California. The three aquifer systems account for about 35 million acre-feet of average annual withdrawals (Faunt et al. 2009, Clark et al. 2011, Stanton et al. 2011), representing over 70% of total groundwater used annually for irrigation in the United States.

All three of these aquifer systems, as well as many others, are slowly being depleted as annual withdrawals typically exceed annual recharge. Based on a series of USGS estimates, these three aquifers have been depleted by 8–22% since pumping began (Table 2). While there is still extensive water available in these system, this groundwater overdraft tends to be concentrated in specific subareas of each aquifer (Faunt et al., 2009; Clark, Hart, and Gurdak, 2011; Stanton et al., 2011).

Table 2. Volume and Extraction of Major Aquifers



	Volume (mil. acre-feet)		
Aquifer	Pre-development	Depletion	Percent Depleted
High Plains	3,200	267	8.3%
Central Valley	800	125	15.6%
Mississippi Alluvial	686	150	21.9%

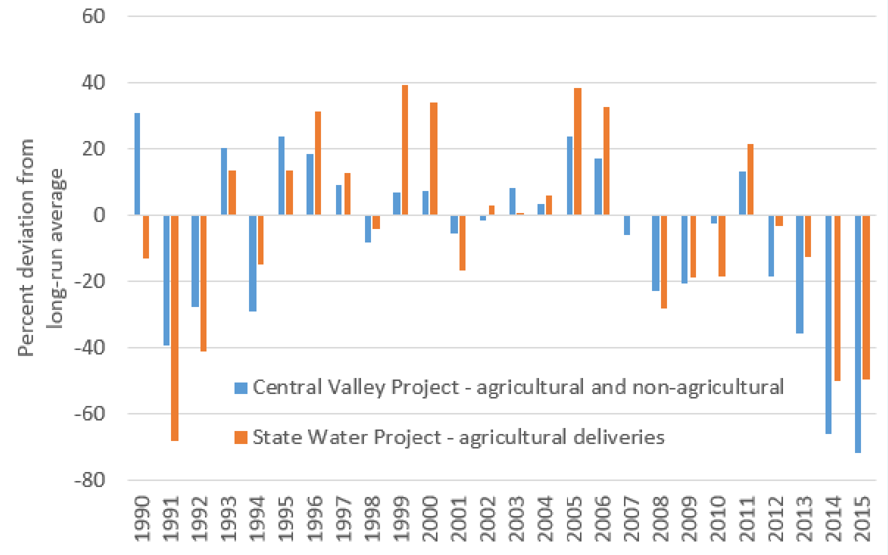
Source: USGS regional groundwater availability studies (Faunt et al., 2009; Clark, Hart, and Gurdak, 2011; Stanton et al., 2011).

About 46% of all water used for irrigation in the United States comes from surface water supplies (U.S. Department of Agriculture, 2013). Surface water plays a particularly large role in the western United States. Surface-water storage systems interact with the larger hydrological system on a much shorter time scale, capturing runoff from streams and the melting of often distant snowpack, absorbing shallow groundwater discharge, feeding shallow groundwater recharge, and, of course, directly capturing precipitation and contributing to evaporation. While irrigation in general serves as a buffer against the risk of shortfalls in rain, surface water is typically more renewable but less reliable than groundwater. When droughts occur and less water is available in the system, surface water systems inevitably have less water available to distribute to farmers. Some of the largest surface water systems in the western U.S. have the capacity to store water over multiple years, but that capacity is rarely sufficient to provide a complete buffer against drought. During the recent drought in California, the state and federal water projects that deliver surface water to the Central Valley and other areas cut back agricultural deliveries by between 50% and 70% (Figure 2). Many irrigators in the Central Valley were able to temporarily offset a large portion of this shortfall in surface water through increased groundwater pumping (Howitt et al., 2014), but many irrigators impacted by surface water variability do not have access to adequate groundwater.

Technology and Government Programs: Practices by Region and Changes in Sprinklers

Federal water conservation policy as implemented through EQIP largely employs a technological approach. Irrigation technology is the system used to apply water to the crop. Gravity irrigation involves adding water at the end of the furrows between crop rows and allowing the water to flow down between the crops. Pressurized irrigation systems deliver water to crops through sprinklers or drip nozzles. There are many variations on each system, and an important characteristic of any system is its technical efficiency. More efficient irrigation systems reduce the amount of irrigation water lost to evaporation, surface runoff, or deep infiltration, but these systems also often involve greater capital expenses, operating costs, or management effort.

Figure 2. Variability in Surface Water Deliveries to Agriculture in California's Central Valley



Source: Author calculations on delivery data proved by the California Department of Water Resources and the U.S. Bureau of Reclamation.

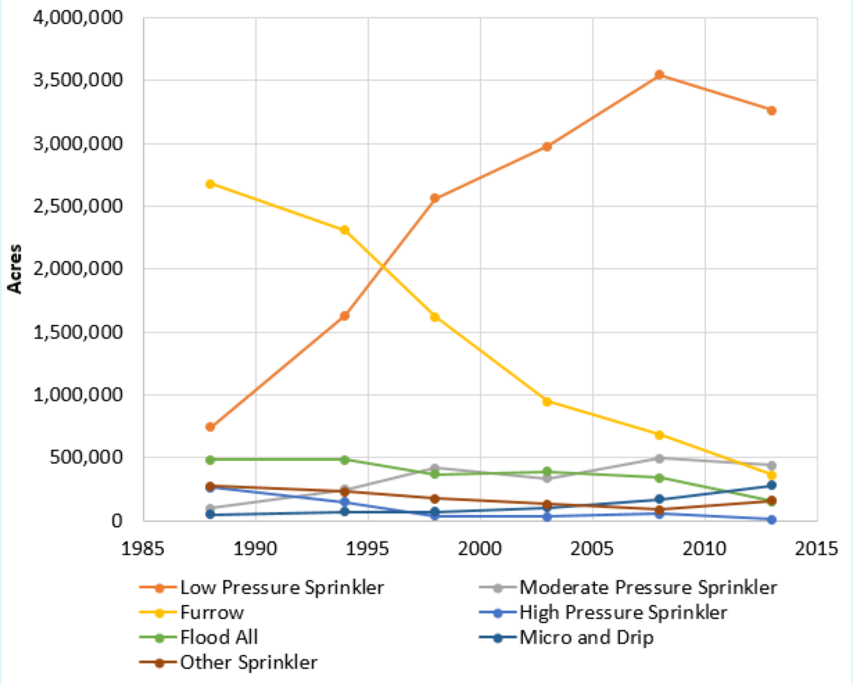
Since water is often not managed through markets or other price-based mechanisms, irrigators may be underinvested in irrigation efficiency. This is one rationale for using government financial assistance programs to encourage the adoption of more efficient irrigation technology. One challenge with this approach is that, given the numerous types of irrigation technologies, improvements in efficiency can take many different forms.

Based on analysis of EQIP contract data, the regional differences described above are reflected in the type of technology that EQIP and similar programs focus on. In the High Plains, the most common irrigation practice supported by EQIP is sprinklers, often low-pressure systems that reduce the amount of applied water lost to evaporation. In contrast, micro and drip irrigation are the most common practices in the Mountain West. In the Gulf Coast Alluvial Aquifers, the most common practice is land leveling, which reduces water loss to runoff. So even though the program involves water conservation at the national level, local initiatives are able to tailor to regional needs. Much of the acreage that receives financial assistance for irrigation technology improvements through EQIP also receives assistance for the adoption of improved water management practices such as better irrigation scheduling.

Large changes in irrigation technology adoption have occurred over the past 20 to 30 years. These changes vary by region and reflect similar shifts as the technology focus of EQIP, although the changes are much larger, in acreage terms, than total program participation over this time. Texas, for example, has seen a decrease of more than two million acres in furrow-based gravity irrigation and an increase of over two-and-a-half million acres in low-pressure center-pivot sprinklers (Figure 3). Much of this represents a true shift in technology at the field level, but some of the change also represents a regional shift. For example, over the past three decades total irrigated acreage—much of which has been gravity-irrigated using furrows— has decreased in the Southern High Plains, and over the same period irrigated acreage— much of which is pressure-irrigated using center-pivot sprinklers—in the Northern

High Plains has increased. In the Mountain West, particularly in California, the shift in technology has involved a similarly dramatic decrease in flood irrigation, but the increase has been predominately in use of micro-irrigation.

Figure 3. Changes in Irrigation Technology in Texas, 1998–2013



Source: USDA Farm and Ranch Irrigation Survey, multiple years.

There are several behavioral obstacles to achieving significant water conservation with the technology-based incentive approach. The first is related to the fact that the programs are voluntary. Since participants self-select into the program, there may be some proportion of participants who would have adopted the practice even in the absence of the program, which means that some of the new technology adoption is non-additional (Claassen et al., 2014). Even when financial assistance does induce additional adoption of improved technology, there are many opportunities for compensating behavior, changes in farmer behavior that may offset any water savings. More efficient irrigation systems reduce the marginal cost per unit of water actually used by the crop, which can induce increased application of water, expansion of irrigated acreage, or crop switching (Ward and Pulido-Velazquez, 2008; Pfeiffer and Lin, 2014). The magnitude of such compensating behavior has not been studied for all of the major practices covered by EQIP or for the impacts of the practices in all regions. Most studies of compensating behavior, sometimes called the "rebound effect," involve statistical comparisons of program participants to a selected group of non-participants. For both groups, over the past two decades, average irrigation applications rates have been modestly declining. (U.S. Department of Agriculture, 2013.)

Emerging Alternatives to a Technology-Based Water Conservation

There are alternative approaches to technology-based water conservation. For example, there is growing interest in managed aquifer recharge (MAR), which involves making investments and water management decisions that increase the rate at water is returned (recharged) to an aquifer. The MAR approach can take many forms—injection wells, recharge basins, flooding of fields during winter months (Niswonger et al., 2017). Conjunctive management, which involves simultaneously managing surface water and groundwater systems, is closely related but doesn’t necessarily involve sophisticated analysis of finding the optimal times and places to recharge groundwater. Many areas in the Mountain West have a considerable history of both formal and informal conjunctive management, such as California’s Central Valley, where decades of relatively inefficient flood irrigation often recharged portions of the aquifer during years with above-average precipitation. Also, the approach of groundwater banking is closely related to MAR, but in most cases banking involves accounting for reduced withdrawals rather than increased recharge. The important aspects of MAR that make it a promising approach for future water conservation efforts include new research that improves MAR geographic targeting and reductions in MAR opportunity costs.

Another interesting area for water conservation is improved water metering. Most groundwater well irrigation in the United States is still unmetered (U.S. Department of Agriculture, 2013). While this makes marginal, volumetric pricing impossible, it also raises behavioral issues related to information. Most groundwater irrigators only know how much water they are applying based on rough calculations made from knowledge of pump capacity and run time. Improved information about water application rates could improve the precision with which farmers make irrigation decisions. The theory on the impact of more metering on water use is not well developed, but if farmers tend to over-apply irrigation water relative to crop water needs, then greater metering could lead to greater water conservation. Also, greater metering would allow peer comparison, which in the residential water conservation area has been shown to reduce water use (Ferraro and Price, 2013).

Conclusions

Through EQIP and other programs, the federal government plays a large role in agricultural water conservation efforts even as most water allocation decisions are made at local, state, and regional levels. Federal agricultural water conservation efforts, like irrigation, occur throughout the country, not just in the western United States, and take different forms in different regions. For the most part, this involves providing financial and technical assistance for farmers adopting more efficient irrigation technologies in different regions. Future opportunities for agricultural water conservation may go beyond this technological focus and look at new methods to improve groundwater management or expand metering.

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Farmer Adoption of Water Management Practices in Response to Recurrent Drought

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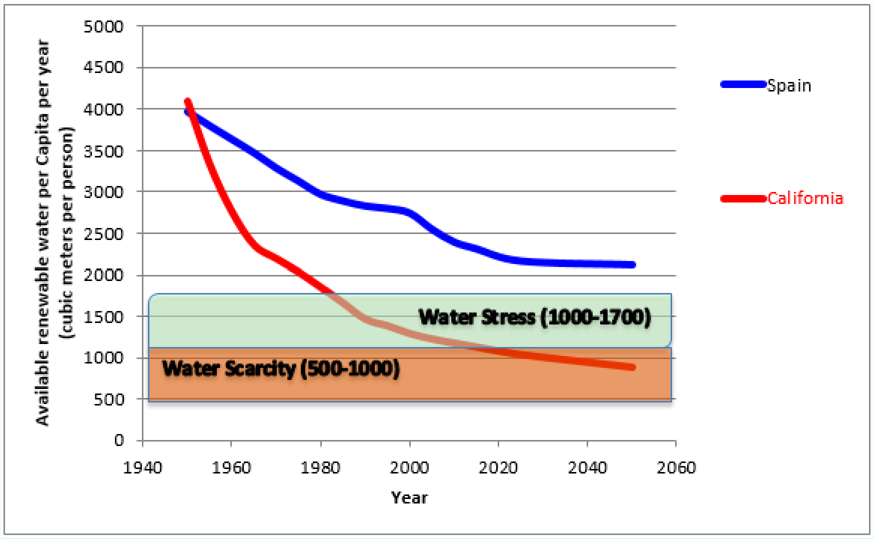
JEL Classifications: Q33, Q16, Q25

Keywords: Adaptation, Avocado, California, Conservation, Drought, Water

California, the leading agricultural producer state in the nation, faces recurrent droughts, including the severe 2009–2016 drought. After record-breaking amounts of rainfall (27.81 inches) (National Oceanic and Atmospheric Administration, 2017) and snow pack in water-tower reservoirs in the Sierra Nevada mountains (89.7 inches) in winter 2016–spring 2017, the National Weather Service (2017) officially declared the drought to be over. However, it would be reckless to think that droughts and water scarcity will disappear from California's agenda. Using a very simplistic measure of water scarcity—the available water scarcity per capita per year over time (Figure 1), it is clear that California faces a much more water-scarce future, even without droughts or other climatic shocks. Comparing California to Spain, a country with similar climate, agriculture, and history of water management, one can see the significant gap that makes California prone to future droughts.

Figure 1. Water Scarcity (Cubic Meter per Capita per Year) 1950–2050 in Spain and California



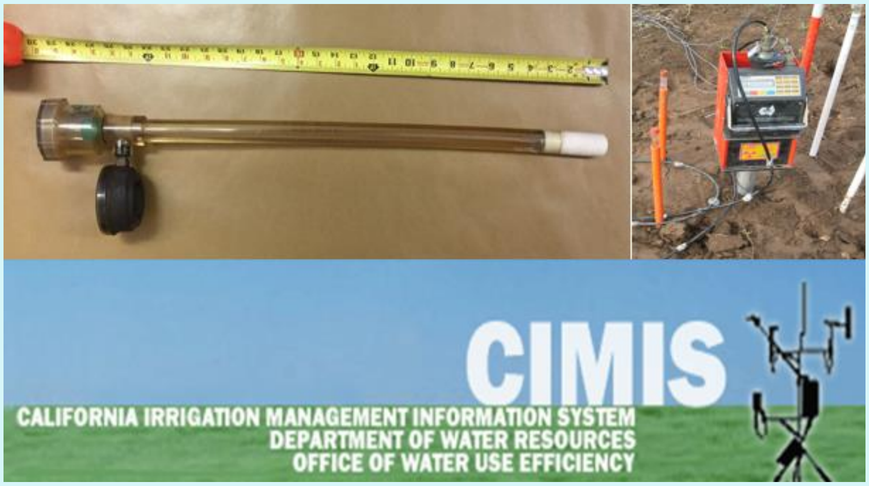
Notes: 1 acre-foot = 1,235 cubic meters.

Source: Calculated by authors based U.S. Central Intelligence Agency (2015), U.S. Department of Commerce (2016), Hanak et al. (2011), and California Department of Finance (2016).

California's agriculture has been affected by droughts to various degrees, depending on the region and the local farming sector's ability to adapt (Medellín-Azuara and Lund, 2016). At the same time, farmers have adapted to drought situations in various ways. In this article, we discuss grower adaptation behavior under water scarcity and deteriorated quality in several distinct Southern California growing regions. Crop types include avocado in coastal counties (Reints, Dinar, and Crowley, 2017) and mixed crop farming under desert conditions (Ashraf 2017).

Previous work suggests that growers may respond to lower availability and quality of irrigation water (e.g., higher salinity level) using different short- and long-term water-management strategies. For instance, growers may modify their irrigation schedule by introducing new monitoring and scheduling techniques and equipment (Figure 2). They may fallow part of their land to adjust the irrigation area to the reduced amount of their available water. They may intensify their consultation for advice on irrigation and related matters with agricultural extension specialists and commercial agents. They may also invest in changes to the irrigation technologies/infrastructure they use. Farmers may switch crops or invest in alternative water sources such as drilling wells to pump groundwater and/or using treated wastewater. In the case of avocado, farmers may also elect a more drastic strategy by stumping the canopy of the trees in their grove (Figure 3) and keeping trees “afloat” (un-productive), surviving on a very small amount of water, until water conditions improve and production can be resumed.

Figure 2. Water/Wetness Monitoring Equipment used by California Avocado Growers



Sources: Row 1 (left to right): Tensiometer, photo taken by Julie Reints; neutron probe, University of Sydney (http://ictinternational.com/products/smart503/neutron-probe-smart503/). Row 2: California Irrigation Management Information System website page header (http://www.cimis.water.ca.gov/Default.aspx).

Figure 3. Drastic Avocado Stumping

Due to lack of water, these avocado trees in San Diego County have been "stumped," taking them out of production for a few years in hope that the water situation improves by the time they grow back into production. Photo courtesy San Diego Farm Bureau

Source: Gordon (2009).

We consider the bundle approach to growers’ adoption of technologies and management practices. Bundling, combining discrete technologies and management practices, occurs when growers use several technologies and management practices instead of adopting one technology or management practice. Using the bundle approach to maximizing scarce resources may provide growers more flexibility than adopting individual technologies or management practices. Such flexibility may help growers fare better under limiting climatic and water conditions, provide resiliency, and result in higher profits, as observed by Wang et al. (2010) and Fleischer, Mendelsohn, and Dinar (2011).

Avocado Grower Adoption of Water-Saving Bundle Technologies and Management Practices

Avocado is commercially grown in six coastal counties of Central and Southern California: Orange, Riverside, Santa Barbara, San Luis Obispo, San Diego, and Ventura. Within these counties, avocado production covers nearly 57,000 acres and is managed by about 5,000 grower operations (California Avocado Commission, 2013). In these regions, avocado growers may face highly saline and/or chlorine water, interruptions to water delivery, mandatory reductions of water use, and rising water costs.

These areas of California have very different evapotranspiration zones, which suggests possible differences in adoption based on farm location. For instance, in Santa Barbara and San Luis Obispo Counties, where avocado is typically grown within 20 miles of the coast, rainfall and humidity are greater and mean annual temperature is lower compared to the most southern parts of the state—such as Riverside, San Diego, and Ventura counties—where avocado is also grown.

Avocado growers reported using several water-saving technologies and management practices, including (1) seven soil moisture measuring devices that allow growers to potentially produce the same level of yield with less water; (2) one irrigation calculator, designed to help growers determine site-specific crop water requirements based on weather data and crop coefficients; (3) five water-saving techniques that temporarily reduce water supply to and consumption by trees; (4) five water-management techniques that improve water-distribution uniformity and salinity control; (5) five irrigation technologies; and (6) miscellaneous techniques.

Four bundles of technologies and water-saving techniques, found to be significantly different from each other, represent the most common types of bundle management approaches (Reints et al., 2017):

- Bundle 0: Growers who do not use a water-management method described in the list above.
- Bundle 1: Growers who use pressure-compensating sprinklers, by feel method, tensiometers, and irrigate by calendar (e.g., every third Tuesday). This bundle is the least advanced, as it requires the least amount of training, education, and money to implement.
- Bundle 2: Growers who stump or heavily prune their trees to conserve water, use CIMIS, gypsum blocks, and utilize free water district water audits to improve farm water use efficiency. This bundle is more sophisticated than Bundle 1. Using CIMIS, although free, requires knowledge of evapotranspiration concepts and learning how to use the CIMIS framework with respect to seasons and type of crop. Utilizing water audits requires knowledge of irrigation systems, how to improve the water efficiency, and paying for improvements after the audit is completed.
- Bundle 3: Growers who use a combination of technologies and management methods from Bundle 1 and Bundle 2, including pressure-compensating sprinklers, by feel, tensiometers, calendar-based irrigation, stumping/pruning trees, CIMIS, gypsum blocks, water audits. This bundle is the most flexible and represents growers who need flexibility in their approach to water management. Bundle 3 is the most sophisticated.

We sought to identify determinants that explain selection of the various bundles among avocado growers in California through surveys of all commercial California avocado growers (5,135 growers farming 53,780 acres) in San Diego, Ventura, Riverside, San Luis Obispo, Santa Barbara, and Orange counties. Riverside and San Diego counties are the most arid avocado-growing regions; they are affected more severely by droughts and lack high-quality irrigation water. This analysis uses 123 avocado growers farming 3,899 acres.

We estimated adoption of water-saving practices using two methods: (1) the likelihood of grower adoption of any technology or water-saving practice, and (2) the likelihood of grower adoption of bundled technologies. For the first case we confirmed that, holding all other variables constant, farm location in arid counties has an effect on adoption. The probability of being an adopter of any irrigation management practice or technology increases when orchards are located in Riverside County, when owners have a higher income share from avocado production, and when they highly value information from cooperative extension. The probability of being an adopter decreases with the farm's irrigation complexity and the owner's age.

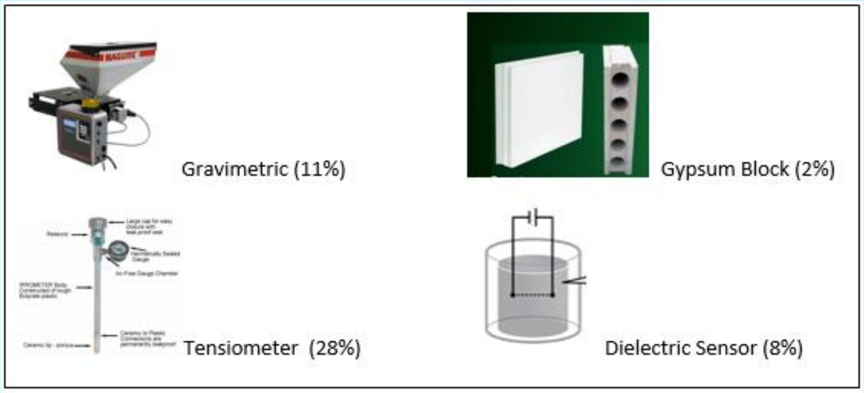
For the second case, estimating bundle adoption, the most significant factor in growers selecting bundle 1 were the grower's income share from avocado production and informational factors such as use of cooperative extension advice. We did not find that farm characteristics, such as location, had an important contribution to selecting bundle 1. However, farm characteristics and location of orchard, were important for a grower to choose bundle 2. Age, education, and share of income from avocado also explained a grower's decision to select bundle 2, as did use of cooperative extension.

The probability of a grower using Bundle 3 increases for farms located in San Diego or Riverside counties, the most arid regions of California. Owner's age in all bundles decreased the probability of using bundles 2 and 3. This trend has been seen in previous literature (Fleischer, Mendelsohn, and Dinar, 2011; Wang et al., 2010). The probability of selecting bundle 3 was decreased by the farm's irrigation complexity. Income share from avocado and use of cooperative extension were also important factors affecting a grower's decision to select bundle 3 for irrigation management.

Farmer Adaptation to Water Scarcity in Desert and Southern California Counties

Desert and Southern California agricultural systems rely on supplies of irrigation water and therefore on water availability. In this analysis, we were interested in incorporating the diverse institutional arrangements, climate, land quality, and crop choices of farmers in agricultural counties in desert and Southern California into a single, meaningful analysis. Previous adoption studies in California have focused on the Central Valley, which tends to have more homogeneous growing conditions relative to Southern California (Osgood, 1999; Green et al., 1996). Additionally, we were interested in the extent to which adopting technologies that promote irrigation efficiency (using the definition in Burt et al., 1997) represents adaptation to an increasingly warm and dry climate.

Figure 4. Moisture-Monitoring Techniques Used by Farmers in Four Desert and Southern California Counties (Percentage of Growers Using Each Technique, in Parentheses)



This analysis focused on measuring farmer adaptation of moisture-monitoring techniques (Figure 4) and water quality (salinity) monitoring devices in four desert and Southern California counties through a survey of 1,268 potential agricultural operator respondents in Imperial, Riverside, San Diego, and Ventura counties. A total of 221 responses, 195 of which were valid, were used in the analysis. Farmer response to water scarcity and deteriorated water quality was a result of various type of information and know how sources. Their choice of management practices was guided by the impact of their perceptions of water scarcity; in extreme cases, they responded by selling their land and moving out of agriculture.

We categorized farmers' perceptions regarding the primary threats to future water supplies as follows: drought, environmental groups opposition, tighter government regulations, population growth in urban centers, and no threats. We found that perceptions about population growth and government regulations increased the likelihood of adopting soil management practices relative to perception of drought. But, perceptions regarding environmental groups opposition impacts may not increase adoption likelihood relative to perception of drought impact.

Findings suggest that farm type (crop mix) plays a role in the decision to adopt soil moisture-monitoring technologies. Several farm types categorize desert and Southern California agriculture: grain/field crop farms, mixed crop farms (without a single majority type of crop), vegetable farms, orchard farms, and vineyard farms. Vineyard, mixed crop, and orchard farms have almost six-, five-, and four-fold increases in the likelihood of adopting soil moisture-monitoring technologies relative to field crop farms. It may be interesting for policy-makers to note that growers who diversify their crop categories (i.e., mixed farms) may also be more likely to adapt by adopting soil moisture-monitoring techniques relative to the baseline farm type (field crops).

In reaching their adaptation decisions farmers indicated using information provided by the following sources: government/university Extension, industry, professional farm managers, friends/neighbors farmers, and popular press. The most relevant finding for policy is that the likelihood of adopting soil moisture-monitoring technologies more than doubled when a grower received information from government or university extension rather than relying on neighboring farmers. This result suggests an important role for information provided by Cooperative Extension.

Another important result relates to the salinity-monitoring variable, the analogous variable for soil moisture monitoring, which represents the use of at least one salinity-monitoring device. We find that the likelihood of adopting a soil moisture-monitoring technology increases by almost by 600% when the grower has also adopted salinity-monitoring devices. Hence, adoption in bundles provides stronger incentives for adoption. This is also an important finding for policy-makers with respect to the target population, as it suggests that those who adopt one practice may be more likely to adopt another. It may be more cost-effective to direct outreach efforts to those growers who have already adopted water management or water quality practices.

We also found a farm size effect in the adoption of soil moisture-monitoring technologies, suggesting that larger farms are more likely to adopt soil moisture-monitoring technologies. This is also an important finding for policy because it suggests the need for different policies to target different farm sizes.

As a final note, we highlight the large magnitude of the intra-annual climatic variability measures (temperature and precipitation) relative to mean conditions, which may be dampening the effect of climate extremes experienced throughout the year. This may suggest that farms experiencing climatic extremes across seasons in a given year—and who therefore experience more uncertainty—may be more likely to offset some of this uncertainty by adopting more monitoring practices.

Conclusions and Policy Implications

Our analysis implies that information providers such as the University of California (UC) Cooperative Extension for California avocado growers and for desert and Southern California farmers. Cooperative Extension advisors and specialists are able to distribute research findings and tools necessary for growers to mitigate the impact of drought and deteriorated water quality. Access to information and knowledge provided by public agencies, such that UC Cooperative Extension, would increase the likelihood of technology adoption among farmers.

It was also found that human capital variables such as age and education are important in grower decision-making concerning water management. The importance of the share of farm income from avocado production was significant for grower bundle adoption, implying that grower specialization positively impacts decisions about water management on the primary crop.

In addition, this research demonstrates that growers will need to be flexible in their approach to water management to mitigate climate change and reductions in irrigation water quantity and quality. Growers who were able to select from many different discrete management tools to manage water were located in Riverside and San Diego counties and had less complex irrigation systems. Riverside and San Diego Counties have higher aridity indexes and are predominantly on district water, typically a more expensive option for growers. Growers may benefit from redesigning and simplifying their irrigations systems in order to keep them maintained and water-efficient in areas where less water is available.

There are several policy implications arising from these analyses. First, we found that a combination of variables motivate farmer adoption, starting with making information available through Cooperative Extension services. County-specific services—such as Extension, laboratory testing, etc.—play an important role in enabling farmers to adopt technologies and bundles. Policies that enhance these services could make a difference in farmers' success when they face water scarcity and deteriorated quality.

Second, we realize that regional differences exist (e.g., soil, climate, access to markets, services) and, thus, policy responses can account for these regional differences and provide a quilt rather than an umbrella policy. Regions with big urban centers could also take advantage of an additional source of water in the form of treated wastewater, which may benefit farmers if properly treated and adequately priced.

Finally, we also realize that farm size is an important factor in the ability of farms to adapt their water management practices and technologies in response to water scarcity. Policies that differentiate between farms of different sizes would be more effective.

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Applying Behavioral Insights to Improve Water Security

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In the United States, the federal government and other organizations spend billions of dollars each year on agri-environmental programs. Between 2014 and 2018, for example, mandatory 2014 Farm Bill spending for conservation programs will amount to an estimated $28 billion (U.S. Department of Agriculture, 2017). Much of that money will be directed to projects broadly connected to water security, which has been defined as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability" (UN-Water, 2013, p. 1). To ensure that funds allocated to water security goals are spent cost-effectively, agricultural researchers and practitioners may wish to consider an approach that is increasingly being adopted in other public policy contexts: embed insights from behavioral sciences into program designs and then use randomized controlled trials to test how well these insights contribute to achieving water-security and other agri-environmental goals.

In recent years, federal, regional and local governments in a number of countries have begun to rely on insights from behavioral economics and psychology to develop programs that are more cost-effective. In several countries and cities, governments have established full-time "nudge squads" to facilitate this work. For example, in the United Kingdom, the national government assembled a Behavioral Insights Team with a goal of improving the cost-effectiveness of their policies and inducing better outcomes using ideas from the behavioral sciences. In the United States, the Obama administration created a Social and Behavioral Science Team (Obama 2015) and called for policies and programs throughout the government to be based on evidence from the behavioral sciences (Office of Management and Budget, 2013), a call that has recently been echoed in the Trump Administration (Office of Management and Budget, 2017). Within the U.S. Department of Agriculture (USDA), the Economic Research Service established the Center for Behavioral & Experimental Agri-Environmental Research (CBEAR) in 2014 to apply behavioral insights and experimental designs to improve water, agriculture, and environmental programs.

Adjustments to programs or policies based on insights from the behavioral sciences are commonly referred to as "nudges" because they tend to involve relatively small additions or changes to the decision environment that encourage, but do not force, changes in behavior. Nudges often consist of minor changes in how choices are presented to decision-makers, which are often referred to as changes to the "choice architecture" (Thaler and Sunstein, 2008). Nudges usually are not financial mechanisms, although they may involve changes in the way in which financial mechanisms are presented or constructed. Because they are often low-cost, not disruptive to existing programs, and preserve citizen choice, nudges have been attractive to program designers.

Nudges have been shown to be effective in inducing better decision-making in a variety of applications, ranging from one-time, life-changing decisions to everyday behavioral habits. Despite the success of a wide range of nudges incorporated into various social policy programs around the world, programs focused on water security have largely ignored the benefits that can be achieved through the power of nudges. Four characteristics of nudges make them potentially useful for addressing water-security issues.

1. Their ability to change policy-relevant behaviors is supported by a growing body of empirical evidence.
2. They are well-suited for programs that encourage voluntary actions, like adopting new technology or practices.
3. They typically require only small adjustments to a program, so they are often politically feasible and cost-effective ways to solve problems.
4. Their effectiveness can be easily tested in randomized controlled trials prior to large-scale implementation, providing evidence regarding what works best under specific conditions.

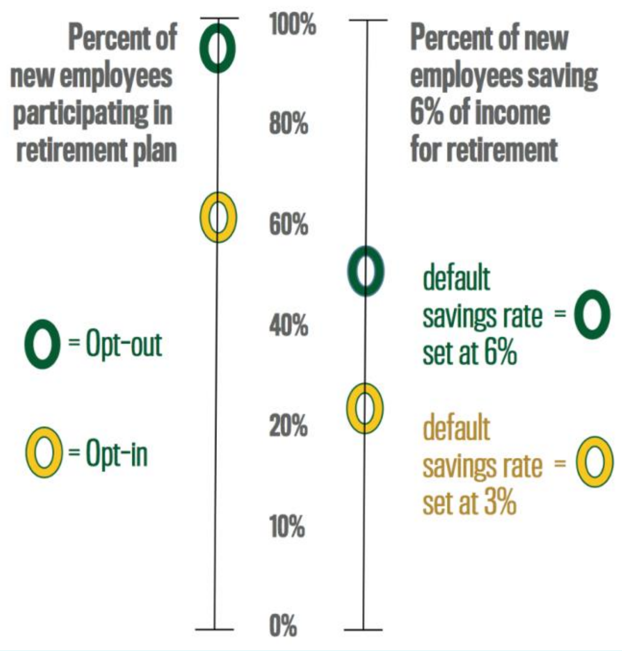
In the sections below, we describe key behavioral insights that have been used successfully in other contexts and briefly discuss how these insights can be used to improve water-security and other conservation objectives.

Defaults and Anchoring

When faced with making decisions, people are prone to inertia and tend to maintain the status quo—they do nothing or make the same kinds of choices they have made before. This tendency is referred to as status quo bias (Samuelson and Zeckhauser, 1988). Studies have repeatedly shown that people disproportionally stick with the status quo even when making significant life decisions.

An example is the default option offered to new employees regarding retirement saving plans. In most standard plans, employees must act (opt in) to enroll, but many more employees choose to participate when enrollment is automatic (the default) and they must act to not participate. Similarly, offering a high default saving rate under such plans increases the number of people who choose that rate relative to offering a low default saving rate and requiring them to act to select a higher one. Employees presented with a default savings rate of 6% were twice as likely to set aside 6% of their incomes as employees presented with a default rate of 3% (Figure 1, Beshears et al., 2009).

Figure 1. The Effect of the Default Choice in a Retirement Savings Plan



Source: CBEAR, 2015.

In an agricultural context, the power of defaults has been proposed as a reason why voluntary contributions to agricultural checkoff (marketing) programs were historically high (Messer, Kaiser, and Schulze, 2008). In this case, producers were automatically assessed a fee to support egg marketing efforts. If they wanted their money, they had to request it back. Similar defaults have also been shown to increase charitable donations to environmental programs (Zarghamee et al., 2017).

In agri-environmental programs, the attractive power of the default option could, for example, be harnessed in the sign-up process for the Conservation Reserve Program (CRP). In the CRP's current enrollment process, farmers compete for limited contracts on the basis of their Environmental Benefit Index (EBI), which reflects the conservation practices they have agreed to implement and their bid. The default starting point for the EBI is no conservation practices. Farmers can improve their ranking by agreeing to implement better, but generally more expensive, practices. Programs might do better, however, by setting the default starting point to the best practices and then allowing farmers to opt out of those practices.

The concept of defaults can be extended to ideas of “active choice.” For instance, the USDA currently offers a number of computer-based and online technical-assistance services, such as the Conservation Client Gateway. These services seek to lower the costs of communication and program transactions for both farmers and the USDA. Yet participation in these platforms is low. To increase participation, USDA agencies could develop alternative choice architectures. For example, the default status for farmers is “traditional modes of interaction with USDA”—if farmers do not contact the USDA to register for the online platform, they will interact with USDA via traditional means: mail, phone, and local office visits. In other words, farmers must opt in to use the platform. An alternative default is active choice: every farmer is directly asked their preferred format for interacting with USDA—traditional or online. With active choice, more producers are predicted to participate in these new online programs, thereby increasing conservation benefits and cost savings.

Using Loss Framing

An important factor in economic decisions is loss aversion. Loss-averse individuals attach greater significance to losses than to gains (Tversky and Kahneman, 1991). For example, a manufacturing company that awarded incentive bonuses based on work teams’ output found that how one frames an incentive payment affects how much people respond to it (Hossain and List, 2012). Although all of its teams worked under the same bonus system, some teams were randomly assigned to a gain frame and others to a loss frame. Gain-frame teams were told that they would earn a bonus for every week in which they met a performance benchmark, up to a maximum annual payment. Loss-frame teams were told that they would receive the maximum payment minus a deduction for every week in which they did not meet the benchmark. Teams presented with the loss framing produced greater output, on average, than teams presented with the gain framing.

Agri-environmental programs frequently use incentive payments and always present them through a gain frame. However, were these programs to present the incentives in a loss frame, landowners might deliver more conservation output. For example, voluntary conservation programs to reduce nonpoint source pollution could change the focus of their enrollment process from payments earned per additional practice or per additional ton of pollution reduced—a gain frame—to the maximum payment the participant could earn and how much the participant would lose for every practice not adopted or every ton of pollution not reduced. Rather than starting with where potential participants are and explaining how much better they can do, program managers can present the best the applicants can do and leave it to participants to reject specific actions or services. By changing the participants’ reference point, program administrators can harness loss aversion to improve the cost-effectiveness of the program.

Social Comparisons and Social Norms

The concept of social comparison originates from Festinger (1954), who posited that humans judge the appropriateness of their behavior based, in part, on the behavior of others. In a field experiment, Allcott (2011) demonstrated that consumption of electricity could be reduced by informing people about their power use compared to their neighbors’ and to that of “efficient users.” In another field experiment, Ferraro and Price (2013) found that similar nudges based on social comparisons could reduce water use. Furthermore, the effects of these social comparisons remained detectable years after the programs started (Allcott and Rogers, 2014; Bernedo, Ferraro, and Price, 2014).

Social comparisons can be used in a similar way but are focused on developing descriptive norms rather than on comparisons of behavior—that is, they use descriptions of the way “most people” behave to influence other people. Studies have found that people often perceive decisions presented as the norm as likely to be effective and adaptive responses (Cialdini, Kallgren, and Reno, 1991). Therefore, people tend to follow the norm, particularly if they are not very familiar with the circumstances of the decision. Goldstein, Cialdini, and Griskevicius (2008), for example, showed that a social comparison treatment that presented people staying in hotels with a descriptive norm such as “the majority of people reused their towels” had a larger effect on their behavior than standard messages about the benefits of reusing towels. And the more the message related to their immediate situation, such as “the majority of people in this room reused their towels,” the better it worked. Lab studies related to non-point-source water pollution have found similar results. For instance, Wu, Palm-Forster, and Messer

(2017) found non-point-source pollution-management programs could reduce pollution by presenting information to potential participants about decisions made by others like them in a similar situation.

The power of social norms and comparisons could be harnessed by conservation and stewardship programs to boost enrollment and the number or quality of practices adopted, and thereby significantly increase their ability to safeguard water resources and quality. Such programs have already been established, including Minnesota's Agricultural Water Quality Certification Program, where farmers, upon adoption of a set of core practices, earn the right to display a sign recognizing their farms as friendly to water or the environment. Programs in the Pacific Northwest identify farms that are "Salmon Safe" or that practice "Fish Friendly Farming". As more producers participate in these programs, publicizing this increasing level of participation can be used to encourage other landowners to participate in the programs.

Social comparisons and norms could also encourage participants to renew their conservation contracts or comply better with their contractual obligations. For example, Wallander, Ferraro, and Higgins (2017) showed how program administrators could test the effect of social comparisons on re-enrollment rates in the CRP. As another example, in counties where contract holders are substantially delayed in meeting their contractual obligations (often never actually completing the agreed-upon practices), notifying contract holders about the high percentage of producers in their state who are in compliance with their contracts could reduce the "late rate." When designing such nudges, research suggests that it is important to use comparison groups that the targeted participants care about, such as their neighbors in the county or other state residents, and to make clear that the desired behavior is common among members of those groups (or uncommon, if seeking to discourage a behavior).

Summary

Programs targeting water security consume billions of taxpayer dollars annually, so thinking about how to make them "smarter" and more cost-effective is important. Despite the fact that social and behavioral nudges have repeatedly been demonstrated as an effective approach for social policies, agri-environmental programs have mostly failed to adopt or test them.

In this article, we discussed a number of nudges that are well-grounded in behavioral economics and psychology and how they might be readily applied to solve water-security issues, including potential applications and tips for designing them. The majority of these nudges would require only subtle changes in how information is provided but could lead to significant increases in participation or effort, making the programs highly cost-effective and desirable to policy-makers. These nudges can also be tested on a small scale to identify the best approach before being rolled out on a larger scale, which is recommended to obtain the best possible result.

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