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Irrigation Organizations:

Water Measurement and Pricing

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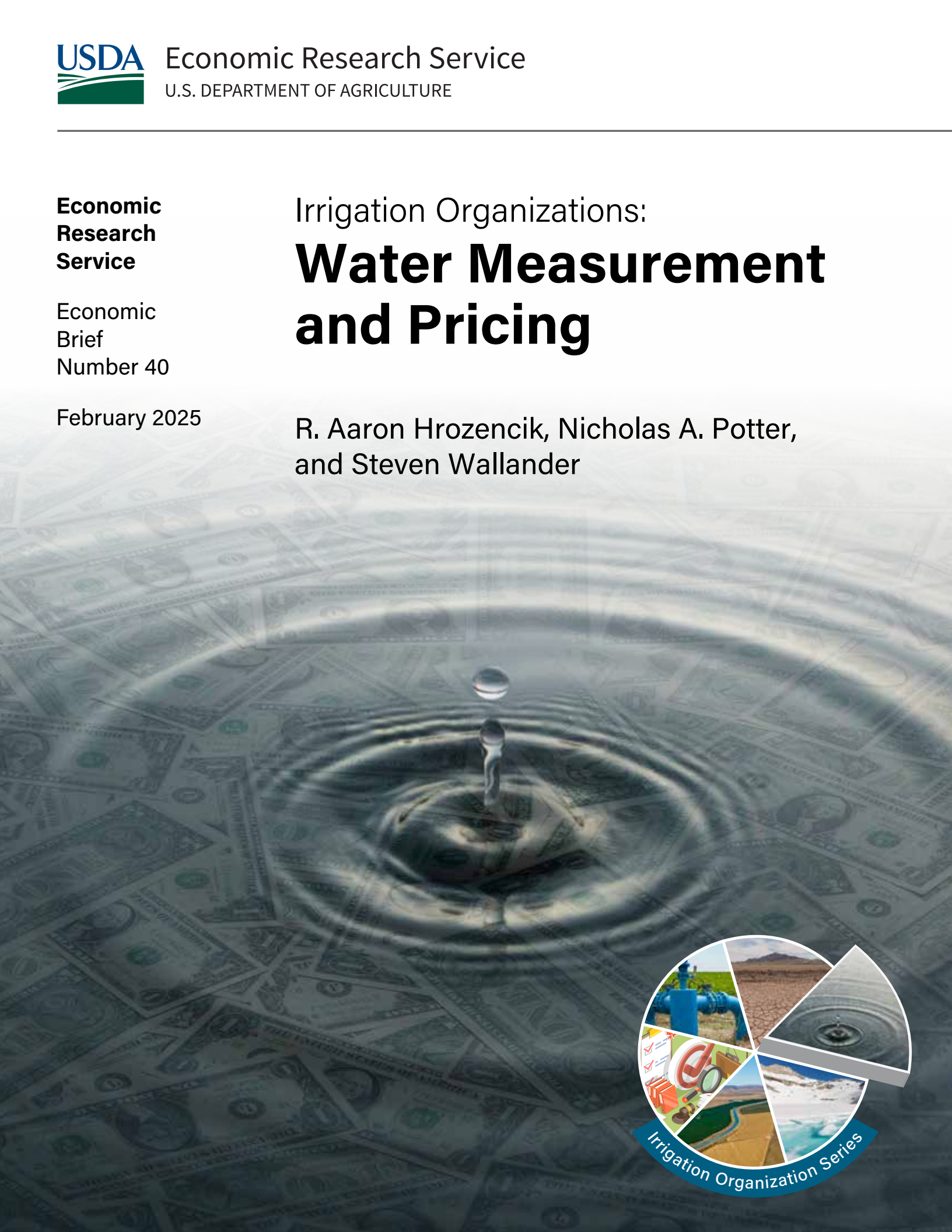

Abstract

Irrigation delivery organizations play an important role in the agricultural sector, particularly in the Western United States where nearly half of all water applied as irrigation comes from an off-farm source. These organizations manage and operate extensive water storage and conveyance infrastructure to divert, store, and deliver water to support irrigated agricultural production. Understanding how these organizations measure water flows within their systems and price water deliveries could help achieve water conservation objectives for the irrigated sector. Accurate and timely water measurement allows organizations to track water flows and deliveries and detect sources of water loss within their systems, while differing water delivery pricing approaches can help facilitate on-farm water conservation efforts. This report uses data from the 2019 Survey of Irrigation Organizations to characterize the state of water measurement and pricing practices among organizations delivering water to farms and ranches.

Acknowledgments: The authors thank the team at USDA, National Agricultural Statistics Service for their work in designing and conducting the 2019 Survey of Irrigation Organizations. This report benefited significantly from comments from Marcel Aillery and anonymous reviewers.

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Summary

Increasing competition for water resources, coupled with current and projected future water scarcity, highlights the importance of water conservation efforts within the irrigated agricultural sector. Water measurement and pricing are among the tools that irrigation organizations can use to conserve water resources. Accurate and timely water measurement can inform organization investment decisions aimed at improving operational efficiency and reducing water losses occurring within storage and conveyance systems. Additionally, the approaches organizations use to price water deliveries can shape, in part, on-farm water conservation incentives. Despite the importance of water measurement and pricing in enhancing sector resilience to water supply scarcity, limited information exists about current measurement and pricing practices among irrigation organizations.

This is one report in a series of economic briefs on key topics related to irrigation organizations that draws on data collected in the U.S. Department of Agriculture's 2019 Survey of Irrigation Organizations (SIO). This report summarizes information from the SIO about water measurement and pricing practices used by water delivery organizations. Water delivery organizations supply water to irrigated farms and ranches and include irrigation districts, ditch companies, acequias (communal irrigation ditches), and similar entities that manage the off-farm infrastructure required to transport irrigation water. Some irrigation organizations also manage or regulate on-farm groundwater use. Organizations that manage on-farm groundwater use but do not deliver water to farms or ranches are not included in this analysis. This report answers several questions to address knowledge gaps surrounding water measurement and pricing by irrigation organizations such as:

- What are the water quantity and flow measurement techniques used by water delivery organizations?
- Where and how frequently do water delivery organizations measure water flows within their storage and conveyance systems?
- What approaches do water delivery organizations use to price water deliveries, and how do these approaches vary regionally?
- How is water pricing generally structured across regions, and what are the average prices organizations charge farms and ranches for water deliveries?

Key findings from this report include:

- Small irrigation water delivery organizations, defined as those serving fewer than 1,000 irrigable acres, were more likely to report not measuring water deliveries. Large irrigation organizations, defined as those serving more than 10,000 irrigable acres, were more likely to measure water deliveries through methods such as direct metering or time of use estimation. More than 20 percent of organizations reported not measuring water deliveries in all survey reporting regions except the Pacific region, where more than four-fifths of organizations used direct metering to measure water deliveries.
- Most water delivery organizations reported measuring water flows at the entry to their systems. Few organizations measured water flows at the requisite locations within their systems to accurately estimate conveyance losses.
- About 45 percent of water delivery organizations priced water deliveries volumetrically, where users pay for water based on a per-unit price. Some of the organizations that used volumetric pricing also charged per-acre taxes or assessments, where users pay for water based on the number of acres irrigated with water delivered.
- Volumetric water pricing is most common in the Pacific region, where over 90 percent of organizations priced water on a per-unit delivered basis. Meanwhile, this kind of pricing was relatively less common in the Southwestern and Northwestern regions.
- Average volumetric water prices were highest in the Pacific region (equaling about $50 per acre-foot) where volumetric water pricing was common among irrigation water delivery organizations.

The SIO was a collaboration among USDA, Economic Research Service (ERS); USDA, National Agricultural Statistics Service (NASS); and the Office of the Chief Economist (OCE). The 2019 SIO provided a nationally representative overview of the local water management entities that deliver irrigation water directly to farms or regulate or otherwise influence on-farm groundwater use.

Introduction

Irrigation water delivery organizations use diversion, storage, and conveyance infrastructure to deliver water to farms and ranches throughout the United States.[1] These organizations are particularly important in the 17 Western States of the continental United States where their deliveries account for nearly half of all water applied as irrigation (USDA, National Agricultural Statistics Service (NASS), 2019).[2] [3] The measurement and pricing of water supplies are essential functions in the operation of most irrigation water delivery organizations, with bearing on the financial performance and operating efficiency of the delivery systems. How these organizations measure the water that flows within their systems and price water deliveries is relevant to water conservation policy, as many Federal, State, and local agencies support water conservation and water scarcity resilience through infrastructure investments and technical assistance. Data collected in the U.S. Department of Agriculture's (USDA) 2019 Survey of Irrigation Organizations (SIO) highlights the role of water measurement and pricing in conservation, as flow rate metering was the most common water conservation investment reported by organizations (Wallander et al., 2022) (See box, "USDA's 2019 Survey of Irrigation Organizations," for more information on the survey). This report draws on these data to characterize the state of irrigation water measurement and pricing in the United States.

Irrigation organizations use a variety of methods to measure water flows within their diversion, storage, and conveyance infrastructure (Hrozencik et al., 2021b). These methods range from direct metering of water flows to the estimation of water delivered based on the duration of deliveries or area of crops irrigated.[4] The measurement of water flows and deliveries within an irrigation organization's system is important for water conservation because accurate and timely measurement allows organizations to track how increasingly scarce water resources are used within their system and allocated among their constituents (Lui et al., 2017). The timely and accurate measurement of water flows and deliveries may also help organizations estimate conveyance losses and identify where these losses occur.[5] Identifying where conveyance losses concentrate within an organization's system can inform water conservation investment decisions.

[1] Rather than delivering water to farms and ranches some irrigation organizations instead are focused on managing or otherwise influencing on-farm groundwater use decisions and may not deliver water to farms and ranches. For more information on these groundwater management organizations, see Hrozencik et al. (2023). This report focuses only on water measurement and pricing among irrigation water delivery organizations which are defined as those organizations that reported delivering water to farms and ranches in 2019. Throughout the report, these organizations are referred to as "irrigation water delivery organizations," "water delivery organizations," or simply "irrigation organizations."

[2] Water delivered to farms and ranches by irrigation water delivery organizations is generally classified as off-farm irrigation water, which USDA, National Agricultural Statistics Service (NASS) defines as "water from off-farm water suppliers, such as the U.S. Bureau of Reclamation; irrigation districts; mutual, private, cooperative, or neighborhood ditches; commercial companies; or community water systems (USDA, NASS, 2019)." USDA, NASS's SIO regions, defined within the 17 Western States of the continental United States, are as follows: SIO Eastern Rockies region (Colorado, Montana, and Wyoming); SIO High Plains region (Kansas, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas); SIO Northwestern region (Idaho, Oregon, and Washington); SIO Pacific region (California and Nevada); and SIO Southwestern region (Arizona, New Mexico, and Utah).

[3] The USDA's 2019 Survey of Irrigation Organizations (SIO), which is the primary dataset supporting the analysis presented in this report, also collected information on irrigation organizations outside the 17 U.S. Western States of the continental United States, where irrigation water delivery organizations are relatively uncommon. Specifically, the SIO collected information on irrigation organizations in the Southeastern region (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina). Irrigation water delivery organizations are relatively uncommon in the Southeastern region. Data from the SIO indicate that only eight irrigation water delivery organizations operate within the Southeastern region, and water delivered by these organizations accounts for less than 0.5 percent of all water delivered by irrigation water delivery organizations in the United States in 2019 (USDA, NASS, 2020).

[4] A variety of technologies is available to measure water deliveries to farms and ranches and the water flows within an organization's conveyance system (e.g., weirs, flumes, and canal metergates) (Hrozencik et al., 2021b). Weirs are specially shaped barriers located within a canal to measure water flow; differing shaped weir barriers use differing equations to calculate water flow. Flumes are fixed hydraulic structures that force flow to accelerate through an opening which can be measured. Metergates are structures where water level measurements correlate with flow rates. See Hrozencik et al. (2021b) for additional information on types of water measurement infrastructures.

[5] Conveyance losses refer to water that is unavailable for irrigation use because of evaporation, seepage, spills, or phreatophyte consumption. Phreatophytes are noncrop plants that use groundwater within reach of their roots for evapotranspiration. Phreatophytes near water conveyance infrastructure can increase conveyance losses as root systems draw from the water being transported. Conveyance losses are not an actual loss of water in a broadly defined hydrologic system. Water seepage from main and lateral canals may recharge groundwater aquifers or downslope surface-water bodies, while evaporated water returns to the land in the form of precipitation. The water is lost in the sense that it is not immediately available for its intended use.

How irrigation water delivery organizations price water deliveries is also important for water conservation because water prices can influence how farmers and ranchers use and conserve water (Caswell et al., 1990; Huffaker et al., 1998). Organizations have several differing water pricing methods at their disposal, including volumetric pricing where farms and ranches pay per unit of water delivered (e.g., acre-foot) and per-acre assessments or taxes where farms and ranches pay a fee for each irrigated acre receiving water from the organization.[6] Farmers can respond to water pricing by changing water use intensity or by changing the amount of land being irrigated.[7] Volumetric water pricing may encourage more water conservation because farmers and ranchers face costs for each unit of irrigation water applied (Al-Rubaye, 2019; Portoghese et al., 2021). Farmers may respond to volumetric pricing changes by reducing water use intensity by deficit irrigating, switching to less water-intensive crops or crop harvesting patterns, or investing in more efficient on-farm irrigation technology (e.g., drip irrigation or low-flow sprinkler systems).[8] Farmers may also respond to volumetric pricing by reducing irrigated acreage when prices are higher or substituting priced surface water for groundwater (Moore et al., 1994; Schuck & Green, 2003). In contrast, per-acre assessments or taxes potentially incentivize farmers and ranchers to adjust acreage irrigated but likely do not reduce water use intensity since irrigators generally pay the same price per acre regardless of the amount of water applied. Water pricing methods influence water conservation outcomes, but employing conservation pricing often requires investing in the necessary infrastructure to measure water delivery volumes.

In many cases, accurate and timely water measurements are a prerequisite for conservation enhancing volumetric pricing (Lika et al., 2017). Direct metering of water deliveries to farms and ranches allows organizations to track the quantity of water delivered and price water deliveries per unit delivered. In some cases, organizations may price water volumetrically without direct metering of water deliveries by relying on self-reported or estimated water deliveries. However, these approaches may not generate the same water conservation outcomes as volumetric pricing paired with direct metering of water deliveries because farmers and ranchers may underreport water use, and estimated water deliveries may be less accurate than those that are directly metered (Lika et al., 2017).

Water scarcity and variability in supply are current challenges for the irrigated agricultural sector. Climate change is posed to further exacerbate these challenges, particularly in the Western United States, where climate change is projected to further stress already scarce water resources (Dettinger et al., 2015; Schaible & Aillery, 2017). Water measurement and pricing are two tools that may increase water conservation and assist the irrigated agricultural sector's resilience to increasingly scarce water. This report provides an overview of the state of water measurement and pricing among irrigation water delivery organizations in the United States.

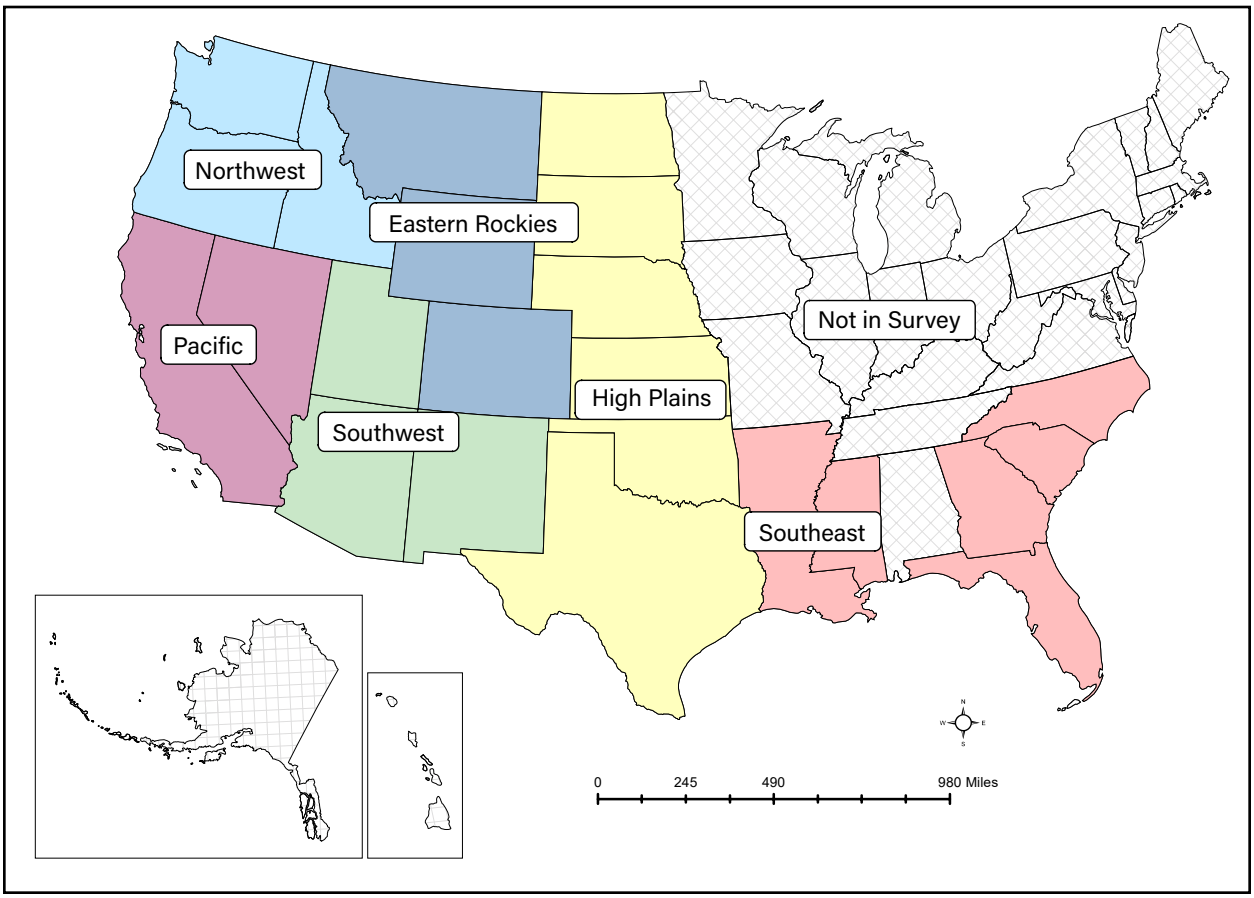
This report also differentiates between irrigation water delivery organizations by the region and size of the organization. Organization regions reflect differences in climate, historical development of irrigation, as well as State institutions (e.g., California State Water Project and Northern Colorado Water Conservancy District). Figure 1 maps the reporting regions for the SIO, which are used here when reporting regional statistics. Organization size represents potential differences in access to capital and management capacity. This report classifies organizations into size categories based on the number of irrigable acres served by the organization. Irrigable acres are farmland that could have potentially received water in 2019, as reported by the organization. Large organizations serve more than 10,000 irrigable acres; medium organizations serve 1,000 to 10,000 irrigable acres; and small organizations serve less than 1,000 irrigable acres.

[6] An acre-foot is equivalent to 325,851 gallons and is enough water to cover an acre of land with 1 foot of water.

[7] Water use intensity is the amount of water applied per unit of land, typically measured as acre-feet per acre irrigated.

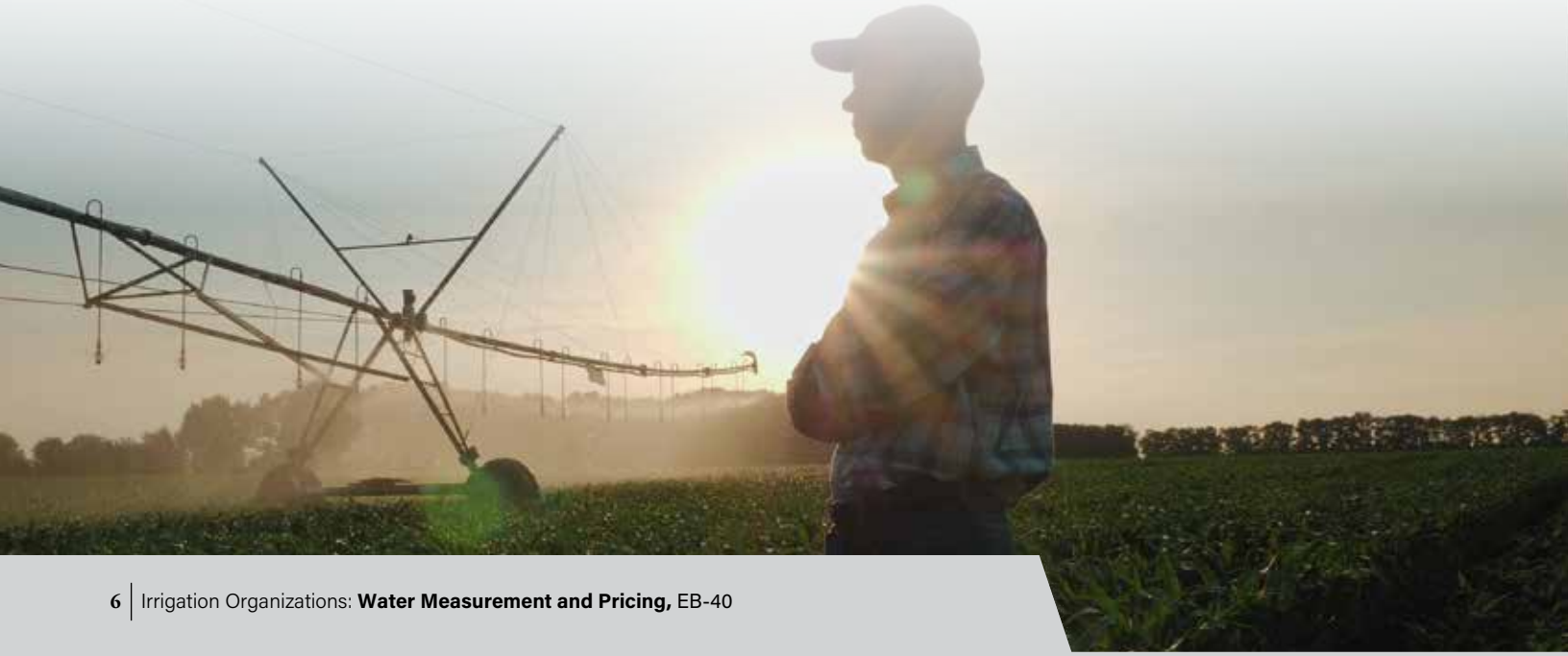
[8] Deficit irrigation refers to the deliberate and systematic underirrigation of crops in response to water scarcity or water price (English & Raja, 1996).

Figure 1
Reporting regions: 2019 Survey of Irrigation Organizations



Note: The cross-hatched shaded areas were not included in the 2019 Survey of Irrigation Organizations (SIO). USDA, National Agricultural Statistics Service (NASS) SIO regions are as follows: Eastern Rockies (Colorado, Montana, and Wyoming), High Plains (Kansas, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas), Northwestern (Idaho, Oregon, and Washington), Pacific (California and Nevada), Southeastern (Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina), and Southwestern (Arizona, New Mexico, and Utah). All remaining States were not part of the SIO because organizations that deliver water to farms or influence on-farm groundwater use are rare or nonexistent in these States.

Source: USDA, Economic Research Service using data from the USDA, NASS, Irrigation Organizations publication (USDA, NASS, 2020).



USDA's 2019 Survey of Irrigation Organizations

The USDA's 2019 Survey of Irrigation Organizations (SIO) collected data on irrigation organizations in 24 States[1] within the Western and Southeastern regions of the United States where these organizations are most common. The SIO was a collaboration among USDA, Economic Research Service; USDA, National Agricultural Statistics Service (NASS); and the Office of the Chief Economist. The SIO was funded through a congressional budget initiative aiming to expand research and data on agricultural drought resilience.

The SIO defined an irrigation organization as an entity that either delivers water to farms and ranches or influences on-farm groundwater use. Irrigation organizations are structured differently across the United States according to State water law and regional water resource development history. Examples of irrigation organizations that deliver water include irrigation districts, canal/ditch companies, acequias (communal irrigation ditches, see Hutchins (1928) for more information), and irrigation mutuals. Organizations that can influence on-farm groundwater use include groundwater management districts, natural resource districts, and groundwater sustainability agencies. Some irrigation organizations engage in both on-farm groundwater management and water delivery. The SIO determined that there were 2,677 irrigation organizations in the United States in 2019. Among these organizations, 2,543 delivered water to farms and ranches, 735 influenced on-farm groundwater use, and 601 engaged in both water delivery and groundwater management. The response rate for the SIO was 44 percent.

The 2019 SIO was the first nationally representative Federal data collection effort aimed at irrigation organizations since the U.S. Department of Commerce, Bureau of the Census conducted the 1978 Census of Irrigation Organizations (CIO). The 1978 CIO did not collect information on organizations that solely influence on-farm groundwater use because these types of organizations largely did not exist in 1978. Additionally, the 1978 CIO collected information on "pass-through" entities, which are organizations that store and deliver water to irrigation organizations but do not deliver water directly to farms and ranches. The 2019 SIO did not collect information on "pass-through" organizations. For a summary of selected survey findings and additional information on survey design, see USDA, NASS Irrigation Organizations publication (USDA, NASS, 2020).

[1] Arizona, Arkansas, California, Colorado, Florida, Georgia, Idaho, Kansas, Louisiana, Mississippi, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Oklahoma, Oregon, South Carolina, South Dakota, Texas, Utah, Washington, and Wyoming.

Water Measurement

Many irrigation water delivery organizations own and/or operate networks of diversion structures, reservoirs, canals, ditches, and pipelines to deliver water to farms and ranches. In 2019, these organizations used this infrastructure to deliver over 67 million acre-feet of water for agriculture and, in some cases, other purposes such as domestic and industrial use (USDA, NASS, 2020). Many organizations measure water as it flows into, within, and out of their systems. Accurate and timely water measurement allows organizations to track how water is allocated within their systems and where potential conveyance losses occur. These losses can sometimes be significant. For example, in 2019, conveyance losses accounted for more than 14 percent of all water entering into organizations' delivery systems (USDA, NASS, 2020; Hrozencik et al., 2021b). Water measurement throughout an organization's system can help to accurately estimate conveyance losses, identify where these losses concentrate, and inform investment decisions on infrastructure upgrades and management. Specifically, measuring flows at system entry points (e.g., diversion structures from a natural water body or point of delivery from a State or Federal water project), turnouts (e.g., the interface between the organization and farm conveyance infrastructure (water delivery points)), and other system exits (e.g., drainage channels, structures diverting water to downstream users or back into natural water bodies) allow organizations to accurately measure losses during conveyance.[9]

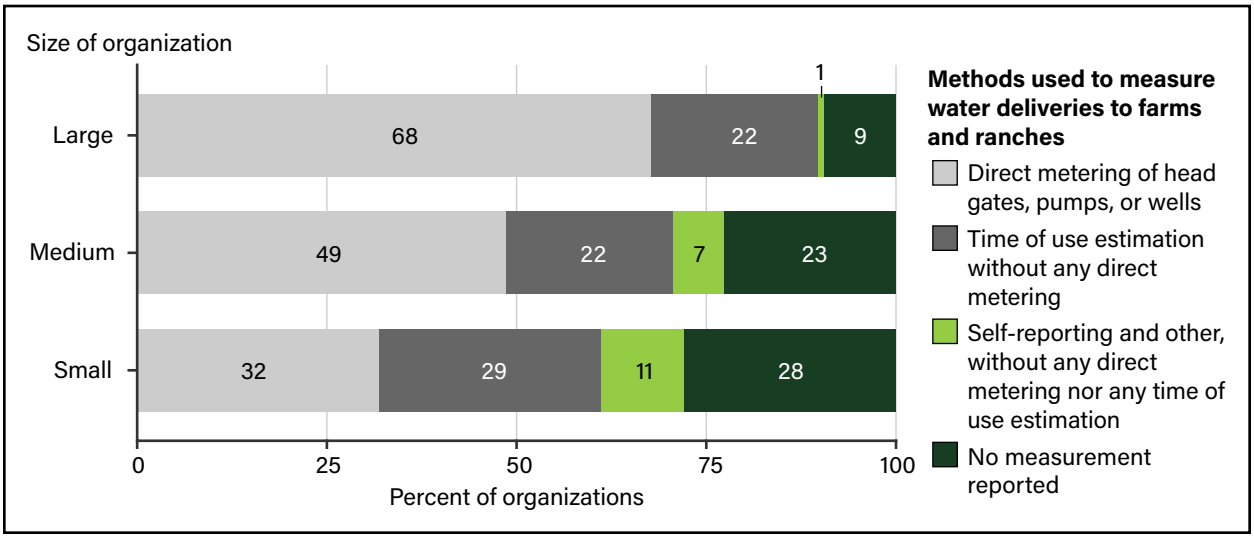
Despite the importance of water measurement for water conservation, less than half of all irrigation water delivery organizations reported using direct metering to measure water deliveries (see figure 2 in Hrozencik et al., 2021b). Absent direct metering of water deliveries, organizations relied on estimation techniques and self-reporting by users (farmers and ranchers) to track water flows within their systems. Recent changes in the USDA's Environmental Quality Incentives Program (EQIP) extended eligibility for program financial assistance to include water management entities, such as irrigation water delivery organizations (Fischer & Willis, 2020). These changes in EQIP eligibility provide a means through which Federal funds can be used to invest in improved irrigation measurement infrastructure to support water conservation objectives.

[9] In some cases, irrigation water delivery organizations may have no points of water exit within their conveyance infrastructure outside of turnouts. In these scenarios, which may occur in organizations located the farthest downstream reach of larger diversion canals, relatively accurate measurements of conveyance losses are likely possible with only water measurement at points of entry and turnouts.

Larger Irrigation Water Delivery Organizations Were Most Likely To Directly Meter Water Deliveries and Least Likely To Report No Measurement of Water Deliveries

- Figure 2 indicates that approximately 68 percent of large irrigation water delivery organizations used direct metering to measure water deliveries. About 9 percent of large organizations reported not measuring water deliveries.
- Nearly half of all medium irrigation water delivery organizations directly metered water deliveries, and 23 percent of these organizations reported not measuring water deliveries.
- Less than a third (32 percent) of small irrigation water delivery organizations directly metered water deliveries. More than a quarter (28 percent) of small organizations reported not measuring water deliveries.

Figure 2
Prevalence of differing water measurement methods by organization size, 2019



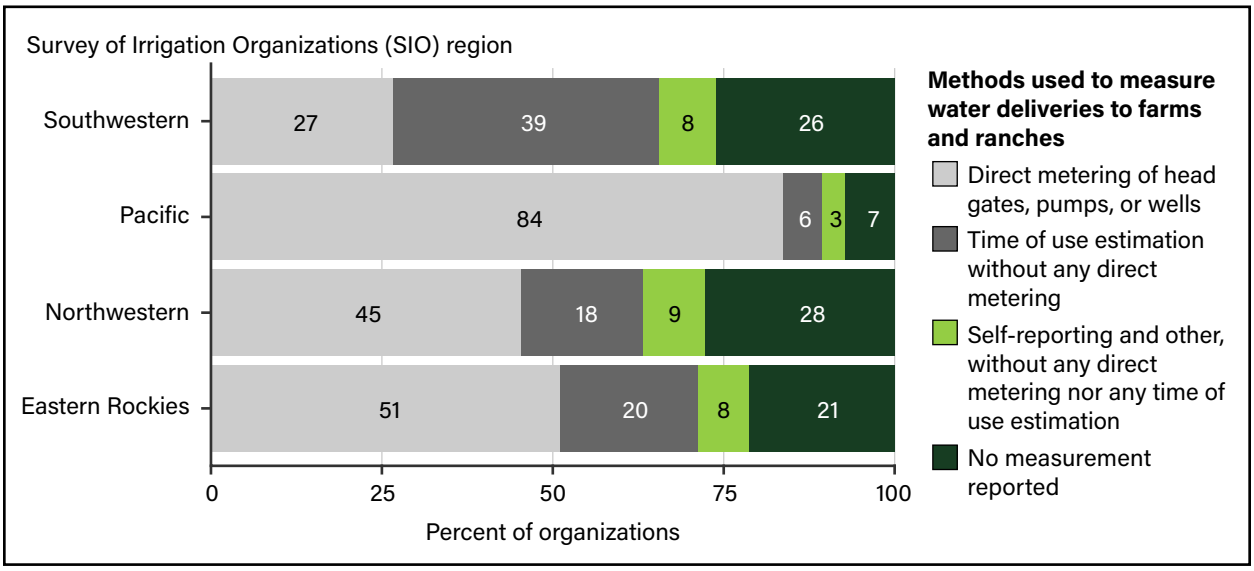
Note: This figure plots the percentage of irrigation organizations that used differing methods to measure water deliveries to farms and ranches, differentiating by organization size, in 2019. Large organizations serve more than 10,000 acres, medium organizations serve 1,000 to 10,000 acres, and small organizations serve less than 1,000 acres. Irrigable acres are farmland that could have received water in 2019. This figure represents only those organizations that identified as water delivery organizations and answered at least 1 of the 4 relevant water calculation questions in the USDA 2019 Survey of Irrigation Organizations. Organizations can use multiple methods to measure water use. The percentages of organizations using differing water measurement methods may not be equal to 100 due to rounding. "Direct metering of head gates, pumps, or wells" refers to organizations that reported directly measuring water flows and deliveries at these locations using a device such as a flow meter. Some of these organizations also reported using other methods to measure water deliveries. "Time of use estimation without any direct metering" refers to organizations that reported using time of use estimation to measure water deliveries and that did not also report using direct metering techniques. "Time of use estimation" refers to water measurement techniques that use information on the duration of water deliveries, canal size, and flow rate to estimate the volume of water delivered. "Self-reporting and other, without any direct metering nor any time of use estimation" refers to organizations that reported using self-reporting or other water measurement techniques and that did not use direct metering nor time of use estimation. "Self-reporting" refers to cases where farmers and ranchers reported their water use to the irrigation organization. "Other" includes all other means that organizations used to calculate water use by farms and ranches, such as evapotranspiration calculations, which use information on the water uptake of differing crops to estimate the amount of water used by the crop. "Self-reporting" and "Other" are combined into a single category in the above figure. "No measurement reported" refers to the case where the organization reported that they did not use any of the water measurement techniques including the "Other" category. "Percent of organizations" refers to the percentage of all organizations that reported delivering water to farms or ranches in 2019 and answered at least 1 of the relevant water measurement survey questions.

Source: USDA, Economic Research Service using data from the USDA 2019 Survey of Irrigation Organizations.

Methods Used To Measure Water Deliveries Vary Regionally

- Figure 3 demonstrates that direct metering of water deliveries is most common in the Pacific region, where 84 percent of organizations reported measuring irrigation water deliveries with direct metering. Organizations that reported no measurement of water deliveries were relatively less common in the Pacific, accounting for 7 percent of organizations within the region.
- Direct metering was the least common in the Southwestern region. Twenty-seven percent of organizations in the Southwest reported directly metering water deliveries.
- Reporting no measurement/metering of water was most common in the Northwestern and Southwestern regions, where about 28 percent and 26 percent of organizations, respectively, reported not measuring water deliveries.

Figure 3
Prevalence of differing water measurement methods by region, 2019



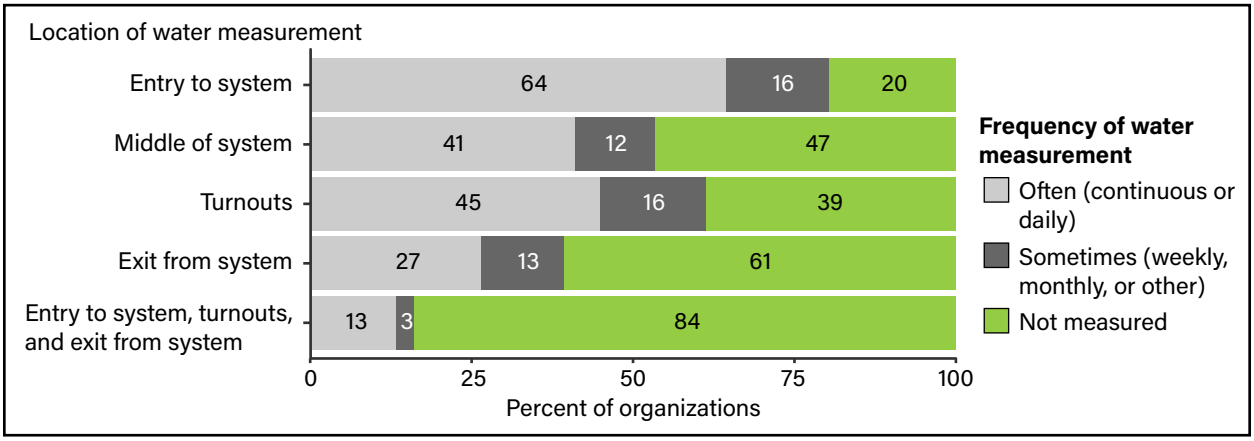
Note: This figure plots the percentage of irrigation organizations that used differing methods to measure water deliveries to farms and ranches, differentiating by region, in 2019. This figure represents only those organizations that identified as water delivery organizations and answered at least 1 of the 4 relevant water calculation questions in the USDA 2019 Survey of Irrigation Organizations (SIO). Organizations can use multiple methods to measure water use. "Direct metering of head gates, pumps, or wells" refers to organizations that reported directly measuring water flows and deliveries at these locations using a device, such as a flow meter. Some of these organizations also reported using other methods to measure water deliveries. "Time of use estimation without any direct metering" refers to organizations that reported using a time of use estimation to measure water deliveries and that did not also report using direct metering techniques. "Time of use estimation" refers to water measurement techniques that use information on the duration of water deliveries, canal size, and flow rate to estimate the volume of water delivered. "Self-reporting and other, without any direct metering nor any time of use estimation" refers to organizations that reported using self-reporting or other water measurement techniques and that did not use direct metering nor time of use estimation. "Self-reporting" refers to cases where farmers and ranchers reported their water use to the irrigation organization. "Other" includes all other means organizations used to calculate water use by farms and ranches, such as evapotranspiration calculations, which use information on the water uptake of differing crops to estimate the amount of water consumption used by the crop. "No measurement reported" refers to the case where the organization reported that they did not use any of the water measurement techniques including the "Other" category. "Percent of organizations" refers to the percentage of all organizations within a given region that reported delivering water to farms or ranches in 2019 and answered at least 1 of the relevant water measurement survey questions. SIO regions are as follows: Eastern Rockies (Colorado, Montana, and Wyoming), High Plains (Kansas, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas), Pacific (California and Nevada), Southeastern (Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina), and Southwestern (Arizona, New Mexico, and Utah). All remaining States were not part of the SIO. Data for the Southeastern and High Plains regions are suppressed due to data disclosure rules.

Source: USDA, Economic Research Service using data from the USDA 2019 Survey of Irrigation Organizations.

Many Irrigation Water Delivery Organizations Measure Water Flows at the Entry to Their System, While Relatively Few Measure Flows as Water Exits Their Conveyance System

- Figure 4 indicates that the most common location of water measurement within an organization's conveyance system was the entry to the system. Sixty-four percent of water delivery organizations reported measuring water flows at their system's entry continuously or daily. Only 20 percent of organizations reported not measuring water flows at their system's entry.
- The second most common location of water measurement within an organization's conveyance system was turnouts, where water deliveries to farms and ranches typically take place. Approximately 45 percent of organizations reported measuring turnout water flows continuously or daily, while an additional 16 percent of organizations reported measuring turnout flows weekly, monthly, or at other time intervals.
- Approximately 16 percent of organizations reported monitoring water flows at both the entry and exit from their system as well as at turnout locations, often or sometimes. Measuring water flows throughout the entire system allows for the most accurate estimates of conveyance losses.

Figure 4
Water measurement within irrigation organization conveyance systems, 2019



Note: This figure plots how frequently irrigation organizations measured water flows at differing locations within their storage and conveyance infrastructure in 2019. "Percent of organizations" refers to the percent of irrigation organizations that measured water at a given point in their system, reported delivering water to farms or ranches in 2019, and answered at least 1 relevant water measurement question in the USDA 2019 Survey of Irrigation Organizations. The percentages of organizations measuring water at differing points within their storage and conveyance systems may not sum to 100 due to rounding. "Entry to system" refers to the location where water enters an irrigation organization's storage and conveyance infrastructure (e.g., diversion structure from a natural water body or point of delivery from a State or Federal water project). "Middle of system" refers to locations within an irrigation organization's storage and conveyance infrastructure (e.g., where water enters or exits a water storage facility). "Turnout," which is also commonly referred to as offtakes, delivery gates, or head gates, diverts water and control flow volumes within an organization's water conveyance system and often serves as the interface between organization and farm conveyance infrastructure where control of the water shifts to the farm or ranch. "Exit from system" refers to a location or locations where water leaves the irrigation organization's conveyance and storage infrastructure. Exits may route water back into natural water bodies, State or Federal water projects, or into the conveyance and storage infrastructure of another irrigation organization. "Entry to system, turnouts, and exit from system" refers to organizations that measured water flows at all 3 locations within their system. "Often" refers to organizations that measured water continuously or daily at a given location within their conveyance and storage infrastructure. "Sometimes" refers to organizations that measured water weekly, monthly, or other (e.g., quarterly) at a given location within their conveyance and storage infrastructure. "Not measured" refers to organizations that reported not measuring water at a given location within their conveyance and storage infrastructure.

Source: USDA, Economic Research Service using data from the USDA 2019 Survey of Irrigation Organizations.

Water Pricing

Most irrigation water delivery organizations require revenue to maintain and operate their conveyance and storage infrastructure.[10] Organizations often raise the necessary revenue by charging farms and ranches for water deliveries. These charges are important for the financial solvency of organization operations but can also help determine water conservation outcomes. Specifically, if organizations use volumetric water pricing approaches (e.g., charging a price per unit of water delivered), then farmers and ranchers receiving water deliveries face a price for each unit of irrigation water applied which may encourage water conservation (Olmstead, 2010; Smith et al., 2017; Al-Rubaye, 2019; Portoghese et al., 2021; Zetland, 2021). Organizations may increase the water conservation potential of their volumetric pricing by further differentiating prices based on time/season or charging higher prices for farms and ranches that use more water (Bar-Shira et al., 2006).

In contrast, organizations may also raise revenue through per-acre taxes or assessments, where farmers and ranchers pay the organization a specified price per acre irrigated with water delivered by that organization. In some cases, organizations use both volumetric pricing and per-acre assessment/tax approaches to generate revenue from irrigation water deliveries. While per-acre assessments/taxes require minimal water measurement infrastructure to implement, this pricing approach does little to impact field-level water use decisions (Tsur & Dinar, 1997; Johansson et al., 2002; Tsur, 2005). Namely, without a specific price per unit of water applied, farmers and ranchers have minimal financial incentives to conserve water resources. As such, the water pricing approaches used by irrigation organizations shape irrigator incentives for water conservation.

Irrigation Organizations Use a Variety of Approaches To Price Water Deliveries, With Organizations Serving More Acreage and Delivering More Water Tending To Use Volumetric Pricing More Frequently

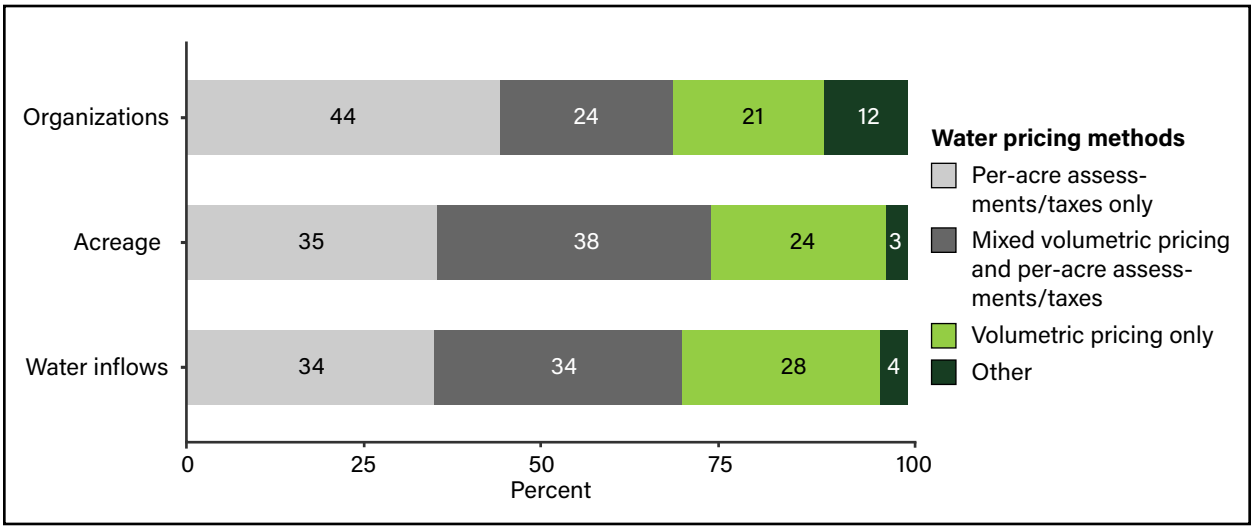
- Figure 5 shows that the most common method for pricing water deliveries was charging a per-acre assessment/tax. About 44 percent of water delivery organizations reported generating revenue through a per-acre assessment/tax and not generating revenue through a volumetric water price. Organizations that used only per-acre assessments/taxes account for 35 percent of the acreage and 34 percent of water inflows attributable to water delivery organizations.

- The second most common method for pricing water deliveries involved a mix of both per-acre assessments/taxes and volumetric pricing. Twenty-four percent of water delivery organizations reported using both per-acre assessments/taxes and volumetric pricing to generate revenue from agricultural water deliveries. Organizations that used both per-acre assessments/taxes and volumetric pricing accounted for 38 percent and 34 percent of the acreage and water inflows, respectively, attributable to water delivery organizations.

- About 21 percent of water delivery organizations reported using only volumetric water pricing to generate revenue from agricultural water deliveries. These organizations accounted for approximately 24 percent and 28 percent of the acreage and water inflows, respectively, attributable to water delivery organizations.

[10] Some organizations may not rely on revenues to operate and maintain their conveyance and storage infrastructure. Instead, some organizations may rely on the labor of their constituents to maintain and operate their systems. These labor arrangements are relatively common among the communal irrigation organizations, or acequias, of the southwestern United States (Cox, 2014).

Figure 5
Methods used by irrigation organizations to price water deliveries, 2019



Note: This figure plots the percentage of organizations, acreage, and water inflows that used differing water pricing approaches in 2019. Percentages of organizations, acreage, and water inflows may not sum to 100 across the differing pricing approaches due to rounding. "Organizations" refers to the percentage of all organizations that reported delivering water to farms or ranches in 2019. "Acreage" refers to the percentage of all irrigated acreage that received water from an irrigation organization in 2019 and reported using a given water pricing approach. "Water inflows" refers to the percentage of all water brought into irrigation organization storage and conveyance facilities that reported using a given water pricing approach. "Volumetric pricing only" refers to those organizations that reported generating revenue derived from a volumetric (per acre-foot) price for irrigation water delivered to agricultural water users and also reported generating 0 revenue from per-acre assessments or taxes. An acre-foot is approximately 325,851 gallons of water. "Per-acre assessments/taxes only" refers to those organizations that reported generating revenue derived from per-acre assessments or taxes levied on agricultural water users and also reported generating 0 revenue from a volumetric (per acre-foot) price for irrigation water delivered to agricultural water users. "Mixed volumetric pricing and per-acre assessments/taxes" refers to those organizations that reported generating revenue derived from a volumetric (per acre-foot) price for irrigation water delivered to agricultural water users and also reported generating revenue from per-acre assessments or taxes levied on agricultural water users. "Other" corresponds to organizations that did not report generating revenue through either a volumetric or per-acre assessment/tax. In some cases, these organizations may have generated no revenue and instead relied on constituent labor to maintain and operate the organization's infrastructure. For example, some acequias, or communal irrigation organizations common in New Mexico and Southern Colorado, operate in this fashion.

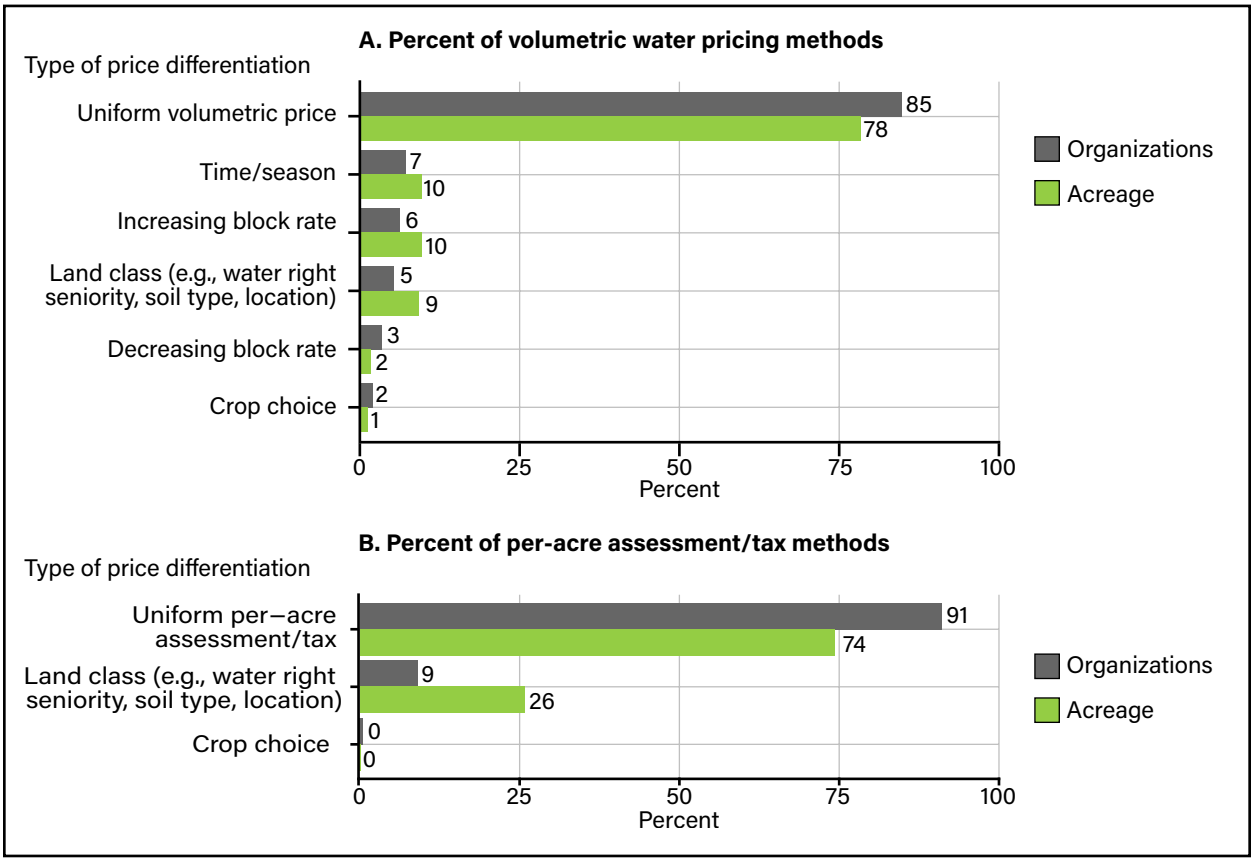
Source: USDA, Economic Research Service using data from the USDA 2019 Survey of Irrigation Organizations.

Relatively Few Irrigation Organizations Differentiate Their Volumetric Prices or Per-Acre Assessments/Taxes Based on Season, Use, Etc.

- Figure 6 shows that most irrigation water delivery organizations that reported using volumetric water pricing for irrigation water deliveries used a uniform price schedule where the price per acre-foot does not vary across time or users. About 85 percent of organizations that used volumetric pricing had a uniform price. These organizations accounted for about 78 percent of the acreage where volumetric pricing is used.
- It was relatively uncommon for water delivery organizations that used volumetric pricing to differentiate their prices. Only 7 percent of organizations that used volumetric pricing reported differentiating their prices based on time or season. Among those organizations that used volumetric pricing, 6 percent used an increasing block rate price schedule, while 5 percent differentiated prices based on land class.

- About 91 percent of organizations that charged per-acre assessments/taxes used a uniform price schedule where the per-acre assessment/tax did not vary across land types nor crops. These organizations accounted for approximately 74 percent of the acreage where per-acre assessments/taxes were used.
- Differentiating per-acre assessments/taxes for water delivery was relatively uncommon. About 9 percent of organizations that used per-acre assessments/taxes to generate revenue differentiated based on land class. However, these 9 percent of organizations accounted for about 26 percent of the acreage served by organizations that used per-acre assessments/taxes suggesting that larger organizations were more likely to differentiate per-acre assessments/taxes based on land class.

Figure 6
Differentiation in Volumetric Water Pricing and Per-Acre Taxes/Assessments, 2019



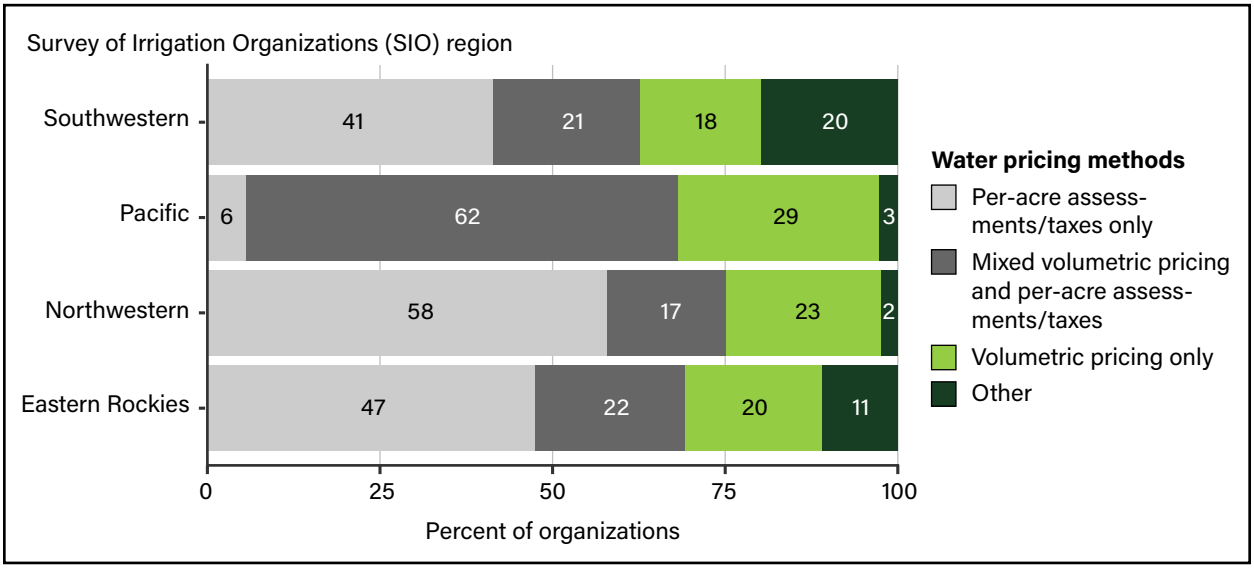
Note: This figure plots the percentage of organizations and acreage that differentiates volumetric prices and per-acre prices for irrigation water delivery in 2019. The top panel, A, presents the percentages of organizations and acreage served by those organizations that generated revenue through volumetric water pricing (i.e., per acre-foot) and used differing volumetric pricing approaches. The bottom panel, B, presents the percentage of organizations and acreage served by those organizations that generated revenue through per-acre taxes or assessments (i.e., per acre irrigated) and used differing per-acre pricing approaches. Organizations may differentiate volumetric water prices or per-acre taxes/assessments with multiple approaches. As such, sums may exceed 100. "Uniform volumetric price" refers to a pricing schedule where each unit of water has the same constant price. "Uniform per-acre price" refers to a pricing schedule where each acre of land irrigated has the same constant price. "Time/season" refers to volumetric pricing that varies across the growing season. "Increasing block rate" refers to volumetric pricing that varies based on the total quantity delivered within a given unit of time where the marginal price increases for larger quantities of water demand. "Land class" refers to volumetric prices or per-acre taxes/assessments that vary according to water right seniority, soil, location within the organization's system, etc. "Decreasing block rate" refers to volumetric pricing that varies based on the total quantity delivered within a given unit of time where the marginal price decreases for larger quantities of water demand. "Crop choice" refers to volumetric prices or per-acre taxes/assessments that vary according to the crop grown.

Source: USDA, Economic Research Service using data from the USDA 2019 Survey of Irrigation Organizations.

Approaches That Irrigation Organizations Use To Price Water Deliveries Differs Regionally, With Volumetric Pricing Being the Most Common in the Pacific Region

- Figure 7 indicates that the use of volumetric water pricing was most common in the Pacific region where about 29 percent of organizations used only volumetric water pricing to generate revenue from irrigation water deliveries. An additional 62 percent of organizations in the Pacific region generated revenue through a combination of volumetric pricing and per-acre assessments/taxes.
- Per-acre assessments/taxes were most common in the Northwestern region where approximately 58 percent of organizations generated revenue through per-acre assessments/taxes only. Volumetric water pricing was relatively uncommon in the region because 23 percent of organizations used volumetric pricing only, and 17 percent of organizations used a mix of volumetric pricing and per-acre assessments/taxes.
- The use of "other" water pricing approaches to maintain and operate water delivery systems was highest in the Southwest region where about 20 percent of organizations reported not charging volumetric nor per-acre prices.

Figure 7
Methods irrigation organizations use to price water deliveries by region, 2019



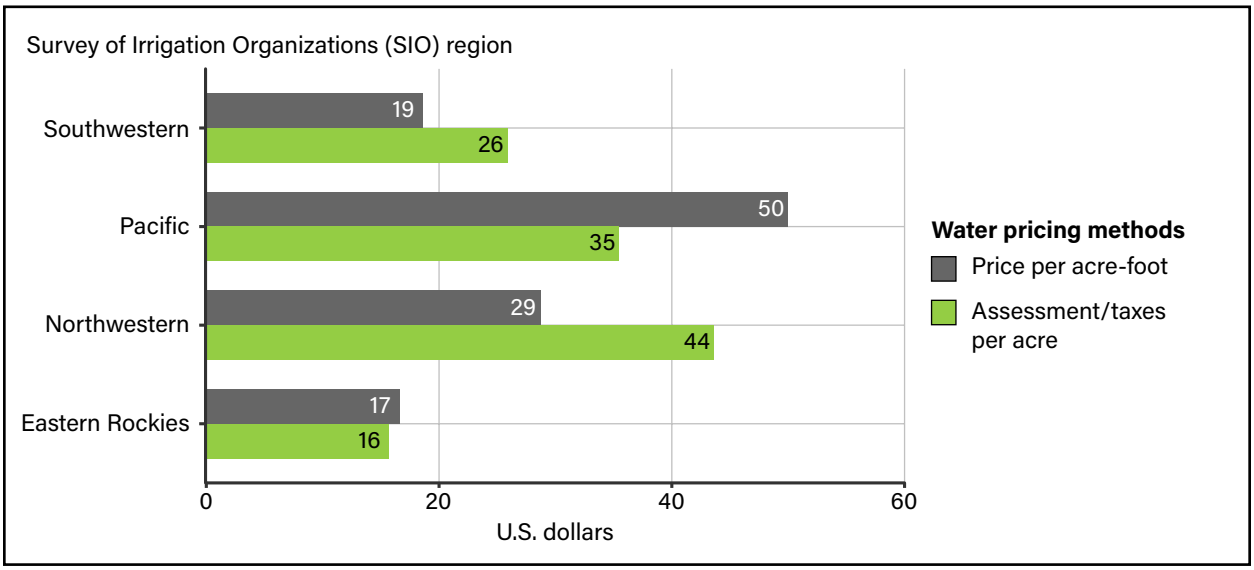
Note: This figure plots the percentage of organizations that used differing water pricing approaches in 2019. Organizations refers to the percentage of all organizations that reported delivering water to farms or ranches in 2019 and reported using a given water pricing approach. "Volumetric pricing only" refers to those organizations that reported generating revenue derived from a volumetric (per acre-foot) price for irrigation water delivered to agricultural water users and reported generating 0 revenue from per-acre assessments or taxes. An acre-foot is approximately 325,851 gallons of water. "Per-acre assessments/taxes only" refers to those organizations that reported generating revenue derived from per-acre assessments or taxes levied on agricultural water users and reported generating 0 revenue from a volumetric (per acre-foot) price for irrigation water delivered to agricultural water. "Mixed volumetric pricing and per-acre assessments/taxes" refers to those organizations that reported generating revenue derived from a volumetric (per acre-foot) price for irrigation water delivered to agricultural water users and reported generating revenue from per-acre assessments or taxes levied on agricultural water users. "Other" corresponds to organizations that did not report generating revenue through either a volumetric or per-acre assessment/tax. In some cases, these organizations may have generated no revenue and instead relied on constituent labor to maintain and operate the organization's infrastructure. For example, some acequias, or communal irrigation organizations common in New Mexico and Southern Colorado, operate in this fashion. SIO regions are as follows: Eastern Rockies (Colorado, Montana, and Wyoming), High Plains (Kansas, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas), Pacific (California and Nevada), Southeastern (Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina), and Southwestern (Arizona, New Mexico, and Utah). All remaining States were not part of the USDA 2019 Survey of Irrigation Organizations. Data for the Southeastern and High Plains regions are suppressed due to data disclosure rules.

Source: USDA, Economic Research Service using data from the USDA 2019 Survey of Irrigation Organizations.

Average Volumetric and Per-Acre Prices Are Highest in the Pacific and Northwestern Regions

- Figure 8 demonstrates that volumetric water prices (price per acre-foot) were highest in the Pacific region where the average organization charged about $50 per acre-foot of water delivered.
- Volumetric water prices were lowest in the Eastern Rockies and Southwestern regions where the average organization charged less than $20 per acre-foot of water delivered.
- Per-acre assessments/taxes were highest in the Northwestern region where the average assessment/tax was about $44 per acre irrigated and more than half of all organizations only used per-acre assessments/taxes.

Figure 8
Average volumetric and per-acre water prices by region, 2019



Note: This figure plots the average volumetric and per-acre prices by USDA 2019 Survey of Irrigation Organizations (SIO) region. "Price per acre-foot" refers to the volumetric price charged by the irrigation organization per acre-foot delivered to farms and ranches. An acre-foot is approximately 325,851 gallons of water. "Assessment/taxes per acre" refers to the price charged by the irrigation organization per acre irrigated with organization water. Average prices are calculated excluding observations exceeding the 95th percentile. SIO regions are as follows: Eastern Rockies (Colorado, Montana, and Wyoming), High Plains (Kansas, Nebraska, North Dakota, Oklahoma, South Dakota, and Texas), Pacific (California and Nevada), Southeastern (Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina), and Southwestern (Arizona, New Mexico, and Utah). All remaining States were not part of the SIO. Data for the Southeastern and High Plains regions are suppressed due to data disclosure rules.

Source: USDA, Economic Research Service using data from the USDA 2019 Survey of Irrigation Organizations.

Conclusion

Increasing competition for available water resources, combined with climate change projections suggesting greater water scarcity, underscores the importance of water conservation for the irrigated agricultural sector (Lehner et al., 2017). Irrigation water delivery organizations play a role in determining sector-level water conservation outcomes because these organizations manage much of the surface water used by the agricultural sector, particularly in the Western United States. How these organizations measure and price water deliveries contributes to water conservation. Accurate and timely water measurement allows organizations to identify and mitigate system losses, while volumetric water pricing can influence farmer and rancher incentives for conservation. This report provided an overview of the state of water measurement and pricing among irrigation water delivery organizations using data from the USDA 2019 Survey of Irrigation Organizations. Results indicated that many organizations do not measure water deliveries or incentivize on-farm conservation through volumetric pricing. This information might be useful in managing water supplies in the future.

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This Economic Brief is the fifth in a series of briefs based on the USDA 2019 Survey of Irrigation Organizations:

Irrigation Organizations:
Water Storage and Delivery Infrastructure

Irrigation Organizations:
Drought Planning and Response

Irrigation Organizations:
Groundwater Management

Irrigation Organizations:
Water Inflows and Outflows

Irrigation Organizations:
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