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INSTITUTIONAL BARRIERS TO WATER CONSERVATION IN THE RIO GRANDE BASIN: CHALLENGES AND OPPORTUNITIES[1]

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Abstract

The Rio Grande basin shares the problems faced by many arid regions of the world, in which water is over-allocated, there are growing competing demands, and river flows and uses are vulnerable to drought and climate change. Recent years have witnessed the emergence of legislation, administrative action, and other measures in the basin to encourage private investment in increased water use efficiency with the intent of promoting agricultural water conservation. Nevertheless, several institutional barriers discourage irrigators from investing in measures to conserve water.

This talk examines institutional barriers to agricultural water conservation and identifies challenges and opportunities for emerging efforts to promote water conservation in the basin's agriculture. A water management practice is found to constitute conservation when it conserves a given supply of water through reduction in water use and it produces a net increase in society's economic welfare. Several institutional barriers to water conservation are identified: clouded titles, water transfer restrictions, illusory on-farm water savings, insecure property rights to conserved water, an uncertain duty of water, shared carryover storage, interstate compacts, conservation attitudes, land tenure arrangements, and incomplete stream adjudications. Using data on water use and crop production costs for Elephant Butte Irrigation District, New Mexico, price is found to be a major factor influencing water conservation. Results show that a low price of water discourages water conservation even if other institutions promote it. A high price of water encourages water conservation even in the presence of other factors that discourage it. We conclude that water-conserving policies can be more effectively implemented where existing institutions that regulate the use of water are designed to be compatible with water's underlying economic scarcity.

Introduction

In most of the western United States, existing water supplies are claimed and diverted for irrigation and growing municipal and industrial demands. Remaining flows are increasingly protected for instream flows and environmental purposes. Most easily accessible groundwater is developed or is depletable. Throughout the west, drought, climate change, and emerging environmental laws and regulations intensify the competition for water. The United States federal government recently identified the Upper Rio Grande (Figure 1 map) as among river basins having the highest potential for conflict and crisis, especially in drought conditions (U.S. Department of Interior 2003). The Rio Grande exemplifies the problems faced by many arid regions of the world (e.g., Colorado, USA; Yellow, China; Jordan, Middle-East; Murray-Darling, Australia; and Nile, Africa) in which water is over-allocated, there are growing competing demands, and river flows and uses are vulnerable to drought and climate change. These factors along with the need for water policies that are sustainable have highlighted the interest by policymakers, scientists, and water managers to examine carefully water management alternatives that encourage, promote, and reward water conservation.

Figure 1. Study area

Originating in the southern Colorado Rocky Mountains, the Upper Rio Grande extends 600 miles (960 kilometers) from its headwaters and flows through New Mexico to the border cities of El Paso, Texas, USA and Ciudad Juárez, Chihuahua, Mexico (Fig. 1). Downstream of El Paso, the river forms the international border between the U.S. and Mexico on its way to the Gulf of Mexico. The Upper Basin (hereafter referred to as the basin) supports a rapidly growing population of more than three million[2], extensive irrigated agriculture, and fish and wildlife habitat in Colorado, New Mexico, Texas, and the Mexican state of Chihuahua. Some 80 to 90 percent of the water in the basin is used for irrigated agriculture.

Yet, the basin's population is expected to double in the next 50 years, potentially doubling urban water demands. This rapid population growth in conjunction with increased demands by all users, will further intensify the competition for limited water resources. Recent years have witnessed the emergence of legislation, administrative action, and other measures to encourage private investment in increased efficiency with the intent of promoting agricultural water conservation. Nevertheless, several institutional barriers may discourage irrigators from investing in measures or otherwise taking actions designed to conserve water. In the basin, more than a century of federal water development programs and policies have attached great importance to providing plentiful and reliable supplies at a low price. Because of the widespread successes of these programs, a large number of institutions have arisen that promote, reward, and support heavy water use, especially in agriculture.

Factors that influence water conservation, both inside and outside agriculture, have seen recent attention in the literature. Schaible (1997) found that major water price reforms are required to compensate for institutional barriers to conservation for irrigators in the U.S. Pacific Northwest. Moore and Negri (1992) found that reducing the supply of water to western irrigators by 10 percent would increase the national price of three of ten major crops produced by Bureau of Reclamation farms. Yang, Zhang, and Zehnder (2003) found that rapid increases in irrigation costs in northern China since 1993 have failed to generate a sufficient force for water conservation, and that more generally water pricing reform by itself is not an effective measure for promoting water conservation. In an analysis of municipal water use in Ontario, Canada, DeLoe and others (2001) found that limited finances, lack of political will, and public resistance all constrain the effectiveness of municipal conservation programs. Jenkins and Lund (2000) found that the high economic cost of dealing with water shortages can be reduced by jointly expanding infrastructure as well as eliminating institutional constraints.

Winter-Nelson and Amegbeto (1998) developed an economic model of optimal investment under uncertainty to analyze the effects of both the level and variability of water's price on the decision to conserve. Loaiciga and Renehan (1997) examined the effects of pricing and drought on water conservation in Santa Barbara California during the 1986-1996 period when per capita supplies fluctuated considerably. DoMonte, Angelakis, and Asano (1996) analyzed how water use guidelines could be designed to deal with similar problems in Europe's Mediterranean region.

Michelsen, McGuckin, and Stumpf (1999) found that non-price programs could be an effective instrument for achieving water conservation for seven cities in the southwestern U.S. Huffaker and Whittlesey (2000, 2003), Stonehouse (1996), and Huffaker and others (1998) found that increasing the price of water, possibly through greater water marketing opportunities, is more effective than subsidizing the cost of improved on-farm irrigation efficiency at promoting water conservation in irrigated agriculture. Anton (1995) summarized the Seattle Water Department's experience with water use curtailment measures for promoting water conservation during the 1987 and 1992 droughts. Mulwafu and others (2003) found that irrigators in Malawi Africa made the fewest water conservation investments when the price of water was lowest. Michelsen and others (1999) confirmed a long history of research findings showing that a low price of water charged by the U.S. Bureau of Reclamation for irrigation water strongly discourages water conservation in agriculture. Peterson and Ding (2005), in their analysis of the U.S. High Plains area, found that the presence of water-saving irrigation systems do not guarantee water conservation in irrigated agriculture, as long as water's price remains low.

Pender and Kerr (1998) found that water conservation investments by irrigators in the semi-arid lands of India are significantly lower on leased land and on lands subject to sales restrictions than on deeded lands. Their results suggest considerable potential for land market reforms as a way to increase water conservation investments. Sokolov (1999) found that various water saving methods in Uzbekistan, when combined with price incentives, could secure a path of sustainable development for agriculture. Zougmore, Mando, and Stroosnijder (2004) found that efficient combinations of organic resources and fertilizers will improve water use efficiency and productivity of agriculture in Burkina Faso, Africa. Cuthbert and Lemoine (1996) found that increasing numbers of U.S. water utilities practice seasonal rates, inverted block rates, and excess use rates to provide pricing signals that promote water conservation.

Despite these above contributions, little research has examined institutional barriers to water conservation and identified institutional innovations that could circumvent those barriers. The goal of this talk is to help fill those gaps by examining institutional barriers to agricultural water conservation and identifying challenges and opportunities for emerging efforts to promote water conservation in the basin's agriculture. It accomplishes these aims by briefly examining selected organizations, laws, and system operating procedures that act as institutional barriers to agricultural water conservation. It also examines how those barriers have influenced irrigation water use in the basin. Finally it identifies some challenges and opportunities presented by attempts to deal with these barriers in the search for increased water use efficiency in the basin's irrigated agriculture.

What is Water Conservation?

Water conservation could be defined as any action that promotes a reduction in its use. In the Rio Grande Basin, various actions could be taken that encourage or require irrigators to substitute additional land, labor, capital, or money for reduced use of water. Under that definition, all water use reductions are conservation. While this is a precise and clear definition, it is economically naive and politically impractical: water is only one of many scarce resources required for agricultural production. For example, regulations could be enacted requiring all irrigators to reduce their water use by changing from flood irrigation to drip irrigation if drip irrigation is not already being practiced. Drip irrigation does reduce water applied in agriculture, and it typically increases crop yields as well. However, that particular reduced use of water applied in agriculture will usually be accompanied by increased use of other scarce resources, most notably labor, capital, and money. Unless crop yields increase considerably under drip irrigation and unless water is much more expensive than normally seen in the irrigated west, changing from flood to drip irrigation typically reduces net farm income under typical economic conditions. These economic conditions usually include a comparatively low price of water, especially for the use of water provided under federal reclamation projects. Irrigators are typically in business to increase their income or to meet other personal or farming goals, not to conserve water.

Only actions that reduce the use of water without disproportionately increasing the use of other resources can be labeled as water-conserving in the economic sense. So an acceptable definition of water conservation requires that the beneficial effects of the reduced water use must be greater than the adverse effects associated with the use of other resources required to support conservation. Where all beneficial and adverse effects are measurable in monetary units, this test amounts to the requirement that the benefits of reduced water use exceed its costs. What this means is that the essence of conservation is reduced use, but more must occur. A water management practice constitutes conservation in the economic sense when it meets two tests: (1) it conserves a given supply of water through reduction in water use; (2) it produces in a net increase in society's economic welfare, that is, the additional resources used to support the water conservation (e.g., increased labor and greater capital to support drip irrigation) have a lower economic cost than the value of the water saved.

The first test insures that the practice results in a reduction in use, while the second establishes that overall benefits exceed costs. This definition of water conservation is simply a specified subset of those practices that comprise economically efficient management of water resources. When conservation is thus differentiated from other desirable water management measures, it becomes possible to formulate policies and propose practices that are directed to promote conservation, and it becomes possible to evaluate their success on economic grounds.

Barriers to Conservation

This section identifies several institutional barriers that can limit the effectiveness of future water conservation programs in the Rio Grande Basin. Removing or alleviating any of these barriers could promote conservation, thus freeing up water for alternative uses or providing more water for future use in agriculture, cities, or the environment.

Clouded Titles

In both New Mexico and Texas, a person or organization must apply to a state administrative agency to obtain a valid water right, either through a new appropriation or a water transfer from another user. In both states, there is a constitutional requirement that the appropriator must show to the state's satisfaction that the water will be applied to beneficial use. In both states, within the Rio Grande Project, downstream of Elephant Butte Reservoir (Fig. 1), the water right permit is granted in perpetuity or until the land and/or water has been transferred to another user. After the permit is granted, the appropriator is required to put the water to beneficial use. Nevertheless, producers often express the fear that investments made in water conservation, such as changing irrigation technologies that reduce water applied or adopting new management techniques like irrigation scheduling, will result in the saved water being lost to the state or to the irrigation district, because of the presumption that the saved water was not used beneficially.

Water Transfer Restrictions

Short-term water transfers through mechanisms like water banks could provide an economic incentive for agriculture to save water, especially in periods of drought or other shortages. Temporary water transfers, such as a one-season water rental or leasing arrangement, possibly through an arrangement similar to banking, could provide agricultural producers an incentive to reduce water use in agriculture.[3] The advantage of such a short-term transfer is the immediate infusion of cash into agriculture when the transfer takes place.

A water bank is a special form of a spot market organized and operated by a central banker, such as the state, a state-appointed water broker, irrigation districts or private companies. The bank, if established, is a mechanism for willing water right owners to lease water to the bank or renters, such as cities or an environmental group, on a short term basis. A bank can typically acquire water in at least three ways: by paying farmers for water they would have used to irrigate their fields; by purchasing surplus water from local irrigation districts; or by paying farmers to use groundwater instead of surface water. A successful water bank experiment in California in the early 1990s taught several lessons: water markets, even when they are severely constrained and controlled, will work; water has a very high value for city and environmental buyers, and at a suitably high price there are likely to be many sellers; very large amounts of water can be found for the bank if money is put on the table; and third-party interests in water market transactions can be protected (Dziegielewski et al. 1993; California Department of Water Resources 1992; Pratt 1994).

Nevertheless, some Rio Grande Basin producers have expressed concern that these short-term transfers may be interpreted by water administrators or by the public as evidence of a nonbeneficial use of water. Furthermore, some producers may fear that the water right will be lost through a temporary transfer into a bank. This could occur because of unclear or unenforced legislation or poor communication by water administrators to producers. As a result, this important potential source of conservable water for use by others currently is unavailable.

Illusory On-Farm Water Savings

Agricultural producers continue to adopt more technically efficient irrigation methods to produce higher net incomes through increased crop yields, increased efficiency in nutrient and chemical use, reduced labor costs and more efficient water use. One definition of on-farm irrigation efficiency is the ratio of water stored and depleted in the crop root zone for crop consumption to the total water diverted from the stream for irrigation. One method to increase on-farm efficiency, defined in this way, would be to encourage producers to apply water more consistently across fields, which enables crops to maintain or increase their consumptive water use from reduced stream diversions.

Many policy makers believe that reduced diversions resulting from increased on-farm efficiency produce water savings that become available to meet other growing demands. Some states across the West are passing or are considering passing legislation that encourages producers to invest in improved on-farm irrigation technologies. However, this kind of legislation should be approached carefully, because many of these on-farm investments in greater irrigation efficiency can reduce the available water that would have been otherwise supplied through return flows to downstream appropriators (Huffaker and Whittlesey 2000; Huffaker et al. 1998).

An on-farm investment that reduces water applied from the individual producer's view by X acre-feet can reduce downstream supplies by as much or more than X.[4] A policy measure that guards against this false water savings would encourage only those private investments in on-farm irrigation efficiency that do not decrease return flows relied on by downstream appropriators and instream users (Huffaker and Whittlesey 2000). Return flows are not impaired only if the on-farm investment leads to reductions in the water consumed or irretrievably lost to the basin.

Insecure Rights to Conserved Water

One definition of water conservation is when the appropriator saves water otherwise irretrievably lost to the system.[5] Water is irretrievably lost to the system when it is depleted through uptake by plants, evaporation, runoff to saline groundwater basins or to aquifers too deep for economic use. Conserved water, according to this definition, is that use of a particular stream or other watercourse or supply source that is saved from loss and made available for current or future beneficial use. For water to be conserved, the potential conserver must show that the conservation efforts will not damage other appropriators on the same watercourse, typically by reducing return flows (Glickstein et al. 1981). For example, a producer who intercepts his return flows from a field that would otherwise flow unimpeded to a downstream user fails to conserve water. This water saved would not otherwise be lost, since it takes water from another downstream appropriator.

There are many ways to conserve water. Concrete-lined canals or ditches, for example, prevent water from seeping to uneconomical depths or to saline aquifers. Other ways include removing water-using weeds (phreatophyes) to decrease water lost to nonbeneficial uses or substituting water stored in surface reservoirs to shallow groundwater basins. Institutions that block producers from securing a water right to the water conserved in this way discourage investments in conservation.

Uncertain Duty of Water

Many Western states, including New Mexico, are in the process of adjudicating their streams, that is, defining clear titles to the right to use water. A completely adjudicated stream system clearly defines all owners' rights to use water under all possible future hydrological conditions. Adjudication began in earnest in New Mexico's Lower Rio Grande in the late 1990s, with the first offers of adjudicated water rights sent to landowners in 2000.

Despite the considerable progress made on these adjudications, the "duty of water," that is the amount of water right assigned per acre, has yet to be established. There is considerable uncertainty over what the duty of water will be or how it will be established. Will all irrigators receive an equal amount of adjudicated water per acre, for example, 3 acre-feet per acre for every irrigator? Or will the offer vary with type of crop? For example, pecan growers could receive more water rights per acre than cotton growers because of the greater water applied historically per acre to pecan trees.[6] This uncertain duty of water prior to the completed adjudications may establish perverse incentives for water conservation: If there is widespread belief that producers who plant more water-using crops will secure a larger adjudicated offer per acre, growers have an incentive to plant crops or trees that use larger amounts of water solely to receive more water in the future.

Shared Carryover Storage

Producers sometimes express an interest in seeing a policy that permits or encourages them to carry over and keep track of this year's unused water, which can be kept in a storage reservoir for use in a subsequent year. Rio Grande Project water users in southern New Mexico and West Texas are discouraged from saving water in any given year and storing it at Elephant Butte Reservoir for later use.[7] Three preventable losses occur when water is released from a reservoir and used for irrigation: part of the water is consumed by evaporation; a portion percolates to the aquifer; and the drainage water is sometimes damaged by salts or chemicals. If a system of carryover storage credits could be enacted with property rights assigned to those who reduce their current water use by fallowing land, adopting water-conserving irrigation technology or shifting to lower water-using crops, these losses could be reduced. In drought years, this saved water would be especially valuable.

The common property nature of an irrigator's saved water in Rio Grande Project lands combined with the historical 57 percent water allocation to New Mexico users and 43 percent to Texas users means that any water carried over this year is shared by everybody the next year. For example, suppose a Texas user reduces current use by 1,000 acre-feet and stores it behind Elephant Butte in hopes of receiving extra water the following year. The unevaporated part of the 1,000 acre-feet saved by the Texas user will accrue as 43 percent to the Texas user and 57 percent to New Mexico users. The fact that a well-defined, transferable and enforceable private property right fails to be earned in water carried over discourages irrigators from conserving water.

Interstate Compacts

The Rio Grande Compact and the 1906 U.S.-Mexico Treaty are the overriding mechanisms for allocating water to Colorado, New Mexico, Texas and the Republic of Mexico. The quantity of water allocated to each is set out clearly within the compact and treaty allocations with little opportunity to trade water surpluses or shortfalls for cash or other considerations. The Rio Grande Compact[8] currently has no institution in place that would permit water users in Colorado or New Mexico to sell or rent surplus water to users below Elephant Butte Reservoir or to buy deficit water from these same users. If, for example, the Rio Grande Compact were amended to allow Colorado or New Mexico users to under deliver to Elephant Butte in exchange for cash (buy water) or over deliver to Elephant Butte Reservoir in exchange for cash (sell water), agricultural users in all three states may be encouraged by cash incentives to conserve water. Mexico is allocated 60,000 acre-feet per year under the 1906 U.S.-Mexico treaty, an amount of water that is not normally subject to negotiation. If irrigators in southern New Mexico or West Texas could sell or rent some of their unused water to Mexico in exchange for cash, the associated financial incentive may encourage all users to invest in water conservation measures.

Conservation Attitudes

Negative attitudes toward water conservation can represent a major barrier to it practice, despite the fact that people who conserve water are generally respected and admired. To understand more about these attitudes, a survey of water management practices administered in 2002-03 to members of the Elephant Butte Irrigation District (EBID), New Mexico on drought conditions during this irrigation season were comparable to other drought season conditions observed in New Mexico. The survey was designed to identify the attitudes that discourage irrigators from conserving water. Table 1 shows irrigated acreage for the producers sampled by the survey for both 2002 and 2003 by crop and by irrigation technology used. Table 2 shows that a strong majority of producers identified several barriers to water conservation: conservation is too expensive, the basin's stream adjudications are not yet complete, additional labor required to implement conservation, inadequate financial incentives for reducing water use, an inadequate water distribution system, and increased soil salts resulting from reduced water use.

Land Tenure

Additional results from the survey showed that those farmers renting acreage were more sensitive to reasons for not reducing current water use compared to farmland owners. Most farm rentals in the area were based on a crop sharing arrangement, but renters paid a flat fee for the right to farm the acreage in the production season. Any additional water usage over the District allotment became part of the renters production cost. During the survey several renters described the considerable lack of financial incentives for owners to invest in water conservation when their farmland is rental property. Not surprisingly, both owners and renters respond strongly to needing all of the water they receive.

Table 1: Irrigated Acreage by Crop and Irrigation Method, Lower Rio Grande Basin, New Mexico

Year	2002				2003			
Crop / method	Flood		Drip		Flood		Drip	
	acres	pct total	acres	pct total	acres	pct total	acres	pct total
Alfalfa	6302	16.02	220	0.56	5683	15.53	270	0.74
Cabbage	3110	7.90	310	0.79	2670	7.30	360	0.98
Chile	6855	17.42	690	1.75	5841	15.96	690	1.89
Corn	2729	6.94	70	0.18	2544	6.95	120	.33
Cotton	5979	15.20	480	1.22	5206	14.23	530	1.45
Lettuce	3007	7.64	310	0.79	2582	7.06	360	0.98
Onion	4755	12.09	310	0.79	5250	14.35	620	1.69
Pecans	3077	7.82	210	0.53	2699	7.38	262	0.72
Wheat	880	2.24	50	0.13	800	2.19	100	.27
Total Acres	36694	93.26	2650	6.74	33275	90.95	3312	9.05

Table 2: Water Conservation in Agriculture by Land Tenure Arrangement, Rio Grande Basin, New Mexico 2004		
Land Tenure Arrangement	Own Land N=67	Rent Land N=20
Reasons for not reducing water use		
Water conservation costs too much	69[9]	60
Incomplete stream adjudications	88	75
Water conservation requires additional labor	76	70
No buyers for saved water	96	100
No financial incentive to reduce water use	85	65
Water distribution system restricts conserving	90	93
Reduced water use builds up salts in soil	79	67

[9]Entry reflects percentage of all respondents indicating agreement with statement

Incomplete Stream Adjudications

General stream adjudications fulfill three functions: (1) public recording and validation of all water claims and rights; (2) facilitating the fair distribution of water; and (3) enabling improved and more planning and management of future water allocations. Stream adjudications give certainty to water rights, provide the basis for water right administration, reduce conflict over water allocation and water usage, and facilitate important market transfers for water rights. Most of the stream segments in the Rio Grande basin are still not adjudicated, which means that there is considerable uncertainty over who currently has the right to use how much water in what water supply conditions. One problem presented by this legal uncertainty over who owns what water rights is that water authorities have a difficult time administering water rights (e.g., locking gates of junior users) to guarantee sufficient downstream flow to meet interstate compact obligations, for it is unclear who the junior users are.

Despite all these advantages of completed stream adjudications, the question of how water administrators should assign the initial property rights to support as part remains a major unresolved challenge. Where most use is for agriculture, adjudication of a stream based on irrigated acreage requires establishing the duty of water per irrigated acre. That duty of water in the Rio Grande basin is currently unknown. Assigning a higher duty of water per acre based on historical crop water requirements effectively assigns greater amounts of real economic wealth to people who can demonstrate the highest historical use. This widespread recognition of real wealth created by the higher potential duty produces incentives discouraging current water conservation in an effort by irrigators to show higher historical use and to begin carrying out that higher use in anticipation of that favorable higher duty of water.

Despite the ultimate greater certainty targeted by the ongoing adjudications in the basin their current incomplete status creates its own significant institutional barrier to incentives for conserving water, a hypothesis borne out by Table 3. The table presents results of the survey organized by major crop cultivated. Crops listed are onion, pecans, alfalfa, and cotton. Onion farmers were especially sensitive to the incomplete status of the ongoing adjudication process; 67 percent stated that the adjudication process discourages them from conserving water. Producers of other crops were somewhat less sensitive to uncertainties caused by the ongoing adjudications.

Price and Conservation

The price of water as well as the price of water-conserving technologies are important indicators of economic scarcity. Economic theory suggests that producers will pay close attention to both sets of prices. These prices can be expected to exert a major influence on the intensity and duration of producers' search for water saving substitutes.

Effective Price

Various institutions set both the price of water and establish the rules governing how water can be traded both within and outside agriculture. These institutions potentially have an important influence on water conservation. For example, each EBID member is charged $50 per acre per year for the right to use up to 2 acre-feet per acre, if there is enough water available at the reservoir. Any water user who conserves that 2 foot allotment still pays the $50. For this reason, the $50 charge is a district membership charge and not a price of water. Because any increase or decrease in water use between 0 and 2 acre-feet per acre results in the producers paying the same $50 price, the first 2 acre-feet per acre are effectively priced at zero.

Table 3: Water Conservation in Agriculture by Major Crop, Rio Grande Basin, New Mexico, 2004

Most Important Crop	Onions N=3	Pecans N=35	Alfalfa N=38	Cotton N=19
Reasons for not reducing water use				
Water conservation costs too much	67[10]	69	74	63
Incomplete stream adjudications	33	91	89	68
Water conservation requires additional labor	67	83	76	68
No buyers for saved water	67	100	97	95
No financial incentive to reduce water use	67	86	87	63
Water distribution system restricts conserving	100	82	94	94
Reduced water use builds up salts in soil	50	71	81	82

[10]Entry reflects percentage of all respondents indicatitng agreement with statement

EBID members also have the right to purchase additional water at $18 per acre-foot if the water is available, so the incremental price after two acre-feet is $18. If policies were instituted that allowed members to buy each acre-foot after two at $18, then rent any unused portion of it out at $100 or even $200 per acre-foot to a city or recreational or industrial buyer, there would be considerable financial incentive to invest in on-farm water conservation measures. However, current water transfer practices do not permit trading of water outside agriculture. Thus, water is effectively locked into agriculture, which discourages investments in water conservation and raises the price of water to city or environmental users.

Price and Use

The scarcity of water itself as well as the price of various irrigation technologies both influence water conservation decisions in agriculture. Economic conditions for irrigated agriculture in the basin are shown in Table 4. As of 2005, virtually all EBID producers use flood irrigation, as shown in Table 1. So the question of what changes it would take to promote investments in water conservation, defined here as allocating some acreage into drip irrigation, takes on considerable economic and political importance. As is typical in much of the irrigated west, drip irrigation in the Lower Rio Grande Basin is considerably more expensive than flood irrigation, but it also uses less water per acre and produces greater crop yields.

Table 4: Economic Conditions for an Irrigation Farm, Lower Rio Grande Basin, New Mexico, 2005

Water supply	300 acre feet
Crop	Onions
Farm size	100 acres
Crop price	$6.38 per sack
Flood irrigation	
Production cost	$4120 per acre
Crop yield	675 sacks/acre
Water use	4 acre feet/acre
Drip irrigation	
Production cost	$5320 per acre
Crop yield	845 sacks/acre
Water use	2 acre feet/acre

The answer to the question turns on what combination of economic conditions and water supplies makes it profitable to favor drip over flood irrigation. Table 5 shows the impact of changes in water scarcity and adjustments in water institutions that affect water conservation in agriculture. The table shows four sets of future production cost and crop prices. Rows 1-4 show current conditions, consisting of high production costs ($4120 / acre for flood irrigation) and low crop prices ($6.38); Rows 5-8 show conditions of high production costs and high crop prices ($7.38); Rows 9-12 show low production costs ($3820 / acre for flood irrigation) and low crop prices ($6.38). Rows 13-16 show low production costs and high crop prices. Drip irrigation is priced at a constant $5320 per acre except where reduced through a conservation subsidy.

For each set of these three future economic conditions described above, the table shows three possible irrigator responses to a water supply reduction from 300 to 200 acre feet for the 100 acres. In all cases the producer is presumed to maximize net income subject to constraints of water supply and available land. The first possible response is continued income maximization while facing any institutional constraint that blocks the producer from adopting added drip irrigation acreage than occurs under the base water supply of 300 acre feet. The second response is continued income maximization with no institutional constraint to investing in drip irrigation. The third response assumes the that government water conservation program is enacted. Under the program, the cost per acre of drip irrigation is reduced through a subsidy by the minimum amount per acre needed to maintain equal farm income that was earned with a 300 acre feet supply, but after the 100 acre foot shortfall occurs. Results of the income maximization provide insights into factors that most influence farmers' water conservation investments.

Table 5 shows that net farm income is lowest under current conditions where production costs are high and crop prices are low (row 1). Under these 2005 conditions, abundant water (300 acre feet) and low crop prices make it economically attractive to substitute water for land and for other inputs. Some drip irrigation could be put onto the 25 acres of idled land, shown in row 1. But at $6.38 the crop price is too low for the value of the additional yield to pay for the additional costs of drip technology. Row 1 shows that income maximization requires idling 25 of the 100 available acres, and that all 75 acres production occurs under flood irrigation, which actually occurred in 2005. The value of one additional acre foot of water to the 100 acre farm is $47, and the farm produces a total net income just under $14,000. When water supply falls to

Table 5: Factors Affecting Water Use in Irrigated Agriculture, Lower Rio Grande Basin, New Mexico, 2005

Supply	Institutions		Input costs		Price	Land Allocation			Water Allocation		Economic Impact		
	Subsidy	Barrier[11]	Flood[12]	Drip[13]	Onions	Flood	Drip	Idled	Average Use	Idled	Water Value	Net Income	Program Cost
(a-f)			($/ac)	($/ac)	($/sack)	(ac)	(ac)	(ac)	(a-f/ ac)	(a-f)	($/a-f)	($)	($)
300[14]	no	no	4,120	5,320	6.38	75	0	25	4.00	0	47	13,988	0
200	no	yes	4,120	5,320	6.38	50	0	50	4.00	0	47	9,325	0
200	no	no		5,320		50	0	50	4.00	0	47	9,325	0
200	yes	no		5,205		25	50	25	2.67	0	47	13,988	5,770
300	no	no	4,120	5,320	7.38	0	100	0	2.00	100	0	91,610	0
200	no	yes		5,320		0	100	0	2.00	0	0	91,610	0
200	no	no		5,320		0	100	0	2.00	0	0	91,610	0
200	yes	no		5,320		0	100	0	2.00	0	0	91,610	0
300	no	no	3,820	5,320	6.38	75	0	25	4.00	0	122	36,487	0
200	no	yes		5,320		50	0	50	4.00	0	122	24,325	0
200	no	no		5,320		50	0	50	4.00	0	122	24,325	0
200	yes	no		4,905		25	50	25	2.67	0	122	36,487	20,770
300	no	no	3,820	5,320	7.38	50	50	0	3.00	0	123	103,880	0
200	no	yes		5,320		25	50	25	2.67	0	290	74,842	0
200	no	no		5,320		0	100	0	2.00	0	123	91,610	0
200	yes	no		5,197		0	100	0	2.00	0	61	103,880	12,270

[11] Institutional barrier prevents producer from investing in water conservation even if it increases net income.

[12] Equals cost per acre of crop production under flood irrigation technology; crop yield is 675 sacks per acre; water use is 4 a-f/ac. Data source is (http://costsandreturns.nmsu.edu/2005Projected.htm).

[13] Equals cost per acre of crop production under drip irrigation technology; crop yield is 845 sacks per acre; water use is 2 a-f/ac.

[14] The top row of numbers reflect 2005 conditions

200 acre feet, irrigators simply reduce the scale of farming from 75 to 50 acres. No investments in drip irrigation are made because the added economic value of the higher yields are too small to pay for drip's added costs of production (rows 2-3). Row 4 shows that a subsidy for drip irrigation of $115 per acre is enough to maintain original income through the producer's investment in the drip technology while having 100 acre feet less water to apply to the land.

Irrigators' highest willingness to invest in water conservation occurs when flood irrigation is expensive and crop prices are high, shown in row 5. The increased crop price shown by comparing row 1 and row 5 produces a dramatic increase in the producers' willingness to invest in drip irrigation. The higher crop price enables the yield increment produced by drip irrigation to pay for its higher production costs. By contrast, under low crop prices, the economic value of the added yield produced by drip is insufficient to pay for its added production costs. Under conditions shown in row 5, drip irrigation becomes so profitable that all 100 acres are produced under drip even without reducing the water supply. Furthermore drip conserves so much water that its adoption results in 100 acre feet of unused water in agriculture. This water becomes available for uses outside agriculture. For this reason, when agricultural water supply falls from 300 to 200 acre feet, there is no economic loss whatsoever to agriculture. In these conditions the cost of a water-conservation program subsidy is zero, since maximum conservation already occurs. These results are shown in rows 5-8.

The highest cost to the taxpayer of implementing a program to subsidize water conservation occurs when flood irrigation is cheap and crop prices are low, as shown in row 12's $20,770 total program cost. Producer responses to these conditions are shown in rows 9-12. In this situation, an on-farm water supply reduction from 300 to 200 acre feet encourages no water conservation investments whatsoever by irrigators, as shown by comparing rows 9 and 10. A low crop price means that the added cost of drip irrigation is larger than the economic value produced by drip's increased crop yield, so the irrigator reduces water use by the required 100 acre feet by simply reducing the scale of the farm's operation and idling 25 more acres of land (compare rows 9 and 10). These economic conditions, while weak at encouraging drip irrigation investments, are precisely the same conditions that cause the conservation program subsidy required of the taxpayer to be so high. When farm income falls from $36,487 to $24,325 after the water supply reduction, the cost-minimizing drip irrigation subsidy needed to maintain farm income at the $36,487 base after the 100 acre foot water loss is a high $415 per acre.

Institutional barriers to water conservation have the largest negative effect on net farm income after water supply is reduced when flood irrigation is cheap and crop prices are high. Rows 13-16 show that the economic value of access to drip irrigation about $17,000 ($91,610 - $74,842). That is, removing the institutional constraint to water conservation saves the irrigator about $17,000. In the face of institutional barriers to water conservation (row 14) in these most attractive economic conditions, the economic value lost by suffering a water supply shortfall of 100 acre feet produces the highest of all losses, about $29,000. This very large economic loss produced by institutional rigidities blocking conservation, not surprisingly also produces the highest economic value of water at $290 per acre foot. Remarkably the economic cost of a water conservation program subsidy is comparatively small ($12,270 shown in row 16) compared to conditions described in rows 12 ($20,770). It is smaller because the most flexible producers already discover they can afford to invest in drip irrigation thanks to a high crop price. Therefore the drip irrigation subsidy required to restore their base income ($103,880) is only about $123 per acre or a total of $12,270 for the 100 acres that the subsidy induces.

Price and Substitution

Groundwater substitution occurs when irrigators respond to surface water price increases or shortages by reducing surface water demand and tapping instead into groundwater. An unfortunate side effect of this is that groundwater substitution can lead to actions that conserve one water resource at the expense of another to which it is hydrologically connected. As a result of the interdependence between ground and surface water use, it is difficult to determine if a surface water pricing or conservation program promotes saved water from the view of the system. One water source is potentially conserved at the expense of the other. For this reason, the hydrologic and economic ease with which groundwater is substituted for surface water is important to understand and measure when discussing, designing or enacting policies that promote water conservation by agricultural producers. What all this means for policy analysis is that the net result of surface water pricing, including marketing and conservation legislation or incentives, is an uncertain conservation policy tool when groundwater is available as a close substitute for surface water. An effective conservation policy will account for the interaction between the two water sources and will attempt to encourage irrigators to manage the two water sources jointly (Schuck 2001).

Conclusions

The ability for an irrigator to realize an economic gain by reducing current water use in agriculture is an important incentive to promote conservation. Several barriers to water conservation were identified. These include lack of clear titles to water rights, barriers to water transfers, on-farm water savings that fail to save water for the basin, and barriers to securing rights to conserve water. Other barriers include the ease with which greater groundwater use can be substituted for reduced surface water, water's uncertain duty, the common property nature of carryover storage, interstate compact constraints, and water's low price, which locks water into agriculture.

One constructive measure to promote water-conserving decisions is to design institutions that remove barriers to informing water users about the opportunity cost of current water uses. Another is to enact laws and policies that guarantee that reduced upstream water use does not simply come at the expense of water taken from a downstream appropriator. Considerable differences in the value of water used in agriculture versus urban and environmental use create an opportunity for designing legal and pricing institutions that reduce barriers to market transfers and incentives that discourage conservation. Water that could be saved in agriculture is typically quite responsive to price changes. Owners or users of agricultural water rights could use this price sensitivity to their advantage by renting or leasing their water to cities or environmental users in periods of drought or other shortages with no change in water rights ownership. Without legislative action, perceptions by many farmers that all unused water may be lost pose a barrier to water conservation. Many water users in the basin avoid conservation because of incomplete stream adjudications that throw into doubt the security of their water right. Higher current use is believed by some to be an indication of beneficial use of a larger quantity of water than is currently needed, although that water might be needed for the future, particularly when severe drought reduces all quantities. Where there is water infrastructure to store and move traded water, legislation that defines water trading to be a beneficial water use could remove this barrier to conservation.

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Endnotes

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[2]In 1900 the population of El Paso, Las Cruces and Ciudad Juárez was 44,000. By 1950 it had grown to 357,000 and in 2000 the population was over two million, almost a 50 fold increase over the century. The population is projected to nearly double again by 2020.

[3]Permanent transfers are even more attractive to municipal and industrial users, such as the city of El Paso; surface water treatment plants need a predictable and continuous water supply.

[4]This counterintuitive result occurs because of reduced return flows. For example, a producer who switches from flood to drip irrigation, applies the crop's needed water by diverting X acre-feet less from the stream. However, this change in technology, while appearing to save water from the adopter's view, may reduce return flows by X, producing zero net water savings to the basin.

[5]Some states refer to this as "salvaged" water, that is, water saved that takes no wet water from anybody else either currently or in the foreseeable future.

[6]Tied to this is uncertainty of groundwater adjudication. The question centers on whether or not water rights offers will be defined on combined rights to surface and groundwater use. For New Mexico producers, groundwater is an important source of water during drought, but it also is used widely in normal years.

[7]High evaporation, which causes considerable losses to water carried over, and limited reservoir storage space at Elephant Butte (stored water may displace future inflows to the reservoir) are two reasons why little carryover storage is seen.

[8]In the Rio Grande Basin above El Paso, Texas, water is managed to comply with the Rio Grande Compact. Colorado's water deliveries to New Mexico at the Colorado-New Mexico state line are a function of headwater flows produced by Colorado's snowpack runoff. All water not delivered to New Mexico is available for use by Colorado. Water that New Mexico delivers to Texas at Elephant Butte, measured at the gauging station below Elephant Butte, is a function of annual flows at the Otowi gauge above Santa Fe, excluding San Juan-Chama flows. So flows in New Mexico are delivered to the Elephant Butte gauge based on native flows at the Otowi gauge. In very wet years, when New Mexico does not have the capacity to use its full compact allocation, New Mexico may receive an annual credit of up to 200,000 acre-feet for its over delivery to Texas. In dry years, New Mexico may underdeliver to Texas by an amount not to exceed 150,000 acre-feet, and an annual debit is incurred in such cases. New Mexico, under the compact, may accrue total debits, offset by wet year credits, of up to a total of 200,000 acre-feet.