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How Agricultural Water Conservation Can Save the Great Salt Lake

Man Li and Asif Ahmed Khan

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Water is essential for meeting basic human needs and sustaining healthy ecosystems. The demand for water is rising due to rapid population growth, urbanization, and increasing use in agriculture, industry, and energy sectors. Even with advancements in water-use efficiency, water stress and scarcity remain critical issues worldwide, including in Utah. This article highlights a recent study assessing the economic feasibility of protecting Utah's shrinking Great Salt Lake (GSL) by incentivizing agricultural water conservation. The study demonstrates that an annual water conservation goal of 471 thousand acre-feet (KAF) can be met by fallowing irrigated alfalfa fields, with unit water-saving costs ranging between $688 and $806 per acre-foot (AF) (Li and Khan, 2024a). These costs are comparable to the lowest-tier residential water rates in many Utah cities. This research could support agricultural water conservation decisions, and the methodology is transferable to other regions seeking to preserve land-based natural resources.

Why Is Water Important to Utah?

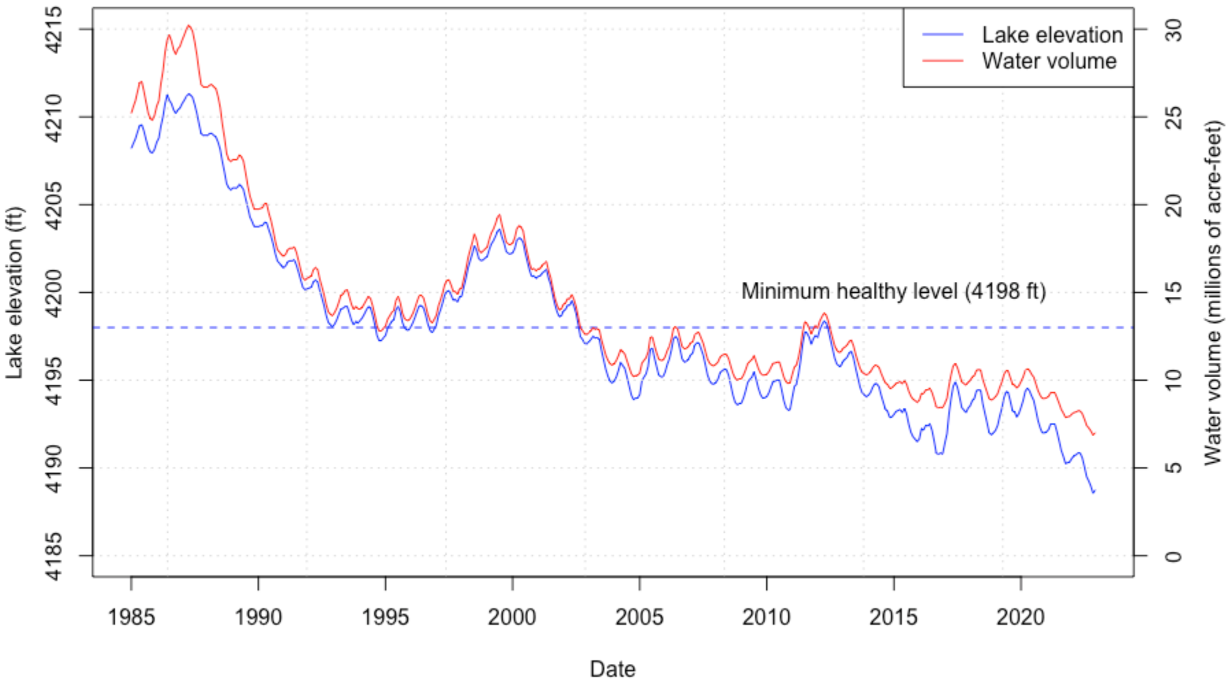
Located in the semiarid and desert climate zone of the western United States, Utah has consistently faced droughts and water scarcity. Ensuring an adequate water supply to meet demand has been a persistent challenge for the legislature, government agencies, and stakeholders in the state. The state's steadily growing population adds to the challenge. Over the past decade, Utah's population has grown at nearly 3 times as fast as the national average, making it the one of the fastest-growing states in the country (U.S. Census Bureau, 2019). The increasing use of water by humans, especially for agriculture, has led to a significant reduction in the amount of water flowing into the GSL.

Known as "America's Dead Sea," the GSL is the largest saline lake in North American. The GSL has shrunk by about 50% since pioneers settled the Wasatch Front (Null and Wurtsbaugh, 2020). This trend has been significantly accelerated since the late 1980s (Figure 1), due primarily to human extraction of water from the lake's three major tributaries (Wurtsbaugh et al., 2017; Null and Wurtsbaugh, 2020; Brooks et al., 2021). While the elevation of the GSL fluctuates in response to changes in precipitation, these natural events do not have a lasting effect on lake elevation (Null and Wurtsbaugh, 2020). Instead, consumptive water use in the three tributary watersheds has been the primary driver of the lake elevation decline, lowering it by approximately 11 feet between 1847 and 2016 (Wurtsbaugh et al., 2017). Notably, of the state's total consumptive water use of 1.46 million AF in 2016, 63% went to irrigated agriculture, 13% to salt pond mineral production, and 11% to urban and industrial use (Wurtsbaugh et al., 2017).

What Would Be the Consequences of Losing the Great Salt Lake?

Similar to the disappearance of many other saline lakes worldwide, the drying up of the GSL could trigger severe, irreversible environmental and economic losses (Wurtsbaugh et al., 2017; Wang et al., 2018). The GSL has enormous economic and ecological value, supporting tourism and the ski industry through the lake-effect snow; the mineral industry by producing salt, magnesium, and lithium; and the aquatic industry by providing brine shrimp eggs (Abbott et al., 2023; State of Utah, n.d.). Additionally, it serves as a vital habitat for millions of migratory shorebirds, including endangered species. It is estimated that the GSL directly contributes $1.9 billion annual to Utah's economy and provides over 7,700 jobs, with an additional $1.2 billion and another 20,000 jobs from the ski industry (State of Utah, n.d.). More important, airborne sediments from the dried lakebed contain heavy metals, making dust from the drying GSL an increasing threat to public health. These issues have become a matter of public concern statewide and urgent action is needed to prevent the disappearance of the lake.

Figure 1. Monthly Elevation and Volume of the Great Salt Lake, 1985–2022



Note: The elevation is the average of the north arm elevation and the south arm elevation.
Source: Tarboton (2024).

What Actions Have Been Taken So Far?

In October 2022, the GSL dropped to 4,189 feet in elevation, the lowest level ever recorded, making 2022 a milestone year for legislation to protect and preserve the GSL (Tarboton, 2024). Since 2022, the Utah Legislature has enacted a record number of bills to promote water conservation from multiple perspectives. These bills appropriate more funding for agricultural optimization and landscape conversion (HB410, HB381, SB277, and SB118), with a total of nearly $1 billion. The bills also update Utah water laws to ensure that sending water to the GSL is considered a beneficial use (HB33 and SB18), establish government agencies and encourage nonprofit partnerships to coordinate water conservation efforts (HB491 and HB307), require water suppliers to meet water conservation goals or municipal and county agencies to establish water preservation plans (SB89 and SB110), and enhance monitoring of secondary water use (HB242 and SB125).

Additionally, researchers from Utah State University and the University of Utah—in collaboration with the state leaders from the Utah Department of Natural Resources and the Utah Department of Agriculture and Food and experts from other entities—have formed a GSL Strike Team to provide timely, relevant, and high-quality data and research to inform decision to protect and preserve the GSL (https://gardner.utah.edu/great-salt-lake-strike-team/).

How Much Water Needs to Be Saved Each Year?

According to recent data analysis by the GSL Strike Team, the lake elevation must increase to 4,198 feet to return a healthy level; to reach that level, additional annual inflows are projected to increase by 471 KAF over 30 years under an aggressive conservation scenario, 705 KAF over 10 years under a highly aggressive scenario, or 1,164 KAF over 5 years under an extremely aggressive conservation scenario (Great Salt Lake Strike Team, 2024). These inflows are calculated based on an assumed initial lake elevation of 4,191 feet, which represents the record-low average elevation for 2022.

The Strike Team proposed a variety of policy options to increase water deliveries to the GSL in their 2023 report, including commitments to conserve water to the lake, optimizing agricultural water use, optimizing municipal and industrial water pricing, limiting municipal and industrial water consumption growth, water banking and leasing, active forest management at the GSL headwaters, optimizing mineral mining in the GSL, diverting water from the Pacific Ocean (or other sources) to the lake, and increasing winter precipitation through artificial cloud seeding (Great Salt Lake Strike Team, 2023). Among these policy tools, water conservation in agriculture is promising not only because it balances economic trade-offs well while considering policy feasibility but also because natural and human consumptive use accounts for 67%–73% of the lake's historical low water level, and a majority of the state's consumptive water is used for agriculture (Great Salt Lake Strike Team, 2023).

What Is the Major Challenge to Conserve Irrigation Water?

In well-functioning markets, shortages are usually addressed by raising prices, thereby encouraging conservation and providing extra supply. However, water prices rarely reflect the true value of water, which is considered essential for fundamental human needs (Tsur et al., 2004). For instance, surface water prices are too low due to the use of historic average costs to set rates and the exclusion of marginal water scarcity rent. Additionally, water allocation in the western United States follows the appropriative rights doctrine, which assigns water-use rights based on the historic order of request (Li, Xu, and Rosegrant, 2017; Li, Xu, and Zhu, 2019). In agriculture, conserved water is not always retained by the irrigator who conserved it (Grafton et al., 2012). As a result, agricultural irrigators have little incentive to conserve water when they do not perceive direct monetary benefits from their conservation efforts (Edwards et al., 2017). This situation calls for incentive-driven policies to encourage effective water conservation in the agricultural sector.

To develop efficient conservation policies, regulators must collect sufficient information to prioritize conservation areas and design effective payment contracts. This is crucial because fixed-price contracts have been criticized for being economically inefficient when regulators lack comprehensive information about landowner payoffs (Cason and Gangadharan, 2004; Schillizzi and Latacz-Lohmann, 2007). But in practice, obtaining comprehensive information is challenging due to the labor-intensive, costly, and difficult-to-scale nature of measuring site-specific conservation benefits and costs. Consequently, scholars and policy makers often conduct analyses using simplified, scaled-up calculations (Lankford, 2012; Li et al., 2015).

How Does Our Research Address This Challenge?

Our recent study introduces a methodological framework that combines a discrete choice land-use model, publicly accessible remote-sensing data, and county- and state-level agricultural statistics to estimate site-specific willingness-to-accept (WTA) payments to private farmers for reducing irrigation water withdrawals from the lake's three major tributary watersheds (Bear, Weber, and Jordan) in Utah (Li and Khan, 2024a). The remote-sensing data are in raster format, including the annual Cropland Data Layer (CDL) developed by the National Agricultural Statistics Service of the U.S. Department of Agriculture (USDA-NASS, 2023) and the 16-day Moderate Resolution Imaging Spectroradiometer (MODIS) Enhanced Vegetation Index (EVI) developed by the National Aeronautics and Space Administration (Didan, 2001).

The process involves several steps:

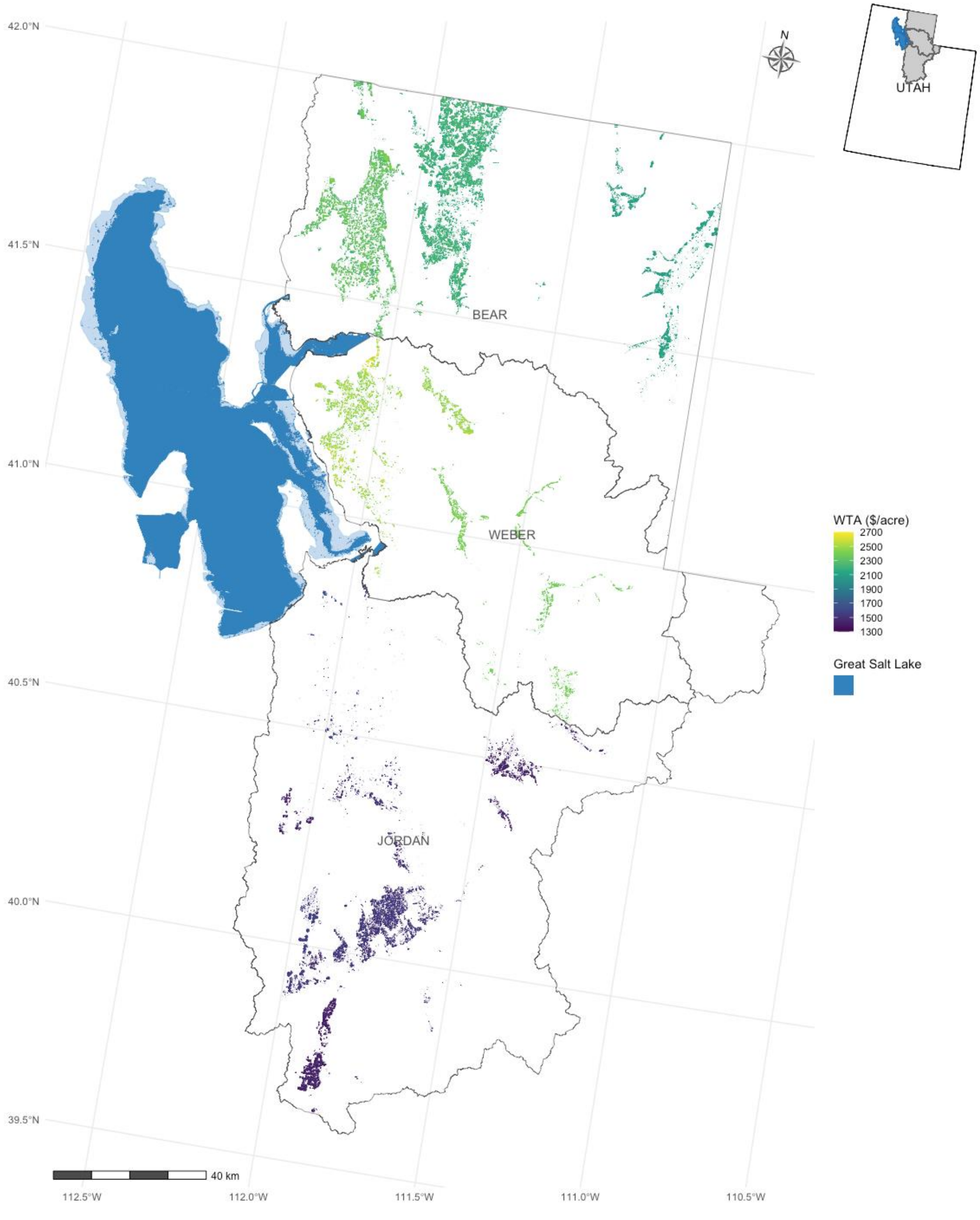
1. The annual crop-specific EVI is calculated for each site by combining CDL and annual maximum EVI.
2. Annual crop yield at each site is estimated by calibrating the annual crop-specific EVI against annual state-level crop yield.
3. Annual crop revenue at each site is then determined by multiplying the site-specific annual crop yield by state-level annual crop price.
4. These site-specific annual crop revenues are aggregated to calculate county-level annual revenue for all crops.
5. The site-specific annual crop revenues are multiplied by an adjustment factor, yielding the site-specific annual crop net returns, where the adjustment factor is obtained by dividing county-level annual cropland rent statistics by county-level annual revenue from step 4.
6. A discrete choice land-use model is estimated to examine how private landowners choose cropping activities based on their net economic returns using annual data from 2017 to 2022 with a two-step sampling strategy for this panel data setting (Li and Khan, 2024b).
7. Finally, site-specific WTA payments to farmers for irrigation water savings are estimated using model outputs with data from 2022.

In simpler terms, satellite data and state agricultural statistics are used to evaluate how much money different crops make at various locations. These estimates are then adjusted using land rent to get a more accurate picture of crop net returns across different sites. The site-specific crop net return is a key explanatory variable used for estimating a land-use model and subsequently WTA payments for converting current land uses to alternative uses. Note that CDL identifies around 40 crops in the three watersheds. However, alfalfa, nonalfalfa hays, winter wheat, and spring grains together cover about 80% of the cropland, with additional 15% being fallow. To streamline the analysis, the CDL crop types are consolidated into six main groups: alfalfa, nonalfalfa hays, winter wheat, spring grain crops, other crops, and fallow, representing the six land-use choices to be estimated in the discrete choice land-use model.

How Much Does It Cost to Fallow Alfalfa Fields?

Alfalfa is a major water-intensive crop in Utah, accounting for about 46% of the total cropland in the three watersheds in 2022 (USDA-NASS, 2023), of which 65% is irrigated (UDWRe, 2023). Figure 2 shows the annual WTA payment estimates, in real 2022 US dollars,

Figure 2. Spatial Distribution of Annual WTA Payments in the Bear, Weber, and Jordan Watersheds of Utah



Note: Dollar amounts are in real 2022 USD.
Source: Authors' calculations.

for fallowing 167,300 acres of irrigated alfalfa across the study area. The payments show significant variation, ranging from $1,300 to $2,700 per acre.

Among the three watersheds, the Jordan watershed has the lowest WTA payments, averaging $1,483/acre annually, with a 95% confidence interval (CI) of $1,412/acre to $1,549/acre. Conversely, the Weber watershed has the highest WTA payments, with an average of $2,464/acre annually and a 95% CI of $2,294/acre to $2,711/acre. The Bear watershed falls in between, with an average annual WTA for Bear is $2,229/acre and a 95% CI of $2,156/acre to $2,309/acre. These 95% CIs are derived from 1,000 bootstrap samples, capturing the uncertainty inherent in the WTA estimates. This spatial variation reflects the large differences in the profitability of growing alfalfa in different regions. The more profitable it is to grow alfalfa, the higher the opportunity cost of fallowing alfalfa fields, and the larger the amount of WTA payments.

Where Is It Worth Conserving?

To determine where fallowing irrigated alfalfa fields is worth promoting, it is important to consider the amount of irrigation water saved. This is done by using a combination of the 2022 irrigation method map from water-related land use inventories developed by the Utah Division of Water Resources (UDWRe, 2023), the annual net irrigation requirements for alfalfa from the Utah Agricultural Experiment Station, and the recommended irrigation efficiency from Utah State University extension experts. By dividing the WTA estimate by the water saved at each site, the unit cost of water savings for each specific location can be calculated. This information helps create a water supply curve (that is, marginal cost curve) for each watershed and then develop priority maps for the study area.

The results indicate that the spatial variation in unit water-saving costs aligns closely with the spatial variation in WTA payments across the three watersheds. In the Jordan watershed, the costs are the lowest, ranging from $434/AF to $586/AF, with water savings of about 139.3 KAF annually (Figure 3c). In contrast, the Bear watershed, which has the largest area of alfalfa, can achieve water savings of up to 291.4 KAF per year. The unit water-saving costs in Bear range from $658/AF to $862/AF (Figure 3a). The Weber watershed has the highest unit water-saving costs, ranging from $746/AF to $980/AF, and offers the smallest water-saving potential at approximately 81.8 KAF per year (Figure 3b). This is due to Weber having the smallest alfalfa area among the three watersheds.

In light of the above results, fallowing all irrigated alfalfa fields in the study area could reduce a total of 512.5 KAF of irrigation water withdrawals from lake’s three tributary watersheds. This exceeds the annual saving target of 471.0 KAF proposed by the GSL Strike Team in their aggressive conservation scenario but falls short of the higher targets in their highly or extremely aggressive conservation scenarios. A further calculation shows that to achieve an annual saving goal of 471.0 KAF, at least $324.0 million per year would be required if payments are made at the county level, $347.5 million if a watershed-level payment implemented, or $379.8 million if a uniform payment scheme is used (Table 1). These payment systems are designed by ordering WTA estimates in ascending order and selecting the smallest WTA at different levels to meet the water-saving target (see Appendix Table A1 for details).

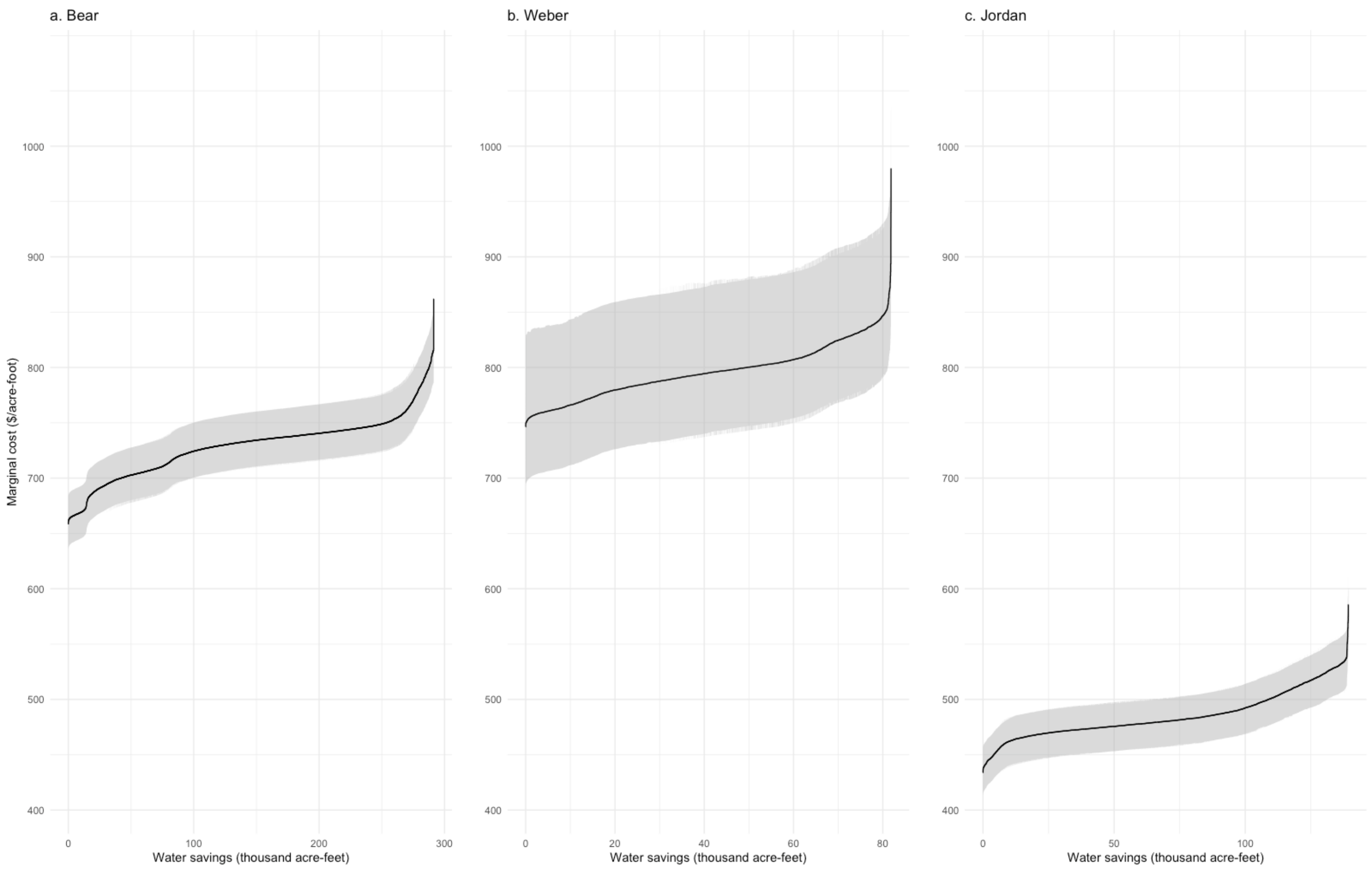
Additionally, all farmers in Jordan and Bear watersheds would fallow their irrigated alfalfa fields—45,600 acres and 13,200 acres, respectively—regardless of the payment level. In contrast, only half of irrigated alfalfa acres in Weber, approximately 95,200 acres, would be fallowed. Although the total amount of water saved is the same across the three levels of payment, their 95% CIs vary significantly. For both the uniform and watershed-level payments, there is a 95% confidence that at least 415.2 KAF would be saved annually (Table 1), meeting 88% of the conservation goal. However, the county-level payment strategy has a 95% confidence to save 193.0 KAF of water every year (Table 1), which is just 41% of the goal. This finding indicates that the county-level payment has greater risks in achieving the annual water-saving target compared to the other two systems. Therefore, if agricultural water conservation is main option, the watershed-level payment strategy is recommended because it offers a better balance between cost-effectiveness and risk control than the other two levels of payment.

Discussion

To determine the economic viability of these payment methods, the average unit water-saving costs in the three payment levels are compared to current residential water rates, since collecting irrigation water prices is challenging. Most Utah cities have adopted an increasing block rate structure, where water rates increase with higher usage. In the study area, the lowest-tier water rates roughly range from $1.40 to $4.25 per 1,000 gallons, equivalent to $456 to $1,385 per AF. Our study estimates the average unit water-saving cost to be between $688/AF and $806/AF (Table 1), falling within the lower-middle end of the residential water price range. This comparison suggests that the proposed agricultural water-saving strategies are economically feasible.

Would fallowing irrigated alfalfa fields lead to significant job loss in Utah? According to the 2022 Census of Agriculture (USDA-NASS, 2024), the 11 counties in the study employed 8,245 local agricultural workers (excluding a small number of temporary migrant workers with H2A visas). Assuming labor is evenly distributed across all agricultural fields, approximately 2,331 of

Figure 3. Estimated Marginal Costs of Irrigation Water Saving by Fallowing Alfalfa Fields



Note: Values are in real 2022 USD. Gray shaded area represents a 95% confidence of each marginal cost estimate, calculated based on 1,000 bootstrap samples.

Source: Authors' calculations.

these locally hired workers were employed on the alfalfa fields proposed to be fallowed. Of those, only 40% (927 workers) were employed for 150 days or more in 2022, while the remaining 1,404 worked fewer than 150 days. As a result, the impact on the local job market is minimal, with the loss of seasonal jobs representing just 16% of all locally hired agricultural workers (14,979, excluding migrant workers) in the state, or only 0.14% of the state's total employment, which reached nearly 1.7 million across all sectors in 2022 (U.S. Bureau of Labor Statistics, 2024). Even when factoring in the 3,956 unpaid family laborers and 216 migrant workers potentially affected by fallowing, the total impact would still represent just 0.43% of the state's workforce, indicating a very small overall effect (USDA-NASS, 2024). Likewise, the impact on the local dairy industry would be limited, as the reduction in alfalfa production accounts for about 19% of Utah's total alfalfa output, which represents less than 4% of national production; approximately 12% of Utah's alfalfa output has been exported in recent years (Sall, Tronstad, and Chin, 2023; USDA-NASS, 2024).

People may worry that taking land out of production could lead to soil erosion and dust. However, the risk of soil erosion during fallow periods varies significantly depending on the amount, type, and quality of residue left on the land (Nielsen and Calderón, 2011). Standing residue is generally more effective than flat residue in reducing wind speed at the soil surface, which helps control wind erosion (van de Ven, Fryrear, and Spaan, 1989). One potential strategy to prevent erosion is to skip alfalfa harvests, allowing the alfalfa to remain in the field. Other options include converting irrigated alfalfa fields to dryland farming without irrigation or fallowing them as grassland. These practices can help maintain or even improve soil conditions (Kozak and Pudełko, 2021).

Another concern is the traditionally low adoption rate of agricultural conservation practices in the United States, often due to factors such as costs outweighing benefits, land tenure issues, partial adoption, information gaps, or status quo bias (Ranjan et al., 2019; Canales et al., 2024). However, our study suggests an annual conservation payment ranging from $1,452 to $2,466 per acre (Appendix Table A1), which is well above the state average alfalfa revenue of $1,222/acre in 2022 (including production costs) and significantly higher than the 2022 farmland rent, which ranged from $45 to $161 per acre in the 11 counties studied (USDA-NASS, 2024). Therefore, cost-benefit concerns and land tenure issues are unlikely to be major barriers to fallowing irrigated alfalfa fields as recommended in this study. With strong economic incentives and rigorous government oversight, including penalties for noncompliance, the risk of partial adoption can also be mitigated. Additionally, educating farmers on the importance of fallowing irrigated alfalfa and offering flexible exit terms will be crucial for encouraging widespread adoption. Given Utah's favorable sociopolitical climate for water conservation, legal and institutional barriers, such as the "use-it-or-lose-it" clause under the prior appropriation system, are unlikely to pose significant challenges. The newly enacted HB33 ensures that water rights holders will retain their rights while conserving water to support the GSL.

Table 1. Water-Saving Potential and Conservation Costs

	Water Savings (KAF)		Total Cost ($millions)		Unit Cost ($/AF)	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Uniform payment	471.3	[415.5, 512.0]	379.8	[335.2, 412.1]	806	[805, 807]
Watershed-level payment	471.3	[415.2, 512.0]	347.5	[302.7, 379.8]	737	[729, 742]
County-level payment	471.2	[193.0, 512.0]	324.0	[130.3, 356.4]	688	[675, 696]

Note: Values are in real 2022 USD.
Source: Authors' calculations.

Appendix

Table A1. Suggested Annual Payment under Different Payment Systems

Watershed	County	Uniform Payment ($/acre)	Watershed-Level Payment ($/acre)	County-Level Payment ($/acre)
Bear	Box Elder	2,466	2,466	2,466
Bear	Cache	2,466	2,466	2,255
Bear	Rich	2,466	2,466	2,138
Weber	Weber	2,466	2,466	2,466
Weber	Davis	2,466	2,466	2,466
Weber	Morgan	2,466	2,466	2,449
Weber	Summit	2,466	2,466	2,423
Jordan	Salt Lake	2,466	1,753	1,753
Jordan	Utah	2,466	1,753	1,609
Jordan	Wasatch	2,466	1,753	1,465
Jordan	Juab	2,466	1,753	1,452

Note: Values are in real 2022 USD.
Source: Authors’ calculations.

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About the Authors: Man Li (man.li@usu.edu) is an Assistant Professor with the Department of Applied Economics at Utah State University. Asif Ahmed Khan (khan598@purdue.edu) is a Graduate Research Assistant with the Department of Agricultural Economics at Purdue University.

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