ABSTRACT: The Rio Grande basin shares problems faced by many arid regions of the world: growing and competing demands for water and river flows and uses that are vulnerable to drought and climate change. In recent years legislation, administrative action, and other measures have emerged to encourage private investment in efficient agricultural water use. Nevertheless, several institutional barriers discourage irrigators from investing in water conservation measures. This article examines barriers to agricultural water conservation in the Rio Grande basin and identifies challenges and opportunities for promoting it. Several barriers to water conservation are identified: clouded titles, water transfer restrictions, illusory water savings, insecure rights to conserved water, shared carry-over storage, interstate compacts, conservation attitudes, land tenure arrangements, and an uncertain duty of water. Based on data on water use and crop production costs, price is found to be a major factor influencing water conservation. A low water price discourages water conservation even if other institutions promote it. A high price of water encourages conservation even in the presence of other discouraging factors. In conclusion, water-conserving policies can be more effectively implemented where water institutions and programs are designed to be compatible with water's underlying economic scarcity.

(KEY TERMS: water economics; irrigation; institutions; water policy; water conservation; sustainability.)


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 ground water is developed or is depletable. Throughout the west, drought, climate change, and emerging environmental laws and regulations intensify the competition for water. The U.S. federal government recently identified the Upper Rio Grande (see Figure 1) 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 overallocated and there are growing and competing demands and river flows and uses that 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.

Originating in the southern Colorado Rocky Mountains, the Upper Rio Grande extends 600 miles (960 km) from its headwaters and flows through New Mexico to the border cities of El Paso, Texas, USA, and Ciudad Juárez, Chihuahua, Mexico (see Figure 1). Downstream of El Paso, the river forms the international border between the United States and Mexico on its way to the Gulf of Mexico. The Upper Basin (hereafter referred to as the basin) supports a growing population of more than 3 million. For example, 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 2 million, almost a 50-fold increase over the century. The population is projected to nearly double again by 2020. The basin also supports extensive irrigated agriculture, and fish and wildlife habitat in Colorado, New Mexico, Texas, and the Mexican state of Chihuahua. Some 80% to 90% of the water in the basin is used for irrigated agriculture. Yet, the basin’s population is expected by some experts 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 has 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 water use, especially in agriculture.

Factors that influence water conservation, both inside and outside agriculture, have seen recent attention in the literature. Schable (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% would increase the national price of three of ten major crops produced by farms using Bureau of Reclamation water. Yang et al. (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 water pricing reform by itself is not an effective measure for promoting water conservation. In an analysis of municipal water use in Ontario, Canada, De Loe et al. (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 1986-96 period when per capita supplies fluctuated considerably. Do Monte et al. (1996) analyzed how water use guidelines could be designed to deal with similar problems in Europe’s Mediterranean region.

Michelsen et al. (1999a, b) found that nonprice programs could be an effective instrument for achieving...
water conservation for agriculture and seven cities in the southwestern U.S. Huffaker and Whittlesey (2000, 2003), Stonehouse (1996), and Huffaker et al. (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 et al. (2003) found that irrigators in Malawi, Africa made the fewest water conservation investments when the price of water was lowest. Michelsen et al. (1999a, b) 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 does 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 is 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 et al. (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 are implementing 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 article 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?

This is an old question. Yet, it continues to be asked today partly because so many modern public policy sentiments favor water conservation. “Indeed, part of the allure of water conservation is that it can be molded into a concept that is attractive to anyone (Griffin, 2006).” Many conservation concepts presume that all programs that reduce water use are desirable, independent of cost or benefit. While this may be approximately true when all saved water will be used for meeting the drinking needs of the thirsty, it is unlikely to be true in most practical conditions. Economic principles can be used to fashion a definition of water conservation in which economically sound decisions are made in connection with attempts to save water in a wide range of hydrologic, economic, and institutional conditions.

One definition of water conservation is simple technical efficiency in consumptive water use, hereafter referred to simply as “use.” This technical definition expresses the desire to secure the most physical output per unit of water used. Examples include attempts to transport water to end users that minimize nonrecoverable leakage and evaporation, encouraging the adoption of low-flow showerheads, low-flush toilets, or advanced irrigation technologies. The problem with this definition of conservation is it is based on a water theory of value (Baumann et al., 1984; Griffin, 2006). Squeezing as much as is technically possible out of every drop of water used is good economics only when all other resources have a zero cost and when only water is scarce. Actions based on this definition of conservation assume other resources have zero value and that the only resource with any economic value is the water itself. For example, canal water lost in conveyance because of leaks and evaporation is costly to prevent in the sense that other resource costs must be incurred to save that lost water. Do those resources have a lower economic value than the value of the water saved or do they have a greater value? From the technical efficiency view, it is water-conserving to undertake any expenditures to prevent any water losses. From the economic view, those water losses are not wasted unless the cost of preventing the loss is less than the value of the water saved (Griffin, 2006).

Several U.S. states, in attempts to save water, have recently enacted legislation to this effect. In the Rio Grande Basin, various actions could be taken...
that would encourage or require irrigators to substitute additional land, labor, capital, or money for reduced use of water. Under that view, all water use reductions are conservation. While this may be a clear view, 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 can reduce water used in agriculture, and it typically increases crop yields as well. However, that particular reduced use of water used 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 priced much higher than normally seen in the irrigated west, changing from flood to drip irrigation on a given acreage typically reduces net farm income. Irrigators are typically in business to increase their income or to meet other personal or farming goals, not to save 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 saves a given supply of water through reduction in water consumed, and (2) measures taken to reduce water consumed produce a net increase in society’s economic welfare. For example, increased labor and greater capital to support drip irrigation have a lower economic cost than the value of the water saved and made available for other uses.

The first test insures that the conservation practice results in a reduction in consumptive 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. It should be noted that this article’s definition raises the bar that must be vaulted before a policy is said to promote water conservation. It requires that a water-conserving policy produces a reduction in use for which its benefits exceed its costs. While conventional welfare economics would likely use the term “economically efficient water conservation,” this article opts for the simpler term “water conservation.” This definition is chosen because so many modern water conservation policies have had limited success in promoting water use reductions because they ignored the all-important economic incentives affecting water use.

Both New Mexico and Texas water laws consider measures to save water. While neither states’ laws define water conservation directly, they illustrate the kinds of actions that could be considered water-conserving. New Mexico law states that the office of the state engineer (OSE) must consider water conservation when reviewing an application for water rights. Issued water rights permits include a water conservation condition that states that the permittee shall utilize the highest and best technology available to ensure conservation of water to the maximum extent practical.

In 1985, the Texas legislature recognized that conserving water may be a cheaper method for avoiding shortages than developing new supplies. So it required that conservation be a factor in granting or denying a permit. Specifically, conservation considerations in Texas include “those practices, techniques, and technologies that will reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling and reuse of water so that a water supply is made available for future or alternative uses” (Texas Water Code, 1985a). “Applicants for new or amended permits must formulate a conservation plan, which demonstrates that reasonable diligence will be used to avoid waste” (Texas Water Code, 1985b).

Both states’ laws suggest that water conservation is defined as a simple reduction in use. New Mexico emphasizes best technology for reducing use, while Texas place greater emphasis on reduced use through a variety of measures. Despite the good intentions of both states’ laws, neither emphasizes a comparison of the costs of resources required to achieve the reduced use compared with the value of the water for which use is reduced. Water conservation laws will have a greater likelihood of being accepted, supported, and enforced where those laws take explicit account of the economics of water conservation. To summarize this section, the definition of water conservation used for this article is any reduction in water use that promotes economic efficiency or for which benefits exceed...
costs. Defining conservation in this way leads to economically sound water-conserving programs. It is also designed to avoid programs that save low-valued water at the cost of using more expensive resources to save that water.

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 reduced use economically efficiently, thus freeing up water for alternative uses or providing more water for future use in agriculture, cities, or the environment.

In this article, the various institutional barriers described below are first enumerated then described. It is anticipated that future research will measure and rank the importance of each institution. If there is a way to objectively measure the intensity of each institutional barrier to conservation, it would be quite revealing to perform a quantitative analysis. For example, an econometric analysis could be performed with the level of reduced use as the dependent variable and the various measured levels of each of the various institutional barriers as independent variables. If such a model could be estimated, then the comparative size of the coefficients on each barrier would tell something about the comparative importance of each institution.

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. Temporary water transfers, such as a one-season water rental or leasing arrangement, or through an arrangement similar to banking, could provide agricultural producers an incentive to reduce water use. Permanent transfers are even more attractive to municipal and industrial users; utilities responsible for municipal supplies and operation of water treatment plants need a predictable and continuous water supply. The advantages of short-term transfers include the immediate infusion of cash into agriculture as well as benefits to cities and the environment, both of which could include potentially large elements of consumer surplus.

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 water right owners to lease water to the bank or renters, such as cities or an environmental group. 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 ground water instead of surface water where the two sources are hydrologically independent. Where the two sources are interdependent, conjunctive use management can help implement a water bank for which the benefits exceed the costs. There are several excellent sources summarizing the economic theory and applications of conjunctive use management (Burt, 1964; Provencher and Burt, 1994; Knapp (1995); Schuck and Green, 1998, 1999, 2002, 2003).

A successful water bank experiment in California in the early 1990s taught several lessons: Water markets, even when they are severely constrained and controlled, can work. Water can have 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). This successful experiment suggests that this market approach has a considerable potential for dealing with the institutional barrier of water transfer restrictions.

This market approach appears to be a measure with great potential to produce benefits exceeding costs.

Still, it is important to guard against the view that water marketing provides costless incentives to reduce water use. Farmers who switch from surface water to ground water may be pursuing a useful strategy for short-term management during dry years, but this switch is not always sustainable in the long run. While the California Water Bank was successful as a whole, there is evidence that at least some of the farmers who sold their water to the California Bank substituted the use of ground water for surface water and continued to grow low-value crops such as alfalfa. Thanks to an anonymous referee for this insight.

Some Rio Grande Basin irrigators 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. Moreover, some producers may fear that their water rights will be lost through a temporary transfer into a bank. This could occur because of unclear or un-enforced legislation or poor communication by water administrators to producers. As a result, this important potential
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 their consumptive water needs even though stream diversions are reduced.

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 et al., 1998; Huffaker and Whittlesey, 2000).

An on-farm investment that reduces the producer’s applied water by X acre-feet can reduce downstream supplies by as much or more than X. This counterintuitive result occurs because of the potential for increased water consumption (depletion) caused by a change to an irrigation technology that reduces water applied. For example, a producer who switches from flood to drip irrigation diverts and applies to her field X acre-feet less than before. However, this action, while reducing water applied from the adopter’s view, can reduce return flows by more than X because drip irrigation typically increases crop yields through higher evapo-transpiration (ET) or greater consumptive water use. Consider the use of these concrete numbers in which the change in irrigation technology reduces applied water from 4 to 2 acre-feet per acre (1 acre = 4047 m²). Crop water use (ET) could increase from 1 acre-foot per acre under flood to 2 under drip. With no other losses, the overall effect could be reduced return flows to the stream from 3 under flood to zero under drip. The result is reduced water application leading to increased water depletions.

Changes in irrigation efficiency make no new water. They only change the flow patterns between river, storage, and aquifer. In the long run, only reduced consumptive use can deliver more water downstream. A policy measure that guards against false water savings can increase the benefits of reduced use by more than the costs by encouraging the right on-farm investments. Those investments will encourage on-farm applications that reduce net depletion to the basin (Huffaker and Whittlesey, 2000).
phant Butte Reservoir (see Figure 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 reduced water use, 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.

There are many ways to reduce water use. 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 (phreatophytes) to decrease water lost to nonbeneficial uses or substituting water stored in surface reservoirs to shallow ground-water basins. Institutions that block producers from securing a clear title to a water right for the reduced water use in this way discourage investments in water savings.

The doctrine of prior appropriation, typical in the western states, blocks incentives to reduce water use because water rights protected under the law are limited to the amount of water that is diverted and put to beneficial use. The water right owner has no incentive to limit use through water-saving measures. For example in the case of Southeastern Colorado Water Conservancy District v. Shelton Farms, the Colorado Supreme Court found that appropriators cannot sell salvaged water (Colorado Supreme Court, 1974). This legal decision damages economic incentives to make investments that save water. In recognizing this problem of weak conservation incentives, several western states have taken steps to remedy the situation. California and Oregon have assigned the right to use conserved water to the person who implements the conservation measure. Court decisions in Utah and Colorado have produced the same result. In Texas, as stated above, water conservation must be considered when granting permits for proposed new water uses. Beneficial uses in Texas include the following water uses: domestic and municipal uses, agricultural uses and industrial uses, mining, hydroelectric power, navigation, recreation, public parks, and game preserves (Texas Water Code, 1997).

*Shared Carry-over Storage*

Irrigators sometimes express support for a policy that permits or encourages them to carry over and keep track of this year’s unused water, so it can be released from a reservoir and used in a subsequent year. Under the Rio Grande Project in southern New Mexico and West Texas, water users are discouraged from saving water in any given year and storing it at Elephant Butte Reservoir for later use. 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 carry over storage is seen. Several 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 quality is sometimes impaired by salts or chemicals. If a system of carry-over storage credits could be enacted with property rights assigned to those who reduce their current water use by following land, adopting water-saving irrigation technology or shifting to lower water-using crops, these losses could be reduced. In drought years, actions such as these that saved water would be especially valuable in the future, thus contributing to the region’s water conservation.

The common property nature of an irrigator’s saved water in Rio Grande Project area of southern New Mexico and West Texas, combined with the historical 57% water allocation to New Mexico users and 43% to Texas users, means that any water that one state carries over into the region’s storage this year is shared by both states the next year. For example, suppose a Texas user reduces current use by 1,000 acre-feet, the irrigation district can then save it in Elephant Butte Reservoir to deliver in the following year. The un-evaporated part of the 1,000 acre-feet saved by the Texas user will accrue as 43% to the Texas irrigation district and 57% to the New Mexico irrigation district. Subsequently, the water saved will then be allocated, not to the individual who saved the water but, pro rata to all users in each district. 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. Assigning Texas property rights to the irrigation district and/or to individuals in Texas who save water and New Mexico property rights to the New Mexico irrigation district and/or to individual water savers could be a low-cost measure for dealing with this issue, thus promoting water conservation through increased security of tenure.

There may be other cost-effective measures for dealing with shared carry-over storage. For example, the Snake River water bank (Idaho Water Supply Bank, 2005) has established a successful policy for promoting shared carry-over capacity such that irri-
gators can deposit water now and later withdraw it. In 1980, the State Legislature of Idaho established a water bank that authorized water rental agreements that had been in place informally for many years. The legislation assured the owners of stored water that seasonal deposits into the water bank would not jeopardize their rights to later withdraw the water. In this bank, federally supplied water is obtainable by holders of contracts for water from the Bureau of Reclamation reservoirs on the Upper Snake River. Many water right holders keep large water holdings unused as insurance against drought. The Bureau of Reclamation offers US$2.50/AF for water to be leased for 1 year and in turn rents this water to others in the basin who are willing to pay to put it to beneficial use, typically other irrigators and the Idaho Power Company. Thus, by being paid to deposit unused water into the bank, the market institution has coped well with the potential for wasted water in the face of shared carry-over storage.

**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 in the upper part of the basin above Fort Quitman, Texas, about 100 miles southeast of El Paso, Texas. 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 compact is the most important institution governing the allocation of water among the three basin states. In basin above Fort Quitman, Texas, water is managed to comply with the 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 Reservoir, measured at the gauging station just above Elephant Butte, is a function of annual flows at the Otowi gauge above Santa Fe, excluding interbasin transfer San Juan-Chama River flows. So flows in New Mexico delivered to the Elephant Butte gauge under the Compact are 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.

While the compact has proven to be a lasting and respected institution for the basin’s water allocation, it currently provides for no institution 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 surplus water from these users. If, for example, the 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 might 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 might encourage all users to invest in water use reduction measures, thus providing incentives for water conservation where the total benefits of the reduced use exceed total costs.

**Conservation Attitudes**

Negative attitudes toward reduced water use can represent a major barrier to water conservation even when the benefits of reduced use exceed its costs. To understand more about these attitudes and the barriers they form to water conservation, a survey of water management practices was administered in 2002 and again in 2003 to members of the Elephant Butte Irrigation District (EBID), New Mexico. The survey was designed to identify attitudes that discourage irrigators from reducing water use. 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 the top reason for not reducing water use is a lack of buyers for saved water. The lack of buyers means that irrigators perceive weak incentives for reducing water use. Their response is telling policymakers: “Why should we conserve water if there is nobody to buy our water?” Furthermore, if there are no buyers, a message is signaled that there is little social value in reducing water use. So they receive a message that they might as well continue to use water-intensive irrigation methods. Certainly, the development of a well-functioning water trading system depends in part on willing sellers and buyers, otherwise no trades will occur.
Table 2 also shows that a strong majority of producers identified several barriers to water conservation, defined here as a simple reduction in use: conservation is too expensive, the basin’s stream adjudications are not yet complete, additional labor is required to implement conservation, there are inadequate financial incentives for reducing water use, there is an inadequate water distribution system, and there are increased soil salts resulting from reduced water use.

Land Tenure

Most farm rentals in the area are based on a crop-sharing arrangement, but renters typically pay a flat fee for the right to farm a set acreage. Under nondrought conditions, the first 2 acre-feet per acre are typically a part of the lease, essentially a fixed cost. The fee is priced to pay for the District’s operations costs, including the water that comes with it. Recently, EBID implemented a declining block rate with additional amounts of project water available at a lower price, with the intent of providing incentives to avoid pumping ground water. Additional surface water, if available at the reservoir, can be bought for US$18 per acre-foot, so that water is a variable production cost. During the survey, several renters described the lack of financial incentives for water-conserving measures. For example, if a land tenant only has a year-to-year agreement with the landowner, that tenant is unlikely to incur large costs in expensive water use reduction measures, such as drip irrigation, which require several years to pay back. One measure for dealing with the problem might be for owners to offer land tenants a greater stake in water use reduction, thus tenants would share the net benefits produced by water use-reducing measures.

Uncertain Duty of Water

Many Western states, including New Mexico, are in the process of adjudicating their streams by defining clear titles to water rights. A completely adjudicated stream system clearly defines all owners’ rights to use water under all possible future hydrological conditions, but the process is lengthy and uncertain. In New Mexico, many streams have not yet been adjudicated, which means that water rights are not yet clearly defined. This uncertainty can create confusion and disputes over water use, as different parties may have different interpretations of the rights and responsibilities associated with the water. As a result, land tenants may be hesitant to invest in water-conserving measures, as they may not be sure who is entitled to the water if it becomes available in the future.


2Entry reflects percentage of all respondents indicating agreement with statement.
conditions. General stream adjudications fulfill two functions: (1) public recording and validation of all water claims and rights, (2) facilitating a clear set of rules for allocating water in periods of shortfall.

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 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. It is unclear who the junior users are.

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,” or the amount of water right assigned per acre, has yet to be established. The duty of water has little to do with a moral or legal duty. The concept was established to limit the amount of water that may be diverted under a priority system, and was designed to prevent waste. It is the relation between the area to be irrigated and the quantity of water required to irrigate it for the purpose of maturing its crop. Of course, what is required depends heavily on the price of water, the crop grown, soils, and on the price of various water-using technologies. Where water has a low price and where water-conserving technologies are expensive, the amount of water required to irrigate an area economically will be quite high indeed.

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 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. Tied to this is uncertainty of ground water adjudication. The question centers on whether or not water rights offers will be defined on combined rights to surface and ground water use. For New Mexico producers, ground water is an important source of water during drought, but it is also used widely in normal years. Water allocations per acre could be made based on an efficiency criterion defined by the relative economic value of water. Using the efficiency criterion for defining a water right per acre could be accomplished by defining duties of water in such a way that the marginal value of the last acre-foot consumed is equal for all crops (1 acre-foot = 1233 m³).

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 will have an incentive to plant crops or trees that use larger amounts of water solely to receive a favorable higher future assigned property right.

Despite the long run increase in certainty targeted by the ongoing adjudications in the basin, their current incomplete status creates a 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. Crops listed are onion, pecans, alfalfa and cotton. Onion farmers were especially sensitive to the incomplete status of the ongoing adjudication process; 67% 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. Despite the greater water-conserving incentives, these adjudications are typically expensive, both in terms of legal as well as technical expertise. As a measure for promoting increased water conservation, stream adju-

<table>
<thead>
<tr>
<th>Most Important Crop</th>
<th>Onions (N = 3)</th>
<th>Pecans (N = 35)</th>
<th>Alfalfa (N = 38)</th>
<th>Cotton (N = 19)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reasons for not reducing water use</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water conservation costs too much</td>
<td>67²</td>
<td>69</td>
<td>74</td>
<td>63</td>
</tr>
<tr>
<td>Incomplete stream adjudications</td>
<td>33</td>
<td>91</td>
<td>89</td>
<td>68</td>
</tr>
<tr>
<td>Water conservation requires additional labor</td>
<td>67</td>
<td>83</td>
<td>76</td>
<td>68</td>
</tr>
<tr>
<td>No buyers for saved water</td>
<td>67</td>
<td>100</td>
<td>97</td>
<td>95</td>
</tr>
<tr>
<td>No financial incentive to reduce water use</td>
<td>67</td>
<td>86</td>
<td>87</td>
<td>63</td>
</tr>
<tr>
<td>Water distribution system restricts conserving</td>
<td>100</td>
<td>82</td>
<td>94</td>
<td>94</td>
</tr>
<tr>
<td>Reduced water use builds up salts in soil</td>
<td>67</td>
<td>71</td>
<td>81</td>
<td>82</td>
</tr>
</tbody>
</table>

²Entry reflects percentage of all respondents indicating agreement with statement.
dications are unlikely to be the most cost-effective institution for finishing the job, especially in the two-to-four year time horizons that influence most elected representatives.

ECONOMIC FACTORS AFFECTING WATER USE

The price of water, as well as the price of measures that promote reduced water use, are important indicators of water’s economic scarcity. Economic theory suggests that producers will pay close attention to both sets of prices. Several studies have found that the price of water as well as the price of water-saving irrigation technology have a significant major influence on the adoption of water-saving measures (Caswell and Zilberman, 1985, 1986; Caswell et al., 1990; Moore and Negri, 1992; Green et al., 1996; Green and Sunding, 1997).

Effective Price

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

EBID members also have the right to purchase additional water at US$18 per acre-foot up to the amount of water that is available, so the incremental price after two acre-feet is US$18. If policies were instituted that allowed members to buy each acre-foot after two at US$18, then rent any unused portion of it out at US$100 or even US$200 per acre-foot to a city or recreational or industrial buyer, there would be considerable financial incentive to invest in on-farm water-saving measures. However, current water transfer practices do not permit trading of water outside agriculture, so the effective market price of water received from non-agricultural buyers is at or near zero. Thus, water is effectively locked into agriculture, which discourages investments in water-saving measures and raises the price of water to city or environmental users since they will have to search for new supplies.

The Special Role of Price

Section 3 described several institutional barriers to reduced water use, all of which have economic implications. Yet, with increased population, growing environmental demands, and other water demands outside the agricultural sector, there is continued interest in and debate surrounding the design of cost-effective measures for promoting increased water-use efficiency in agriculture. Answers to the following three questions could provide useful insights to inform this debate: (1) what are the economic costs resulting from institutional barriers to the adoption of water-saving measures? (2) what kinds of actions can producers be expected to take to deal with water shortages when there are no barriers to adopting water-saving measures? (3) what are the economic costs of subsidy programs designed to maintain farm income levels while reducing agricultural water use?

The question of what changes it would take to promote investments in reduced water use, defined here as allocating some acreage into drip irrigation, takes on considerable economic and political importance.

Water price reforms are increasingly used to encourage improvements in irrigation efficiency through technology adoption. However, because of the political sensitivity of price reform, debates center on the effectiveness on irrigation technology choices resulting from economic factors like price v. those of environmental characteristics and institutional adjustments (Green et al., 1996).

As is typical throughout the world, drip irrigation in the Lower Rio Grande Basin is considerably more expensive than flood irrigation. It also requires less water applied per acre and produces greater crop yields. The answer to the question of whether or not drip irrigation is economically attractive to irrigators turns on what combination of economic and water supply conditions make it profitable to favor drip over flood irrigation. As of 2005, virtually all EBID producers use flood irrigation. Because Tables 1-3 present few conclusions with rigorous analytical content, the analysis turns to a linear programming approach designed to provide insight into the economic and institutional forces promoting or discouraging water-use reductions.

Table 4 shows economic conditions for a representative irrigated onion farm in the lower Rio Grande Basin. A comprehensive treatment of agricultural impacts in Table 5 would require accounting for a majority of the region’s acreage: pecans, several kinds
of vegetables, alfalfa, cotton, and grains. The analysis shown in the table includes only a single crop, onions. While this is a simplification of reality, it has the advantage of offering clear insight into irrigator behavior. It also provides an understanding of impacts on farm behavior resulting from input and output prices, yields, production costs, and crop water requirements.

Table 5 shows the impact of changes in water scarcity as well as impacts of a range of adjustments under four possible sets of production cost and crop price conditions. Rows 1-4 show current conditions, consisting of high production costs (US$4,120/acre for flood irrigation) and low crop prices (US$6.38); Rows 5-8 show conditions of high production costs and high crop prices (US$7.38); Rows 9-12 show conditions of high production costs and high crop prices (US$7.38); Rows 13-16 show low production costs and high crop prices (US$6.38). Rows 13-16 show low production costs and high crop prices. Drip irrigation is priced at a constant US$5,320 per acre except where it is reduced through public subsidy.

For each set of these three future economic conditions, 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 scenario is one of the continued income maximization in which the producer is constrained from investing in any additional drip irrigation acreage beyond that, which occurred under the unconstrained income maximization produced by a water supply of 300 acre-feet. The second scenario is continued income maximization with no institutional barriers that constrain the irrigator from investing in drip irrigation.

The third scenario assumes the presence of a government subsidy program designed to compensate for the effect of a reduced water supply. In this scenario, the program’s aim is to design a water use reduction subsidy that saves a known amount of water at minimum financial cost to the taxpayer while maintaining farm income at least as high as income earned under full water supply. To simulate this program, a model is developed in which the producer’s net cost per acre of drip irrigation is reduced by the amount of the subsidy. Because the taxpayer-cost-minimizing subsidy is not known in advance, the model’s objective minimizes the financial cost of a drip irrigation subsidy that saves 100 acre-feet of water. It also produces a farm income equal to or larger than that earned under the baseline 300 acre-foot supply. Results of income maximization provide insights into factors that most influence irrigators’ investments in water-use reduction.

The decision to invest in drip irrigation raises important issues in connection with capital investment and with uncertainty. The producers’ decision to invest in drip irrigation or the taxpayer’s decision to subsidize it is made for many years into the future. The decision involves not only current output prices and costs, but an irrigator’s expectation about future output prices and costs. For example, a subsidy on the adoption of drip irrigation might have been paid every year, not just the year of adoption, to cover the additional costs to the farmers. If these subsidies are paid for a longer term, the costs will continue to be higher than those of flood irrigation. Research has shown that uncertainty about future relative prices poses a major impediment to the adoption of conservation irrigation technology. To deal with these complexities, Tables 4 and 5 treat all costs of drip irrigation to both producers and to taxpayer-subsidizers as added costs in annual equivalent terms compared to those of flood irrigation. The authors thank an anonymous referee for this observation.

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 cheap 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 US$6.38 the crop price is too low for the value of the additional yield to pay for the additional annual equivalent costs of drip technology. Row 1 shows that income maximization under initial conditions requires idling 25 of the 100 available acres. All 75 of the acres under production are produced under flood irrigation, a fact that was largely observed in 2005. The value of one additional acre-foot of water is US$47, and the farm produces a total net income just under US$14,000. When water supply falls to 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

### Table 4. Economic Conditions for an Irrigation Farm, Lower Rio Grande Basin, New Mexico, 2005.1

<table>
<thead>
<tr>
<th>Water supply</th>
<th>300 acre-feet</th>
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<tr>
<td>Crop</td>
<td>Onions</td>
</tr>
<tr>
<td>Farm size</td>
<td>100 acres</td>
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<td>Crop price</td>
<td>US$6.38 per sack</td>
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<td>Flood irrigation</td>
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</tr>
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<td>Production cost</td>
<td>US$4,120 per acre</td>
</tr>
<tr>
<td>Crop yield</td>
<td>675 sacks/acre</td>
</tr>
<tr>
<td>Water use</td>
<td>4 acre-feet/acre</td>
</tr>
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<td>Drip irrigation</td>
<td></td>
</tr>
<tr>
<td>Production cost</td>
<td>US$5,320 per acre</td>
</tr>
<tr>
<td>Crop yield</td>
<td>845 sacks/acre</td>
</tr>
<tr>
<td>Water use</td>
<td>2 acre-feet/acre</td>
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1Source: Libbin and Hawkes (2005).
<table>
<thead>
<tr>
<th>Supply (a-f)</th>
<th>Subsidy</th>
<th>Barrier¹</th>
<th>Flood² (US$/ac)</th>
<th>Drip³ (US$/ac)</th>
<th>Onions (US$/sack)</th>
<th>Flood (ac)</th>
<th>Drip (ac)</th>
<th>Idled (ac)</th>
<th>Average Use (a-f/ac)</th>
<th>Idled (a-f)</th>
<th>Water Value (US$/a-f)</th>
<th>Net Income (US$)</th>
<th>Program Cost (US$)</th>
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<td>0</td>
<td>61</td>
<td>103,880</td>
<td>12,270</td>
</tr>
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</table>

ac: acre; a-f/ac: acre-feet/acre; a-f: acre-feet.

¹Institutional barrier prevents producer from investing in drip irrigation even if it increases net income or reduces losses.

²Equals cost per acre of crop production under flood irrigation technology; crop yield is 675 sacks per acre; water consumptive use is 4 a-f/ac. Data source is Libbin and Hawkes (2005).

³Equals cost per acre of crop production under drip irrigation technology; crop yield is 845 sacks per acre; water consumptive use is 2 a-f/ac. This large amount of water savings produced by shifting from flood to drip irrigation may be optimistic. The use of twice as much water for flood irrigation as for drip irrigation is unrealistic for many parts of the country. It is possible for differences in applied water, but as described in the article, is less likely for water consumed from the basin-wide view. It is important to consider and account for recharge that occurs after water is applied to a field, as that recharge contributes to downstream water supplies and use.

⁴The top row reflects 2005 conditions.
Irrigators' highest willingness to invest in water savings occur 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 economic desirability of investing in drip irrigation. The higher crop price enables the added physical yield gained through 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 irrigation is insufficient to pay for its added production costs. Under conditions described by Row 5, drip irrigation becomes so profitable that all 100 acres are produced under drip irrigation even without reducing the water supply. Furthermore, installing drip irrigation reduces water use by so much that its adoption results in 100 acre-feet of unused water. This water becomes available for uses outside agriculture, such as environmental or cities' needs. For this reason, when agricultural water supply falls from 300 to 200 acre-feet, there is zero economic loss to agriculture. In these conditions, the cost of a water-saving 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 savings occurs when flood irrigation is cheap and crop prices are low, as shown in Row 12's US$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 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 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 water-savings program subsidy required of the taxpayer to be so high. When farm income falls from US$36,487 to US$24,325 after the water supply reduction, the cost-minimizing drip irrigation subsidy needed to maintain farm income at the US$36,487 base after the 100 acre-foot water loss is a high US$415 per acre.

Institutional barriers to water savings have the largest effect on reducing net farm income in the face of reduced water supply in conditions where flood irrigation is cheapest and crop prices are highest. Rows 13-16 show that the economic cost of the institutional barrier to installing drip irrigation at US$17,000 (US$91,610-US$74,842). That is, removing the institutional constraint to drip irrigation saves the irrigator about US$17,000. In the face of institutional barriers to reduced water use (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 US$29,000. This large economic loss produced by institutional barriers to saving water, not surprisingly, also produces the highest marginal economic value of water at US$290 per acre-foot. Remarkably, the economic cost of a subsidy designed to encourage water savings is comparatively small (US$12,270 shown in Row 16) compared to conditions described in Rows 12 (US$20,770). It is smaller because irrigators can afford to invest in drip irrigation thanks to a high prices. Therefore, the drip irrigation subsidy required to restore base income (US$103,880) is only about US$123 per acre, a total subsidy of US$12,270 for the 100 acres. Moreover, an anonymous referee reminds us of an even potentially lower cost policy option than the one described for Table 5. That is to provide a lump-sum subsidy to farmers after reducing their water supply, instead of distorting the relative costs of drip compared with flood irrigation. This possibility would allow farmers to keep using flood irrigation if it is more profitable, but still reduce water consumption from 300 to 200 AF per acre. The authors are indebted to an anonymous referee for this insight.

The results above should be qualified by recognizing the importance of output price in the decision about irrigation choices. While few of the crops in the Rio Grande Basin are government supported commodity crops, a considerable amount of irrigated acreage in the west does produce these supported crops. The distinction between supported and unsupported crops is important for several reasons, including the establishment of expected future prices and price volatility. In addition, the above discussion of commodity price, as well as the scenarios presented in Table 5, should make it clear that output prices as well as other costs are a result of both markets and of policy actions that influence those markets.

**Price and Substitution**

Ground-water substitution occurs when irrigators respond to surface water price increases or shortages by reducing surface water demand and tapping...
instead into ground water. An unfortunate side effect of this is that ground-water substitution can lead to actions that reduce the use of one water resource at the expense of another to which it is hydrologically connected. As a result of the interdependence between ground-water and surface water use, it is difficult to determine if a surface water pricing program promotes saved water from the view of the system. One water source is potentially saved at the expense of the other. For this reason, the hydrologic and economic ease with which ground water is substituted for surface water is important to understand and measure when debating, designing or enacting policies that promote water use reductions. 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 ground water 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 and Green, 2003).

CONCLUSIONS

The ability for an irrigator to realize an economic gain by reducing current water use in agriculture is an overarching factor that can be used to design incentives to promote water conservation. Despite the importance of water-conserving incentives, several barriers to water conservation are 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 conserved water. Other barriers include the ease with which greater ground water use can be substituted for reduced surface water, water’s uncertain duty, the common property nature of carry-over storage, interstate compact constraints, and water’s low price, all of which can effectively lock water into low-valued agriculture.

Institutional, as well as hydrologic factors, affect the potential for agricultural water conservation. While institutional barriers to water conservation exist for the entire Rio Grande Basin, the hydrological conditions affecting agricultural water use vary greatly within the basin. A significant proportion of irrigation water rights are dependent on return flows from upstream irrigation diversions in the basin. If water conservation measures that decrease the magnitude of return flows, such as drip irrigation, become widely adopted, the existing hydrologic integrity of the basin will be affected. The potential for agricultural water conservation is greater in basins that are less dependent by irrigation operations on return flows.

The potential for future agricultural water conservation in the Rio Grande Basin varies greatly among regions. More importantly, improved policy initiatives designed to implement conservation would be based on how water is used at the basin level rather than at the individual farm level. Consideration of the existing structure of water use at the basin level will minimize any negative implications of conservation strategies.

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 user. 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 sensitive 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 water conservation because incomplete stream adjudications 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, particularly when a severe drought may reduce 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 water conservation.

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