Agricultural Water Use in the Colorado River Basin: Conservation and Efficiency Tools for a Water Friendly Future

By Nathan Lee and Alice Plant

Key Findings:

-Irrigation efficiency strategies are often cost-prohibitive for farmers and fail to offer a silver bullet for water conservation in agriculture.

-Buy-and-dry methods of water transfers from agricultural to varying uses are short sighted solutions and can have devastating impacts on rural economies and communities.

-Alternative transfer methods must play a crucial role in meeting the competitive needs of urban, environmental, energy, and recreational uses.

-Only through water law that is more flexible, as well as a social shift from conflict to collaboration, will water efficient irrigation technologies and alternative agricultural transfer methods aid in allocating Colorado River water for future generations.

The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

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Introduction

Agriculture in the Colorado River Basin has historically represented the essence of the West. Initiated by the Homestead Act of 1862 and the settlement of the West, agriculture has facilitated, either directly or indirectly, the existence of each inhabitant in the Colorado River Basin while providing the nation with vital agricultural products. Whether agriculture will continue to support the basin's agricultural demand, or whether the basin becomes a region of largely imported agricultural goods with dwindling rural areas will largely be determined by the path of the water discourse in the next decade. As these issues unravel, finding creative ways to balance agricultural, municipal, and energy interests is paramount in the context of total water demand increasingly dwarfing a variable and stressed water supply.

By far the largest sector of use in the region, agriculture, utilizes approximately 56-80% of the water in the Colorado River Basin.[1] Several sources, including the Bureau of Reclamation (BOR), have cited current agricultural water use as consuming as high as 70-80% of Colorado River water.[2] However, there remains a discrepancy between this figure and the predicted decrease in agriculture water demand under the BOR's Current Trends scenario of 56.42% in 2015. This is likely due to the baseline data that was used for the demand scenarios and possibly due to different methods of measurement.

Agricultural users hold many water rights that are senior to municipal, industrial, and recreational users, as agriculture was one of the first sectors to put the water to "beneficial use." The Colorado River is one of the most dammed, regulated, and diverted rivers in the world.[3] Its water is already over appropriated and current growth trends for the region predict that more than 30 million people reliant on Colorado River water will increase to 50 million people by 2035 and again rise to 62 million people by 2060.[4] Since 'new' water supplies have been exhausted or deemed impractical, a reallocation of water in the basin is inevitable; the majority of these transfers will be from agricultural to municipal uses.

Historically, municipal water providers have in the early decades made claim to water, and in the later decades permanently purchased and diverted water rights from farmers or irrigation ditch companies to cities. These sales ensure a more secure water supply for cities, but also have a largely negative impact on rural communities and agriculture production. To counter the growing concern over the adverse social, environmental, and economic impacts of these types of "buy-and-dry" purchases of water rights, numerous individuals and organizations have devoted time to creating alternative programs. Examples of these alternative agricultural transfer methods include temporary water leasing agreements between cities and irrigation ditch companies, rotational fallowing programs, and the creation of "water banks." Successful implementation of these programs has the potential to balance competing interests and moderate conflicts between rural and municipal communities.

Under the current regime of prior appropriation, many farmers have little incentive to practice water efficient irrigation techniques. The Law of the River functions on what is known as a "use it or lose it" system. Farmers can either use the water they are apportioned or "lose it" and allow it to flow to downstream users. Only water that is considered part of the historical crop consumptive use[5] can be transferred to other alternative water uses.[6] Practices that reduce historical consumptive uses are considered "water conservation" practices; alternatively, practices that decrease non-consumptive losses are considered "water-efficiency" (or irrigation efficiency) practices. Changing to more efficient on-farm irrigation techniques generally is not considered to decrease crop consumptive use; therefore, any water "saved" under those practices is nontransferable and must flow downstream to junior users.[7] Further, changing to more efficient techniques can cost $400-$1,000 per acre of land, a prohibitive cost for most farmers. Nevertheless, examples of more efficient irrigation techniques exist in the basin, largely thanks to research and support from the U.S. Department of Agriculture (USDA) and extension offices at the states' land grant universities.

Water is the limiting factor in the vitality of ecosystems, communities, and economies throughout the Colorado River Basin. Although agricultural use is often demonized as using water inefficiently, this is not the case. The Law of the River allows only a specified amount of water to be transferred out of agriculture. Beyond that, irrigation runoff eventually reappears in the river in the form of return flows, ultimately to be used multiple times over by downstream users. The notion that agriculture uses water inefficiently misses the inherent complexities of the system.

Before delving into the different water efficient strategies in agriculture and the potential of alternative agricultural transfer methods, it is imperative to consider both the relative importance of these practices and the complexities involved in implementation. Changing irrigation techniques or creating water sharing programs have costs that are often prohibitively high. Additionally, legal and administrative barriers exist. Adjudication processes can last years as state engineers must ensure that transfers are in compliance with the "No Harm Rule" and interstate compacts. The question remains to be answered whether or not we can develop societal mechanisms to transfer water in a way that is administratively and financially efficient.

What we have sketched in this introduction is the "necessary" element of water efficiencies and water sharing in the Colorado River Basin. In the following pages we show that the technology exists and the costs can be mediated for farmers to use more efficient irrigation techniques. We also provide examples of where water sharing programs have been successfully implemented. The "sufficient" part of the puzzle is highly dependent on the human ability to compromise and the flexibility or adaptability of the Law of the River. The history of water law in the basin has demonstrated instances of rigidity and flexibility; so too have the individuals representing divergent interest groups. Only through future water law that is more flexible and a social shift from conflict to collaboration will water efficient irrigation technologies and alternative agricultural transfer methods be able to fulfill the potential they promise. We owe nothing less to future generations!

Water Efficient Strategies in Agriculture

As population growth and a changing climate stress water availability in the Colorado River Basin, water efficiency strategies in agriculture are believed to have the potential to stretch existing supplies. However, due to prior appropriation and water use laws in the Colorado River Basin, the

Figure 1: Gated Pipe Irrigation System

Source: Alice Plant.

Figure 2: On-Farm Irrigation Systems

System	Method	Description
Surface (Gravity)	Flood	Water is diverted from ditches to fields or pastures.
	Furrow	Water is channeled down furrows for row crops or fruit trees.
	Border	Water is applied to sloping strips of fields bordered by ridges.
Sprinkler (Pressurized)	Pivot and Linear Systems	High Pressure.
		Medium Pressure.
		Low Pressure.
	Side Rolls	Mobile pipelines deliver water across fields using sprinklers.
	Solid Set	Pipes placed on fields deliver water from raised sprinkler heads.
Micro-irrigation (Pressurized)	Surface	Emitters along pipes or hoses deliver water directly to the soil surface.
	Subsurface	Emitters along pipes or hoses deliver water below the soil surface.
	Micro-sprinklers	Emitters on short risers or suspended by drop tubes sprinkle or spray water above the soil surface.

Source: Agriculture Water Conservation: Irrigation Water Use Management- Best Management Practices. Texas Water Development Board, Conservation Division, 2011.

"savings" from on-farm efficiency measures do not necessarily translate into transfers to other uses. Improved methods of water delivery and application generally require less labor, leech less water through the soil, improve soil and water quality, and increase crop yields by increasing the uniformity of water application. These methods do not decrease the necessary amount of water required by an individual plant; the improvements simply increase efficiency, that is, the amount of water consumed by a plant relative to the amount of water applied to a field.

The benefits of improved irrigation and water delivery methods in agriculture are widespread throughout the basin. Instream flows are essential to the health and livelihood of the Colorado River and have the potential to increase with water efficient irrigation methods. In addition to supplying water to downstream users, instream flows improve riparian health and help to maintain aquifer levels. Water quality and soil health also increase with improved irrigation methods. Water applied with more precision leads to decreased erosion, leeching, and runoff. Consequently, decreased runoff reduces the amount of beneficial nutrients removed from the topsoil. In addition, the amount of fertilizers, pesticides, and salts that are absorbed in the runoff decreases, thereby increasing water quality and salinity levels.

Irrigation Technologies

Converting to more efficient on-farm irrigation technologies is not the simple remedy that many may think. Although water efficiency[8] increases and the negative effects of runoff and seepage decrease with these methods, the success of an irrigation system is dependent upon the management of the system and the specific circumstances of each user. Flood irrigation is historically the most basic and low cost means of applying water to crops. Fed by gravity, furrows or gated pipe systems carry the water over the surface of the field (**Figure 1**). However, this system of irrigation has proven to result in low water efficiency, low uniformity of delivery, and high losses to evaporation.[9] To counter these effects, more efficient irrigation methods such as sprinkler, drip, and sub-irrigation are being implemented across the Colorado River Basin. Differences between irrigation systems are due to the amount of runoff, deep percolation, and evaporation. **Figure 2** offers a description of the most standard on-farm irrigation systems.

Sprinkler Irrigation

Sprinkler irrigation systems are a versatile but costly method of irrigating crops that can be utilized where surface irrigation is unsuitable and inefficient. There are several methods of water application, pressure, and movement of sprinklers depending on the type of crop being irrigated. **Figure 3** is an example of a center pivot unit. These systems carry with them the benefit

Figure 3: Center Pivot Sprinkler Irrigation in Montrose, Colorado

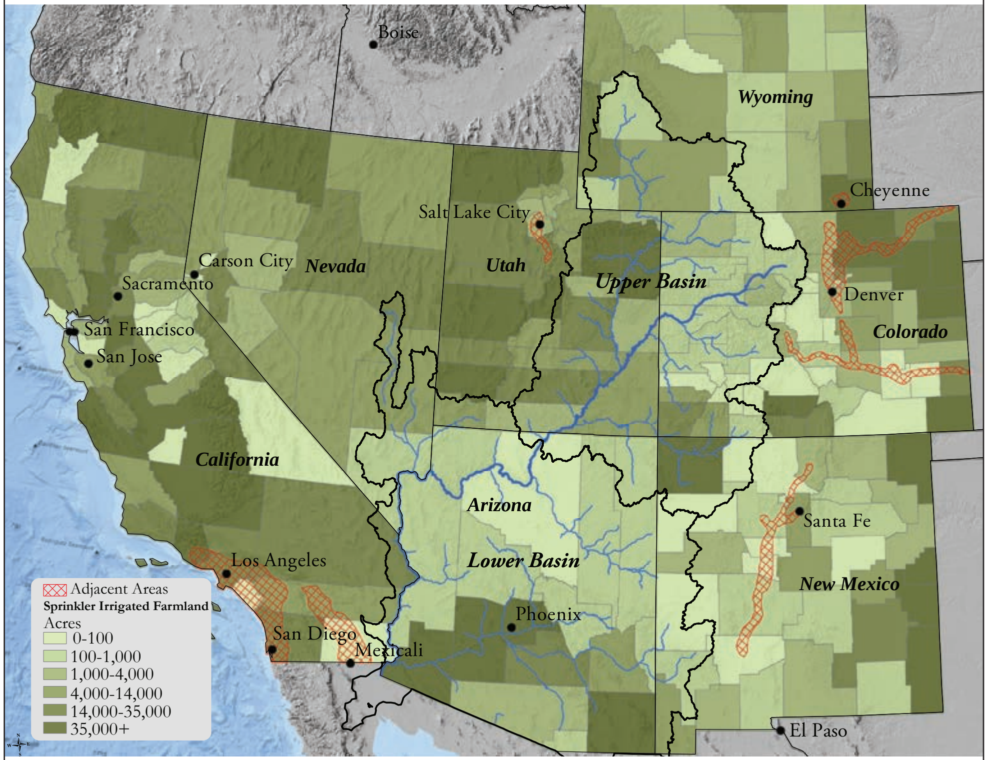
Source: Alice Plant.

of reduced losses to evaporation. Additionally, the increased uniformity of water application can lead to increased yields. As seen in **Figure 4**, there is extremely high variability in efficiencies and cost of implementation within each system and the benefits are dependent upon the management of the system and the selection of an appropriate sprinkler system that fits both the crop's and farm's needs.

An added cost of many sprinkler systems is the high-energy cost of pumping water into the raised system, whereas for a gravity-fed flood irrigation system the energy cost is extremely low or negligible. With a given diesel price of $2.20 per gallon (a low estimate for today's fuel prices), the cost for pumping water through a center pivot system on 130 acres is roughly $65/acre.[10] However, these costs have the potential to be offset by increased yields and productivity.

In 2005, twenty-five percent of the Colorado River Basin's irrigated land was covered by sprinkler irrigation.[11] **Figure 5** describes the distribution of sprinkler irrigated acres across the basin states as of 2005. However, over the last eight years there has been a substantial increase in sprinkler irrigated acres.

Figure 5: Sprinkler Irrigated Land



Source: Estimated use of water in the United States county-level data for 2005 in U.S. Geological Survey [database online]. 2005 [cited October 10, 2012]. Available from http://water.usgs.gov/watuse/data/2005/.

Much of the irrigation infrastructure development is due, in part, to Environmental Quality Incentives Programs (EQIP) run by the USDA Natural Resource Conservation Service (NRCS). EQIP was established under the 1996 Farm Bill and provides financial assistance to plan and implement conservation practices that address natural resource concerns.[12]

Figure 4: Estimated Efficiencies and Costs for Irrigation Methods

Type of Irrigation	Range of Application Efficiency	Average Capital Cost/ Acre	Average Annual Cost/ Acre
Flood	30-50%	--	--
Furrow	40-60%	$37	$30
Gated Pipe	~60%	$178	$51
Center Pivot Circle	~85%	$433	$64
Center Pivot with Corner	~85%	$568	$80
Subsurface Drip Irrigation	~90%	$1,000	$120

Source: Colorado Agricultural Water Alliance. Meeting Colorado's Future Water Supply Needs: Opportunities and Challenges Associated with Potential Agricultural Water Conservation Measures. 2008.

The 2008 Farm Bill prioritized surface water conservation as a national priority for EQIP. As a result, a concerted effort is underway in the Colorado River Basin to address those concerns. In 2010, 5.2 million acres were involved in EQIP projects throughout the basin states. The EQIP program has provided subsidies to many of those acres to offset the $430-$570 per acre cost of implementation of sprinkler irrigation systems.[13]

Micro-irrigation

Micro-irrigation systems are the most efficient and costly method of irrigation and include surface drip, subsurface drip (SDI), and micro-sprinklers or micro-sprayers. Micro-irrigation systems deliver water at a slow and frequent rate to the soil. These systems offer a high level of uniformity in water delivery, flexibility in applying water, and considerably decrease water losses. Under proper management of these systems, water is supplied only to the plant's root zone, decreasing water losses to evaporation, runoff, and water consumption by weeds. These systems' ability to create optimal growing conditions can result in up to 25% increases in crop productivity.[14]

A major disadvantage to micro-irrigation systems is the prohibitive initial costs of equipment. As **Figure 4** indicates, subsurface drip irrigation can cost upwards of $1,000/acre for initial implementation with an additional $120/acre in annual upkeep. In addition to high costs, there is a high potential threat of clogging in the equipment, often going unnoticed until signs of stress are shown through the plant. The state-of-the-art subsurface drip irrigation system shown in **Figure 6** costs $400,000 for 80 acres with the installation of

Figure 6: State-of-the-art Subsurface Drip Irrigation System and Settling Pond

Source: Alice Plant.

20 acres/year over a four-year period. However, the system has a 20-year life expectancy and the ability to irrigate up to 80 acres, double the capacity of most drip irrigation systems. In addition, with EQIP and other government programs covering up to 80% of the cost, the final fee borne by the individual farmer can drop as low as $80,000, or $1,000/acre.[15] **Figure 7** shows the economic advantage micro-irrigation systems offer over less efficient furrow irrigation.

Figure 7: Economic Comparison of Drip and Furrow Irrigation Methods

Economic Activity Evaluated for Each Scenario	**Drip Irrigation Percentage as Compared to the Same Furrow-Irrigated Farm Model, 2000**
Yield	+25%
Chemicals	-18%
Fertilizer	-26%
Capital	+47%
Fixed Costs	+19%
Seed Costs	-20%
Net Operating Profit	**+12%**

Source: Hawkes, Jerry. Drip Irrigation for Row Crops: Economic comparison of drip and furrow irrigation methods for Dona Ana and Sierra counties. New Mexico State University no. 573 (2001): 11.

Irrigation Scheduling

The ability to irrigate efficiently greatly depends on access to information. Peter Williams, Technology Chief of IBM's Big Green Innovations, stated at the 2011 Water Conference in Colorado, "Irrigation efficiency isn't just about water flow; it's about information flow too."[16] Programs like Colorado Agricultural Meteorological Network (CoAgMet) have been developed to increase that information flow to an expansive audience by offering real-time information from a wide-range of locations across various states. CoAgMet allows water users to access information via the internet, including hourly, daily, and monthly summaries of weather and crop water use data.[17] Public access to this data allows irrigators to better manage their water, decide when to irrigate, and at what level. **Figure 8** depicts a CoAgMet station located at the NRCS Limited Irrigation Research Farm in Greeley, Colorado. Irrigation scheduling offers the potential to decrease the amount of water diverted by senior users, leaving more water in the stream system for junior users and environmental stream health.

Deficit Irrigation

The era of agricultural production in a water abundant environment is quickly disappearing. As agricultural production under water scarcity will soon become the norm, agricultural producers must learn how to effectively manage their crops with a limited water supply. Understanding the physiological processes of crops and the amount of water needed to maximize "crop per drop" can help producers maximize profits in times of drought. Deficit irrigation refers to the practice of applying water below the plant's evapotranspiration (ET) requirements. The practice specifically times water application to critical growth stages to obtain maximum yields with limited water supplies.[18]

Figure 8: CoAgMet Station

Source: Alice Plant.

Case Study: Deficit Irrigation Helping Farmers Manage Crops in Times of Shortage

Tom Trout is the lead researcher at the Central Great Plains Limited Irrigation Research Farm (LIRF) in Fort Collins, Colorado. Currently, Trout and his associates are conducting a field study of four common Great Plains crops- field corn, sunflower (oil), drybeans (pinto) and winter wheat- to determine how to maximize productivity per unit of water consumed.[19]

The study takes place on a 50-acre plot with six different irrigation applications ranging from fully irrigated down to 40% of full irrigation. The crops are set up with drip irrigation that is monitored and regulated by real-time readings from a CoAgMet weather tower stationed at LIRF. Each plot is equipped with devices to measure soil moisture in addition to infrared thermometers that are placed throughout the rows to measure canopy temperature – one of the first indications of crop stress (**Figure 9**).

Initial findings indicate that yield per unit of consumptive use of water for corn tends to decrease with deficit irrigation, implying that in watersheds where return flows are depended upon by downstream users (such as the Colorado River Basin), deficit irrigation may not be economically viable.[20] Trout asserts that corn farmers may be more successful by irrigating a portion of their crops with full irrigation, fallowing another section, and leasing that water to other uses in times of shortage.[21] In addition, Trout's research will help farmers determine the price at which to lease water to nonagricultural uses based on projected water use and yields.

Figure 9: Deficit Irrigation Levels at the USDA ARS Water Management Research Unit, Fort Collins, Colorado

Source: Alice Plant.

Irrigation Delivery Systems

Canal Lining

Aging canal infrastructure is a serious problem facing the Colorado River Basin. As current infrastructure ages, water losses to seepage will continue to escalate. Due to the vast geographic scale of the Colorado River and wide distribution of water users, conveyance infrastructure in the basin is immense. Unlined, earthen canals can exhibit water losses to seepage at levels as high as 50%.[22] There is a wide range of strategies to diminish water losses to seepage and evaporation in canals. Compaction can be used in earthen canals and, in some cases, can improve efficiency to levels similar to concrete lined canals. However, compacted earthen canals require frequent maintenance. **Figure 10** describes average canal efficiencies for well-maintained canals for various soil types.

Figure 10: Conveyance Efficiencies for Adequately Maintained Canals

	Earthen Canals			Lined Canals
Soil Type	**Sand**	**Loam**	**Clay**	
Canal Length				
Long (>2000m)	60%	70%	80%	95%
Medium (200-2000m)	70%	75%	85%	95%
Short (<200m)	80%	85%	90%	95%

Source: C. Brouwer, K. Prins, and M. Heibloem. Irrigation Water Management: Irrigation Scheduling. FAO, 1989.

Lining canals with impermeable materials is another option; however, it is often cost-intensive and requires maintenance, although, less frequently. Additionally, in wet years seepage from canals may be relied upon to recharge groundwater resources and meet the demands of junior users.

Polyacrylamides

Water efficiency in earthen-lined canal systems can be enhanced with the addition of a soil conditioner called polyacrylamide (PAM). PAM was used in irrigation canals in the late 1990s to reduce soil erosion, enhance infiltration, and increase water quality in runoff. Erosion in furrow-irrigated canal systems is nearly eliminated with the addition of small amounts of the water-soluble PAM. PAM improves water quality by increasing soil adhesion and strengthening aggregates in the furrow (**Figure 11**).[23] On average, costs of implementing PAM treatments cost $37-88/ha per crop, a price that is easily compensated by reductions in erosion-related operations, increased infiltration, and water conservation.[24] The use of polyacrylamides has proven to be an appealing, low-cost alternative for many agricultural producers who oppose other irrigation efficiency measures.

Figure 11: Polyacrylamide (PAM) Increases Water Quality

Source: USDA ARS Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho.

Crop Management

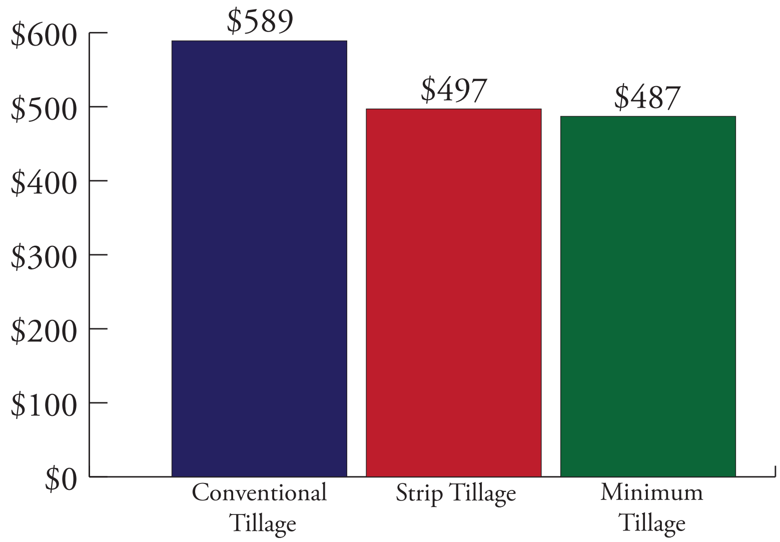
Conservation Tillage

Conventional tillage[25] methods leave soils susceptible to erosion by wind and water and can decrease soil productivity over time. Conservation tillage practices are commonly used in arid agricultural regions to retain soil moisture and better utilize water by leaving up to one third of the surface covered by crop residue at planting time (**Figure 12**).[26] Conservation tillage increases the ability of soil to store water due to reduced soil evaporation and increased infiltration of precipitation and irrigation water during the growing season and increased snow catch during the non-growing season.[27] During the growing season, the plant residue acts as a buffer against solar evaporation, much like canopy shading, and allows the soil to retain higher moisture levels. In addition, conservation tillage protects against losses of organic matter in the soil due to erosion by wind and water.

Tillage management practices are particularly effective when paired with sprinkler irrigation systems. Sprinkler systems often deliver water at a greater rate than the soil is able to infiltrate.[28] When these irrigation systems are paired with residue management, infiltration rates rise, thereby increasing the efficiency of the overall water delivery system. Further, changes in tillage management can allow growers to utilize a more intensive crop rotation, such as wheat-corn-fallow rather than a wheat-fallow rotation.[29]

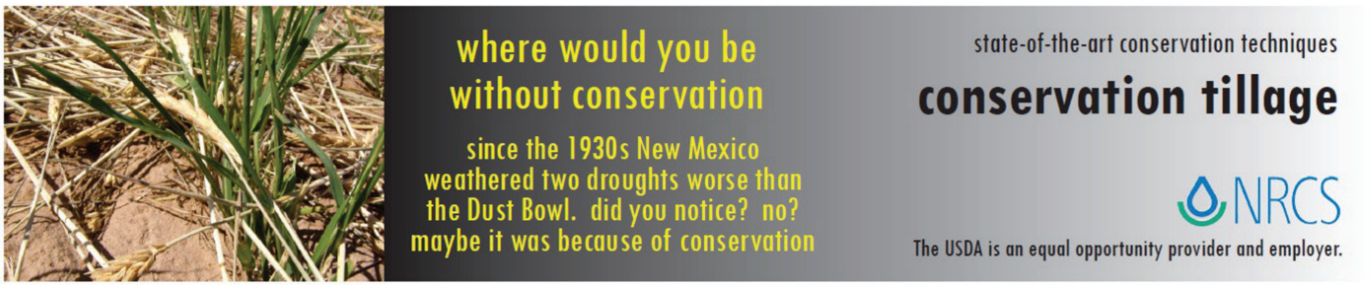
In a study conducted by New Mexico State University, conservation tillage was found to reduce fuel and oil use by up to 60% when compared to conventional tillage. In addition to fuel savings, labor, time, and machinery costs also decrease with conservation tillage practices. The study found that the conservation tillage system saved $27.71/acre in irrigation fuel and oil savings.[30] Colorado State University's Conservation Tillage Demonstration and Outreach Project found that these savings lead to an overall decrease in total cost per acre, as seen in **Figure 13**. Under minimum tillage, this can lead to a 17% reduction in cost per acre.[31]

Figure 13: Total Cost per acre Tillage Comparison



Source: Driscoll 2012.
Notes: Includes variable costs of seed, fertilizer, herbicides, fuel, crop insurance, and fixed cost of machinery ownership. Minimum tillage refers to the minimum amount of tillage required for crop production. Strip tillage refers to the practice of tilling only a narrow strip of land for the crop row.[32]

Figure 12: NRCS Conservation Tillage



Source: USDA, NRCS.

In a future where financial resources are stretched thin and farmers are in a constant battle to remain economically viable, the advantages of conservation tillage are great. Not only are soil, water, and organic matter resources conserved, but high cost inputs are also reduced, while concurrently improving crop productivity. For a farmer then, whose primary concern is to run an economical business, conservation tillage is an appealing way to conserve water, increase crop yields, and ultimately, increase profits. Although it may be an economically rational choice to implement conservation tillage practices, many farmers have yet to utilize the practice due to lack of information, inadequate resources, and a lack of confidence in the system.[33]

Crop Rotation

The sequencing of crops has the potential to increase yields and decrease irrigation water usage, leaving more water available for downstream users. Crop rotations spread the irrigation over a longer period of the season compared with a single crop while maintaining full irrigation levels.[34] Further, crop rotations are strategically designed to leave optimum levels of organic residue to improve soil quality. Due to the variability in soil quality, crops, compatibility of the land, and how the crops are managed, the results of a crop rotation program are dependent upon the appropriate selection of methods. However, with a well-designed rotation there is a great potential for decreased soil erosion, increased levels of organic matter, improved soil health, and improved crop yields.[35] According to agronomist Randy Anderson of the USDA Agriculture Research Service, rotations with winter wheat following dry peas increases the water use efficiency of winter wheat and increases yields by 10-15% with the same amount of water.[36]

Drought-tolerant Crops

Irrigation improvements can only take agriculture so far in terms of water use efficiency. One solution, which has been under investigation for several decades is the development of drought-tolerant crops that would allow producers to grow crops with limited water resources and retain high yields. Adaptive, drought-tolerant crops would allow the agriculture sector to respond to the mounting pressures brought on by a changing climate and a burgeoning population. Drought-resistant crops have been developed to maximize "crop per drop" as well as the ability to tolerate higher salinity levels, allowing the use of lower quality water for irrigation.[37] Currently, drought-tolerant crops are being pursued in many arid developing countries where the prospect of irrigation is nonexistent. However, this practice may come to play an important role in agriculture in the Colorado River Basin as water scarcity stresses the arid region.

Future of Water Efficient Strategies

As a sector that utilizes 56-80% of the water in the Colorado River Basin, pressures for agriculture to reduce usage are mounting. Projections for the Colorado River Basin are predicting a notable decrease in irrigated acres in agriculture moving toward 2060. To counter the impeding impact on rural agricultural communities, increased productivity, yields, and water use efficiency may have the potential to lessen the impact of decreasing irrigated acreage. Although the technologies to do so are available, often the costs of implementation are prohibitive. Water efficient strategies fall under two categories: improvements in irrigation and conveyance systems, and improvements in crop management and the crops themselves.

Case Study: Drought-tolerant Crops Around the World

Gebisa Ejeta, Distinguished Professor of Agronomy at Purdue University, received the World Food Prize for his work in developing a drought-resistant and Striga-resistant strain of sorghum. Striga, more commonly known as witchweed, infests the sorghum root system and parasitically removes nutrients from the plant; losses as high as 40% are common in non-resistant sorghum crops. Originally from Ethiopia, Dr. Ejeta understands the horrific devastation that drought and Striga can reap on a region.[38] Ejeta's early work took place in Sudan, researching drought-tolerance in sorghum and developing the first commercial drought-tolerant sorghum to hit markets in Africa. The hybrid, *Hageen Dura-1*, increased yields up to 150% over traditional sorghum cultivars. Today, nearly a million acres of the drought-tolerant sorghum are grown annually in Sudan. Ejeta's work was soon followed by his release of another drought-tolerant hybrid, NAD-1, that was developed for specific growing conditions in Nigeria and produced four to five times the national sorghum average.[39]

Although the Colorado River Basin is not faced with droughts and food shortages anywhere near the level of those experienced in eastern and western Africa, the potential for drought-tolerant hybrids to address concerns over future droughts in the region is great. Future water shortages in the basin states will undoubtedly limit the water available for agricultural growers; however, the use of drought-resistant crops has the ability to offset the expected losses associated with drought.

Source: Mugoya, Charles, and Wandui Masiga, Clet. Striga resistant sorghum due for release soon. in Asareca [database online]. 2012]. Available from http://www.asareca.org/taxonomy/term/4?page=1.

The lowest cost method of conservation is to improve crop management through specific crop selection, rotation, and tillage management. Although the cost of implementation for irrigation-efficient methods can be three to four times that of crop management methods, the results are considerable and programs to fund implementation of improved irrigation systems should remain a priority. Recent farm bills have made significant steps toward increasing funding for programs like EQIP, CRP and CTA, but more is needed.

The problem with incentivizing "agricultural water conservation" is that the increases in water efficiency, under the Law of the River, cannot be transferred to other uses unless the historical crop consumptive use is decreased. Improvements in irrigation systems do not offer the potential to transfer water to other uses. The only exception is the decrease in evaporative losses under the soil with drip irrigation systems. The conserved consumptive use water could, potentially, be transferred to other uses; however, the quantity of water would be relatively minimal. Therefore, the notion of seeking significant water savings in agriculture through irrigation improvements to meet urban demands is largely inaccurate. Drought-tolerant crops, deficit irrigation, and crop management practices such as conservation tillage are the best options for agriculture water conservation. It should be noted that deficit irrigation will result in saved water, but the individual farmers will lose productivity in crop yields as a result. Due to this outcome, the farmer has little incentive to bear the cost of lost productivity and we recommend that the farmer should be compensated for this water saving strategy.

Water Sharing Strategies

Water Sharing Overview

Because water supplies in the Colorado River are projected to continue to decline in the coming years, Colorado River Basin water users must find ways to utilize every drop of this precious resource. As outlined in the BOR Overview section of this *Report Card*, agricultural water demand is predicted to exhibit a prominent decrease by 2035 (**Figure 14**), and in some scenarios, continue to decrease through 2060. The decrease in agricultural demand is almost entirely due to a decrease in irrigated acres.[40] This decrease in irrigated acreage will largely be a result of water rights sales to urban or municipal uses. However, there is another option that would allow more agriculture land to remain in production and mediate the negative effects of buy-and-dry transfers. Agriculture alternative transfer methods are a means through which water can be leased to uses outside agriculture for temporary periods of time, meeting the needs of urban, environmental, and recreational uses, as well as sustaining the production of agricultural goods.

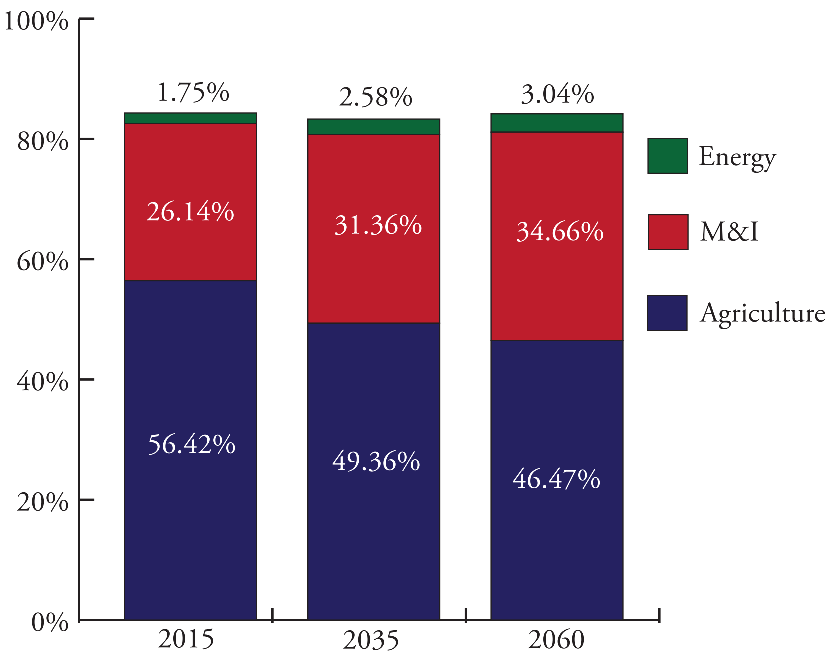
The transfer of water from agriculture to other uses can only occur when the water is part of the historical beneficial consumptive use. The water right holder must first obtain a court decree and prove that the transfer will not increase the water right or cause injury to any downstream or junior user.[41] Under prior appropriation, the "No Injury Rule" recognizes the right of junior users "in the continuation of stream conditions as they existed at the time of their respective appropriations" (*Farmers High Line Canal & Reservoir Co. v. City of Golden*).[42]

The laws governing the circumstances under which water can be transferred to uses outside of agriculture are complex and nuanced. The complexities of water sharing are rooted in a multifaceted interface between stakeholders of diverse backgrounds. However, for productive solutions to be achieved, stakeholders must come together through markets and collaboration, rather than continue to polarize the issue. Each choice carries with it third-party impacts and trade-offs; finding a balance between those choices is vital.

Alternative Agriculture Transfer Methods (ATMs)

Traditional transfers out of agriculture involve what have been coined "buy-and-dry" water transfers due to the drying up of agricultural land as a result of the permanent transfer of water rights. Although traditional buy-and-dry transfers will continue to be important in meeting future water demand, the adverse effects on agricultural rural economies and environmental effects beg for alternatives. To mediate these effects, policymakers are promoting alternative agriculture transfer methods (ATMs). The Colorado Statewide Water Supply Initiative report states, "The goal of the alternative transfer is to minimize the impact on the local economy, provide other funding sources to the agricultural user, and optimize both the agricultural and nonagricultural benefits of the remaining lands."[43]

Figure 14: Bureau of Reclamation Agriculture, Municipal and Energy Demand Projections



Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012).

Interruptible Supply Agreements

Interruptible Supply Agreements (ISAs) involve the temporary, long-term, or permanent transfers of water to uses outside agriculture while on-farm irrigation is temporarily suspended. Current laws in Colorado allow the state engineer to approve up to three temporary ISAs over the course of a 10-year period; however, for long-term ISAs, the water user must obtain court approval.[44] ISAs are often utilized during drought years when farmers predict a low yield or as a means of drought recovery.

Rotational Fallowing

Long-term rotational fallowing programs are a type of interruptible agricultural transfer arrangement comprising several agricultural parties and one or more municipal/industrial, environmental or recreational users.[45]

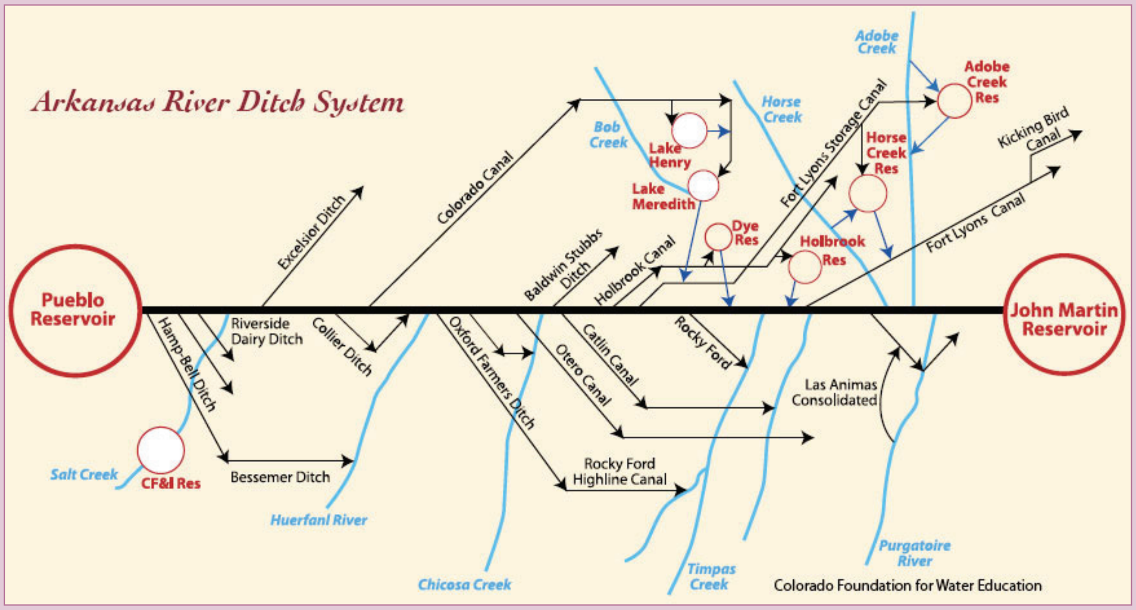
Case Study: The Arkansas Valley Super Ditch

The first example of a rotational fallowing project using Colorado River water started in 2003 between the Imperial Irrigation District and the San Diego County Water Authority. The Imperial Irrigation District is the largest irrigation district in the U.S. and diverts more than three million acre-feet per year of Colorado River water through the All American Canal.[46] The vast majority of diverted water is used to irrigate farmland in the Imperial Valley, which is one of the most productive agricultural regions in the United States. The agreement was negotiated as an alternative to large capital projects - such as the Central Arizona Project and Hoover Dam - that would bring water to urban areas. This was a response to California's limitation in 2003, for the first time, to its annual Colorado River apportionment of 4.4 million acre-feet.[47] Since the program's inception in 2003, more than 500,000 acre-feet have been transferred, with a plan to reallocate nearly 30 million acre-feet over the lifetime of the program.

Municipalities have responded to growing water demand by purchasing water from agricultural interests since the early 20th century. Southern Colorado's lower Arkansas Valley experienced this trend most significantly from 1971-1986, when the rights to 128,000 acre-feet annually were permanently transferred from agricultural to urban uses in eight sales.[48] Each of these sales was met with criticism from the local newspapers and Arkansas Valley citizens became increasingly concerned that the permanent removal of water from agricultural use would lead to degradation of both the quality of community life and economic vitality of the region.[49] In response to these concerns, citizens in five counties- Bent, Crowley, Otero, Prowers, and Pueblo- joined forces to form the Lower Arkansas Valley Water Conservancy District in 2002. This entity represents the interests of the five counties and eight mutual irrigation ditch companies. The Lower Arkansas Valley Water Conservancy District went on to form the "Super Ditch," which is not actually an irrigation ditch, but rather a collective bargaining agent for irrigators to negotiate a rotational fallowing agreement with nearby municipalities.

On May 2, 2012, after six years of planning and negotiation, the Colorado state engineer approved a pilot program for the Super Ditch to transfer 250 acre-feet annually to Fountain Public Utilities.[50] The Super Ditch is the only example of a rotational fallowing agreement being approved in our six-state region of interest. While it is not within the Colorado River Basin, it operates within the same legal and political structure as the regions of Colorado in the Colorado River Basin and thus can provide guidance for future in-basin projects. It is a unique example of collaboration and cooperation between agricultural and municipal interest groups.

Though promising, it is not a one-size-fits-all solution, nor do alternative transfer methods more generally serve as the only answer to the current and future conflicts over water in the Rockies region. Careful planning and cooperation are essential for programs like these to succeed; so too are studies that examine the actual impacts of implementation. Additionally, the fact that this program took six years to overcome legal and administrative barriers is disheartening; another legal complexity is that the Colorado state engineer's authority to allow such a program is being challenged in water court. A water friendly future for rotational fallowing programs and others yet to develop water sharing programs hinges on an expeditious authority granting process. The resolution of the legal disputes of the Super Ditch, it is hoped, will provide just that.



Case Study: Arizona Water Banking Authority: Banking Water Now for Arizona's Future

The Arizona Water Banking Authority (AWBA) was established in 1996 to utilize the state's full apportionment under the Colorado River Compact of 1922. The Compact allocates 2.8 million acre-feet (maf) of Colorado River water to Arizona, which the state has yet to fully utilize. Prior to the establishment of the AWBA, the portion of the 2.8 maf that was left unused remained in the river for downstream use by southern California. The ABWA allows for long-term storage of Colorado River water in existing underground aquifers or is used by irrigation districts in place of groundwater pumping. The program ensures long-term stability to Arizona's water supply and ensures supply during times of shortages or disruptions to the Central Arizona Project (CAP). In addition, the program seeks to assist in the settlement of Native American Indian water rights claims, exchange water with Colorado River communities, and meet the objectives of the Arizona Groundwater Code.[51]

In addition to meeting long-term supply needs, the AWBA is authorized to act on behalf of the state of Arizona in establishing interstate water agreements. In 2005, the AWBA entered into agreements with California and Nevada to store unused water in Arizona aquifers. Currently, Nevada and California pay to store their unused water in Arizona aquifers and in future years will be allowed to withdraw a comparable amount of water directly from the Colorado River. The AWBA is one of the largest and most successful water banking projects in the basin and serves as an example of the needed collaboration and cooperation among basin states that will become paramount in the coming years.

Arizona Water Banking Authority Agua Fria Basin

Source: Agua Fria, Arizona Water Banking Authority, accessed July 10, 2012, http://www.azwaterbank.gov/Photos/Aqua_Fria.htm.

Water Banks

Water banks are an institutional approach to water sharing, allowing free market forces to determine the course of water in the West. The banks serve as a legal mechanism for users who decide to forego their water use during a given year and lease those rights to water users who need it most.[52] Water users can voluntarily lease their water to water banks, which then act as a clearing house and temporarily lease water to other users without disrupting the water rights of the original holder.

Currently in Colorado, the Colorado Water Conservation Board is working with an assortment of agencies across the Front Range and Western Slope to determine the potential of the development of a Colorado water bank.[53] Faced with the potential for a Colorado River Compact curtailment, water banks offer a way to harness the incentives of free market forces to meet water needs across the Colorado River Basin.

Purchase and Lease-back

Purchase and lease-back programs are the most commonly used alternative transfer method in Colorado. Purchase and lease-back programs are a more permanent variation on ISAs and typically range from five to ten years. These agreements involve the purchase of water rights by M&I users with the option of leasing the water back to the agricultural irrigator under specified circumstances.[54]

Barriers to Implementation of ATMs

There are several factors that continue to plague the implementation of water sharing programs. Due to the temporary nature of ATMs, concern on behalf of municipalities regarding long-term supply and dependability of that supply acts as a hindrance to many programs. Certainly, ATMs must work within an overall municipal supply portfolio, but the degree and scope of those programs remain in question.

Perhaps the most serious barriers to implementation of ATMs are high transaction costs. Legal and engineering expenses quickly accumulate during negotiations of transfers and court fees plague the process. However, many of the expenditures are a requirement under the "No Harm Rule" to ensure that injury will not be caused by the transfer of water rights.[55] The court and legal processes required to acquire approval for transfers result in a time-intensive process, which has the potential to kill many projects before they can obtain approval. Other administrative issues also exist, such as state engineer approval to ensure that there are no expansion of water rights and increased transaction costs.

In addressing current barriers to effective agriculture-to-urban transfers, there is a general need for a more efficient water transfer process. If water users and policymakers could develop a more streamlined process, the potential for water transfers to play a larger role in municipal water supply portfolios would greatly increase. ATMs will not be the only means of meeting municipal demands in the coming years, but they will play an important and needed role. Partnerships between agricultural and municipal stakeholders will continue to be essential for the success of these programs.

Conclusion

In this section we have presented a brief list of water efficient irrigation strategies and water sharing programs; by no means is the list exhaustive. Although current technologies and strategies have been implemented in situations where the cost is non-prohibitive, the need for thoughtful and innovative solutions will continue in the coming years. It is important to remember the necessary, but insufficient, nature of the aforementioned strategies and programs. Whether or not the Law of the River can be used as a flexible doctrine may be the most important factor for widespread use of water efficient irrigation and water sharing. With this in mind, we have three recommendations that must be met in order to secure a water friendly future for agriculture in the Colorado River Basin:

1. *Transcend misconceptions of water use in agriculture.*
   One of the most common misconceptions of water use in agriculture is the idea that more efficient irrigation strategies can lead to farmers saving water and freeing it up for other users. Decreases in crop consumptive use generally do not result from improvements in irrigation technology. Another misconception is the notion that water right transfers only affect the buyer and the seller. Farm laborers, harvesters, suppliers, chemical providers, and equipment operators all stand to lose business or jobs when farmland is taken out of production, whether permanently or for a specified number of years.[56]

2. *Seek cooperation and collaboration among stakeholders.*
   Water disputes are often termed "fights" or "battles" over uses of water in the West. This rhetoric reflects the attitudes on both sides of the water issue, many of whom have been embittered by years of conflict and historical mistrust. Polarization of these issues has led to lengthy adjudication processes and counterproductive disputes. Instances of cooperation of habitually disparate groups to meet growing water needs have occurred on several occasions. The rotational fallowing agreement between Imperial Irrigation District and the San Diego County Water Authority that started in 2003[57] and the Agricultural/Urban/Environmental Water Sharing Work Group facilitated by the Colorado Water Institute in 2010[58] are exemplary examples of collaboration in the Colorado River Basin that should be replicated in the future.

3. *Make conscientious decisions, keeping in mind the needs of all stakeholders throughout the basin.*
   The Colorado River is a resource that will be stretched to its greatest limits in the coming decades. Population projections following current trends suggest that by 2060 more than 62 million people, twice the current number, will come to depend on the Colorado River. Agricultural stakeholders must take into account the growing needs of other sectors in the region, just as those sectors must understand the importance of continued agricultural production in the region. The Colorado River is the lifeblood of an arid region. Its inhabitants' adaption over thousands of years to changing conditions reflects its importance and offers hope that future inhabitants can respect the river's constraints. We recommend that the people of the basin follow suit in a serious and concerted way.

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Will Stauffer-Norris

The Down the Colorado Expedition paddling near agricultural diversions in Colorado's Grand Valley.