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Agricultural Producer Decision Making around Water Conservation in the Upper Colorado River Basin

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Water conservation is a pressing issue, especially in the Colorado River Basin, and agricultural water conservation programs (AWCPs) have been proposed as part of the policy response. If implemented, these programs would seek to achieve voluntary and temporary reductions in the amount of Colorado River water consumed by irrigated crops. By participating in AWCPs, producers would receive compensation for conserved consumptive use (CU) (i.e., a reduction in crop water use compared to a historical baseline), which would be stored in downstream reservoirs for other users. The producers would be compensated based on the amount of water conserved, the location, and the practice implemented. This compensation would enable them to receive financial benefits while contributing to preserving the Colorado River Basin. The reallocation of water to AWCPs would not risk abandonment of water rights if the conserved CU is temporarily enrolled in a state or federally approved program.

In this article, we examine the potential for AWCPs to conserve water in the Colorado River Basin from the decision-making perspective of agricultural producers in the Upper Basin states of Colorado, New Mexico, Utah, and Wyoming. Specifically, we consider the technical versus the economic potential of AWCPs, characterize agriculture in the Upper Basin, and discuss three candidate practices: fallowing, deficit irrigation, and crop switching. We then review factors influencing willingness to participate based on recent experience with the System Conservation Pilot Program (SCPP). Currently, no overarching AWCP coordinated by the Upper Basin states exists. However, they are exploring its feasibility to help meet their obligations to Lower Basin states under the Colorado River Compact. Although AWCPs exist in other regions outside the Colorado River, they have many differing designs. Therefore, understanding the Upper Basin context, producer decision making, and implications for future policy is essential.

Upper Basin Context

The Colorado River is divided into Upper and Lower Basins. The 1922 Colorado River Compact requires Upper Basin states not to deplete river flows to the Lower Basin below a threshold of 75 million acre-feet (MAF) over 10 years. This compact obligation has always been met, but Upper Basin states are investigating a demand management (DM) program that would allow them to store water that could be released during future droughts to reduce the risk of mandatory future curtailment (CRCB, 2021). The program would compensate participants in affected sectors (municipal, industrial, agriculture, etc.) who voluntarily implement temporary measures to reduce CU. It would also represent a more measured and planned response to water shortages than the improvised water transfers that might arise when a curtailment is called. The conserved CU would be held in a downstream reservoir through a storage agreement that was approved in 2019. A DM program, if approved, may include an AWCP as a subcomponent specifically related to river depletions from irrigated agriculture. Other DM subcomponents would focus on other sectors (municipal, industrial, etc.) and are beyond the scope of this study.

Water scarcity in the river system is partly driven by a prolonged drought and shrinking snowpack. Low water threatens agricultural, municipal, and industrial water deliveries, hydropower generation, recreation and habitat, and river ecology. Producers in the Upper Basin, primarily farmers and ranchers, own and manage a large share of the water rights (Richter et al., 2024). They put this water to beneficial use by producing food, feed, fiber, energy, and other products. One approach to meeting gaps in basin-wide water supply and demand in the past was permanent water transfers away from agriculture. However, preserving some irrigated agriculture is recognized as important because of its role in farm viability and local economies. The loss of irrigated land can impact rural communities by decreasing land values, diminishing economic activity, degrading amenities, and disrupting a sense of place (Holm, 2022).

Producers in the Upper Basin often pursue multiple objectives, but maintaining a profitable farm or ranch business is a top priority. They also aim to achieve secondary objectives, such as quality of life, environmental stewardship, and risk management. However, ensuring profitability, solvency, and liquidity is crucial for their long-term survival. The cropping systems, production technologies, and management practices they choose reflect how they seek to achieve these objectives. While many producers want to contribute to water conservation efforts, they may be limited by technical, financial, and other factors. Understanding this perspective helps differentiate the technical and economic potential of AWCPs as distinct concepts.

Technical and Economic Potential of AWCPs

Technical Potential

Technical potential refers to the maximum reduction in river depletions that can be achieved through agricultural practices for conserved CU, given the physical (climate, topography, etc.) and legal (beneficial use, return flows, etc.) constraints governing irrigation practices. It provides a theoretical upper bound on how much AWCPs could contribute to balancing future water supply and demand. For example, from 2016 to 2018, the Colorado River provided water to an average of 1.53 million acres of irrigated land in the Upper Basin each year (U.S. Bureau of Reclamation, 2022). Some water is also exported to irrigated lands outside the Upper Basin. Recent estimates put the total annual crop CU on these combined irrigated lands at 3.1 MAF. By comparison, the projected long-term water imbalance in both basins is 3.2 MAF per year by 2060 (U.S. Bureau of Reclamation, 2012). The goal of an Upper Basin AWCP would not be to solve this long-term imbalance. However, the comparison demonstrates that an AWCP alone is insufficient to address overall water scarcity issues.

At the field level, the maximum technical reduction in CU corresponds to the amount of water crops consume, not the amount diverted from the river nor the amount applied as irrigation. Reduced diversions or irrigation at one location makes more water available to downstream users but may not reduce total river depletions. A fraction of the water applied eventually returns to the river through deep percolation or runoff and becomes available to downstream users, potentially resulting in the same total crop CU. Distinguishing between field-level practices that improve efficiency (fraction of water consumed by the crop rather than lost to percolation or runoff) and those that conserve CU is essential. To conserve CU at the field level, one of the following criteria must hold: reduce irrigated area (e.g., fallowing), reduce actual crop water use to below potential crop water use (e.g., deficit irrigation), reduce potential crop water use (e.g., crop switching), or reduce evaporation from the soil surface (e.g., drip irrigation, conservation tillage) (DiNatale et al., 2011). Improving efficiency alone may not conserve crop CU. Technologies and practices that improve efficiency can also improve water distribution within a field such that, for instance, previously under-irrigated areas see an increase in CU. Practices that increase efficiency but do not necessarily conserve CU include conversion from flood to sprinkler irrigation, land leveling, furrow diking, contour farming, and reduced tillage.

Economic Potential

The economic potential of AWCPs is the maximum reduction in river depletions from conserved crop CU that can be achieved while accounting for constraints on profitability and financial feasibility. Profitability is important for ensuring the financial sustainability of farms and ranches and building equity. It implies that compensation for conserved CU should offset increases in operating expenses, decreases in production, and other risks and opportunity costs associated with AWCP participation. The economic potential is less than the technical potential but more accurately reflects the actual conserved CU that can be practically achieved.

The economic potential can be described by the share of the technical potential that is achievable at a given level of compensation for conserved CU. Breakeven conditions can help assess the economic potential. They explain the combination of compensation for conserved CU and changes in crop or management practices that make participation profitable. In most cases, they can be found using partial budgeting. Lower breakeven values imply that a given practice is profitable for more producers, profitable on a larger share of irrigated area for a given producer, or some combination. Setting compensation at appropriate amounts will ensure participation is financially feasible, which is a necessary but not sufficient condition for participation.

The simple breakeven is appropriate for practices that modify an existing crop enterprise (e.g., deficit irrigation). It is met when compensation for conserved CU is equal to the increase in direct costs associated with implementing the practice plus the expected forgone revenue from decreased production (Cabot et al., 2022). Comparative breakevens are useful when changing enterprises (e.g., crop switching) (Mooney and Kelly, 2023). They are met when compensation for conserved CU just equals the difference in expected net returns between cropping options. Breakevens can also account for risk effects, like increased yield or price variability, using methods that account for risk preferences (e.g., stochastic budgeting, stochastic dominance) (Mooney et al., 2022). Calculating breakevens for producers who depend on forage as a feed input will be more complex than for crop producers who do not manage a livestock enterprise.

Table 1. Crop Mix in the Upper Colorado River Basin, 2018

Category	Farms[a]	Acres	% of Total Irrigated Acres
Pasture, irrigated	6,703	570,461	38.7%
Hay, alfalfa (alfalfa hay, other alfalfa mixtures)	7,082	430,590	29.2%
Hay, other	3,185	364,806	24.8%
Corn (grain, seed, sweet)	261	37,840	2.6%
Sorghum & small grains	206	15,145	1.0%
Orchards	783	3,726	0.3%
Nursery	294	3,230	0.2%
All other crops[b]	916	46,522	3.2%
Total	13,125	1,472,320	

Source: Adapted from the USDA Farm and Ranch Irrigation Survey (USDA, 2019a)
[a] Some farms grow crops from more than one category.
[b] Includes wheat, beans, vegetables, tomatoes, lettuce, potatoes, berries, and all other crops not specified.

Agriculture in the Upper Basin

Agriculture in the Upper Basin is shaped by climate, agronomy, and economic factors (Pritchett, 2011). The region has a short growing season due to higher elevations and colder temperatures, which limits irrigated production to summer months. As of 2018, the Upper Basin had 1.47 million acres of irrigated land, which included diversions off the Colorado River, its tributaries, and, to a smaller extent, groundwater (USDA, 2019a). Grass pasture accounted for 39% of this land area, alfalfa and alfalfa mixtures for 29%, and other hay for 25% of the irrigated crop mix in 2018 (Table 1). Together, these forages covered over 90% of the irrigated area and accounted for most crop water use. Irrigated farms and ranches totaled over 13,000 operations in 2018 (USDA, 2019b). Those operations were diversified, with over 75% receiving income from nonirrigated crops or livestock in addition to irrigated crops.

Forage crops are a primary focus of conservation efforts, but only partly due to their physical abundance. Agronomic attributes also make them attractive for conserving CU (Udall and Peterson, 2017a). Alfalfa is a perennial legume that can be harvested or grazed several times per year. It and other hay crops are relatively easy to grow, drought tolerant, and require few external inputs. Some varieties go dormant when irrigation is removed, making them good candidates for limited irrigation. Grasses also go dormant but have shallower roots and cannot access deep soil moisture. Less data on the conserved CU potential of grass pastures for grazing are available compared to alfalfa, but research is ongoing (Cabot et al., 2022).

Despite this technical potential, not all land will be available to AWCPs for economic reasons. Livestock enterprises (cattle, equine, sheep, goat, dairy) represent the main agricultural economic activity in the Upper Basin and irrigated lands provide feed inputs. Census estimates put the Upper Basin inventory at over 1 million head (USDA, 2019b). Livestock producers in AWCPs would face reduced forage production and need to increase supply (rent new pasture, purchase hay, etc.), decrease demand (wean early, retain fewer yearlings, reduce herd size), or some combination. Nevertheless, opportunities for livestock producers to feasibly participate in AWCPs can arise. For example, participation could be tied to replacement cycles for livestock when forage demands are less. Labor availability, cattle prices, or strategic goals may change, causing some to exit livestock production. In this case, they could sell forage to livestock producers. Prospective participants may also face hay price, cattle price, and interest rate variability, and incorporating a risk premium when quantifying participation costs is important.

Elevation also plays a key role in Upper Basin agriculture (Table 2). Irrigated forage at higher elevations is unlikely to change because it is relatively well suited to the aridity, wind, short growing seasons, and dramatic temperature changes that characterize the region. Grain and high-value crops like vegetables and orchards do not grow well at higher elevations but represent a larger share of irrigated land at lower elevations.

Agricultural Practices for Conserved Consumptive Use

Producers will consider multiple factors when selecting practices for conserved CU. However, the amount of conserved CU attributed to a practice is key because it determines the compensation payable to them and the amount of water made available to others.

Fallowing

Fallowing is the practice of leaving land unplanted and terminating irrigation for the entire growing season. This technique has been widely studied within the Colorado

Table 2. Consumptive Use in the Upper Colorado River Basin by Crop Type and Elevation (acre-feet per year), 2018

	Elevation Band (feet above sea level)							
Crop	Under 5,000	5,001 -6,000	6,001 -7,000	7,001 -8,000	8,001 -9,000	9,001- 10,000	Above 10,000	Total
Grass pasture	54,639	217,508	400,738	249,087	133,525	13,905	359	1,069,761
Alfalfa	55,269	48,119	66,177	8,550	634			178,749
Corn grain	15,694	23,232	540	7				39,473
Other grain	7,207	15,723	8,335	1,795	769			33,829
Orchards	5,235	4,683	1,798	7				11,723
Dry beans	223	6,517	4,863	58				11,661
Other crops	2,572	1,373	1,737	1,676	1,233	507		9,098
Vegetables	1,172	300						1,472
Total	142,011	317,455	484,188	261,180	136,161	14,412	359	1,355,766

[a]The consumptive use estimates shown reflect the supply-limited values in the report.

Source: Adapted from the Colorado River Water Bank Water Supply study (Colorado River District, 2012).

River Basin (Udall and Peterson, 2017b). Options for perennial crops are limited, but it may be possible after terminating alfalfa, for example, and before planting the subsequent crop. Eliminating all vegetative growth conserves the most CU; however, fallow also entails additional management actions. Producers must control weeds, dust, salinity, and soil erosion, typically at their own cost. Terminating irrigation on upper-elevation hay meadows is possible, but conserved CU will be lower than other crops because some plant growth still occurs and yield impacts in subsequent years are unknown, creating uncertainty (Hansen et al., 2021).

Fallowing is more easily incorporated into annual cropping systems, where planting occurs yearly. Compensation for conserved CU from incorporating fallow into a rotation spread over multiple fields could provide a steady alternative revenue stream. Fallowing is easy to verify but estimating conserved CU is more complex. Assumptions need to be made about the CU that would have occurred, had the field not been fallowed. One approach is to use a fixed per acre CU savings relative to a reference crop appropriate to the region. Another is to measure historical crop CU on the fallowed field as a baseline for conserved CU calculations.

Deficit Irrigation

Deficit irrigation is the practice of applying less irrigation water than necessary to meet crop water needs. Typically, standard irrigation schedules aim to satisfy a field’s full evapotranspiration potential, but planned deficit irrigation intentionally induces water stress. It can be pursued with any crop but is well suited to alfalfa because of its dormancy. Regulated deficit irrigation applies less water than needed during plant growth stages that are more tolerant to water stress. This strategy is better suited to annual crops like corn and small grains than vegetable crops, where yield and quality are more sensitive to water stress. Orchard crops can also be sensitive to water stress, or producers already intentionally limit irrigation at some stages to improve quality and are unlikely to yield significant additional conserved CU.

Split-season irrigation involves completely stopping irrigation for part of the year. In an AWCP, irrigation diversions could occur as normal early on—for example, during the first two cuts of alfalfa—and then cease entirely, allowing more water to remain in the river. Deficit irrigation would provide less compensation on a per area basis because, unlike fallow, some crop CU still occurs. Applying less water than needed, however, results in lower average crop yields and higher expected yield variability. A risk premium on top of the comparative breakeven value is likely needed to ensure economic feasibility of deficit irrigation practices.

Crop Switching

Crop switching is the practice of replacing a high CU crop with one with lower potential water consumption. At high elevations, differences in CU between forge crops are often small, decreasing crop-switching advantages (Udall and Peterson, 2017c). More opportunities arise at lower elevations where annual crops are more common. The conserved CU potential of early-maturing crops (e.g., winter peas) are being explored. In this case, the CU of the new crop needs to be compared to a historical baseline to determine the level of conserved CU. Promoting new crops, however, could require the development of supporting market channels and infrastructure. Shifts in production could impact market prices for crops or inputs, including labor. Declines in forage production could lead to rising prices, encourage more production, and increase the compensation needed to induce AWCP participation.

Table 3. System Conservation Pilot Program (SCPP) Project Summary

Year	Applications	Implemented	Estimated CCU (acre-feet)	Total Cost ($)
Round 1 (2015–2018)				
2015	15	10	3,227	$0.89 million
2016	32	20	7,475	$1.49 million
2017	46	15	11,408	$2.17 million
2018	30	19	25,097	$3.97 million
Round 2 (2023–present)				
2023	123	64	37,800	$15.80 million
2024	Program currently underway			

Source: Adapted from UCRC (2018) and U.S. Bureau of Reclamation (2023).

System Conservation Pilot Program (SCPP)

Currently, no DM program exists in the Upper Basin, but the feasibility is being investigated. Ongoing pilot projects are helping inform this process. The System Conservation Pilot Program (SCPP) explores producer implementation of agricultural practices for conserved CU. It is jointly implemented by the Upper Basin states through the Upper Colorado River Commission. The SCPP monitors implementation, measures potential conserved CU, and compensates participants. Potential conserved crop CU is the difference between a historical CU at the field level and actual crop CU in the year of participation. In 2023, historical CU was based on remotely sensed data for a field minus effective precipitation.

The SCPP completed two rounds of pilot projects. From 2015 to 2018, the first round consisted of 64 projects completed across Upper Basin states (Table 3) (UCRC, 2018). They included full-season fallow (16 projects), split-season deficit irrigation (34 projects), combined crop switching and deficit irrigation (6 projects), combined full-season fallow and split-season deficit irrigation (6 projects), and municipal conservation (2 projects). Together, they produced 47,207 acre-feet in potential conserved CU at a cost of $8.05 million. Producers made offers to participate based on their implementation costs. Actual payments ranged from $79 to 330 per acre-foot of conserved CU.

The second round began in 2023 and funded an additional 64 on-farm projects for $15.8 million with a potential water savings of 37,800 acre-feet (Table 3) (U.S. Bureau of Reclamation, 2023). The total potential conserved CU was equivalent to 80% of the total conserved CU achieved throughout all 4 years of the first round but at a higher total and per acre-foot cost for conserved CU, even if inflation were to be taken into account.

Insights from the SCPP on Willingness to Participate

The SCPP experience offers valuable insight into Upper Basin producer willingness to participate in AWCPs. One original intention of the SCPP was to determine whether Upper Basin water users would be willing to forgo water use in exchange for payment at any price; the answer was a resounding yes. Lessons learned in the 2023 SCPP (and incorporated into the 2024 SCPP) were an earlier application date (to better align with farm enterprise planning), more transparent pricing (compensation changed to a fixed schedule based on state and practice type, see Table 4), more stakeholder outreach, and a preference for projects incorporating drought resiliency. One lesson learned (and reflected in the high prices in Table 4) is that the opportunity costs of forgone water use are higher than had been anticipated by many in the region, largely due to producer concerns regarding yield impacts and risks to the livestock enterprise associated with reduced hay production.

Findings from the literature reinforce these insights from the SCPP. According to technology adoption and diffusion principles, producer decisions are also influenced by social factors such as relative benefits, compatibility with current practices, and learnability (Pannell et al., 2006). These social factors can be significant. Therefore, even when conditions for technical and economic feasibility are met, producer willingness to participate in AWCPs is expected to vary geographically and temporally. A stakeholder engagement process conducted in the Upper Basin (and whose participants included SCPP participants) broadly supports this notion, particularly highlighting how the significant heterogeneity in operational characteristics and irrigation rights across producers affects willingness to participate (Paige, Hansen, and MacKinnon, 2021). Greater engagement could be expected from those with the land base, financial capital, and managerial capacity to manage the yield and livestock feed effects of reduced CU and increased risk. Hay farmers without livestock, absentee landowners, and nonoperator owners may be more likely to participate because they will be less concerned about potential spillover costs and risks to

Table 4. SCPP Payments for Potential Conserved Consumptive Use, 2024

State	Compensation ($ per acre-foot conserved CU)[a]
Colorado	$509
New Mexico	$300
Utah	$506
Wyoming	$492

[a]Permitted practices for conserved CU in the 2024 SCPP are full season fallow, split season irrigation, and crop switching.
Source: Adapted from UCRC (2024).

their livestock enterprise. Larger operators or operators with off-farm income may also be able to better withstand the increased risks associated with participation.

Raising awareness and providing education on AWCPs and associated compensation are essential for facilitating participation and ensuring that voluntary AWCPs contribute to equitable conservation of CU in the river system (Paige, Hansen, and MacKinnon, 2021; Bennett et al., 2023). Intermediating organizations and information pathways also appear important to producers' voluntary participation decisions. AWCPs offer a unique potential for experimentation and collaboration. Providing Upper Basin producers with information through trusted sources is important (Hansen et al., 2021a,b; Bennett et al., 2023). Most 2015–2018 SCPP projects were facilitated by local nongovernmental organizations (NGOs) that were familiar to and trusted by participants (UCRC, 2018). Identifying practices that are commercially viable in addition to policy appropriate will also improve reception (Mooney et al., 2023). It is also essential to include input from producer organizations, irrigation organizations, and civic groups that support producers and are critical to their ability to participate (Colorado River District, 2021). Risk management tools like insurance for new crops, limited irrigation, or long-term contracts could be available alongside AWCPs.

Summary and Conclusions

Water scarcity in the Colorado River system will continue to be of national importance. AWCPs that compensate producers to voluntarily conserve CU are one policy option being considered to manage this considerable challenge. What takeaways from this article can help inform future policy? Producer willingness to participate will be influenced by technical, economic, and social factors. The technical and economic potential to conserve CU in the Upper Basin for storage in downstream reservoirs exists, but the savings achieved will depend on the compensation offered, general economic conditions, and producer interest. A primary focus of water conservation efforts will be on irrigated alfalfa, other grass hay, and pasture. Practices for conserved CU will include temporary fallowing, deficit irrigation, and crop switching.

Compensation for conserved CU should provide expected benefits that exceed the value of forgone returns and compensate for risk and other considerations that could hinder feasibility. Diffusion patterns for the candidate practices will likely mirror other agricultural conservation practices, with some early innovators eager to experiment with new options and others content to wait and learn about the technical and economic feasibility before committing. Future studies could further explore the role of intermediating institutions like irrigation organizations in producer participation decisions and evaluate the feasibility and cost-effectiveness of alternative accounting and verification programs to measure and track conserved CU.

Overall, AWCPs could be useful in narrowing short-term gaps in water supply and demand in the Colorado River Basin by allowing a portion of agricultural CU to be temporarily sent downstream to other users. However, they will be ineffective at addressing deeper issues that increase expected future gaps in supply and demand. Fixing these issues will require a breadth of long-term measures that slow or limit growth in water demand across sectors. Finally, economics is about the allocation of scarce resources. The considerations provided here can help policy makers weigh the private and public merits of AWCPs relative to alternative options like municipal and industrial conservation or supply augmentation.

For More Information

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