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Irrigation Organizations:

Drought Planning and Response

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Abstract

Using data from USDA's 2019 Survey of Irrigation Organizations (SIO), this report provides an overview of drought planning and response by irrigation districts, ditch companies, groundwater districts, and other similar irrigation organizations. While drought planning is common among State and local governments, only one-fifth of irrigation organizations have a formal drought plan. The majority of those plans include strategies for curtailing water deliveries or groundwater pumping in the event of drought. Irrigation organizations depend upon a wide range of meteorological and hydrologic data sources to plan for and respond to drought. These data allow organizations to choose which short- (e.g., land fallowing, leasing supplemental water supplies) and long-run (e.g., managed aquifer recharge) water management strategies best enhance their resiliency to drought. Conservation investments (e.g., flow rate metering and canal lining or piping) are another tool to improve long-run drought resilience. The most common reason that irrigation organizations cite for making these investments is "water supply variability and production risk," which illustrates the important role that these organizations play in determining the resilience of the irrigated agricultural sector to drought and water scarcity.

Acknowledgments: The authors would like to thank the team at USDA's National Agricultural Statistics Service for their work in designing and conducting the 2019 Survey of Irrigation Organizations. This report benefited significantly from comments received from Chris Hartley and Mark Brusberg from USDA's Office of the Chief Economist, Karina Schoengold from the University of Nebraska-Lincoln, and Jonathan Yoder from Washington State University.

Summary

Drought can have a major impact on irrigated agricultural production. Even though irrigation can provide some resilience to drought, major droughts are likely to diminish water available for irrigation, sometimes substantially. Since irrigation organizations are critical partners in decisions about distributing water or managing groundwater, the decisions and investments they make are vital to on-farm drought resilience. While some studies have looked at State-level, county-level, and even farm-level drought planning, little research exists on drought planning and drought response by irrigation organizations.

USDA's 2019 Survey of Irrigation Organizations (SIO) provides a nationally representative overview of the local water management entities that deliver irrigation water directly to farms and influence on-farm groundwater use. Water delivery organizations include irrigation districts, ditch companies, acequias, and other similar entities that manage the infrastructure required to transport irrigation water. Groundwater organizations include groundwater districts, as well as some delivery organizations. This report is one in a planned series of economic briefs that will provide basic statistics on key topics related to irrigation organizations.

This report asks basic questions about irrigation organizations and drought:

- How many organizations have drought plans?
- How do organizations with and without drought plans manage water supply shortfalls?
- What sort of conservation investments do organizations make that might help to mitigate drought risk?
- How important is drought risk as a driver of water conservation investments?

Key findings from this report include the following:

- Large water delivery organizations, defined as those serving at least 10,000 irrigable acres, serve almost four-fifths of all farmland irrigated with off-farm water.
- One-fifth of irrigation organizations are involved in both water delivery and at least one aspect of groundwater management.
- One-fifth of irrigation organizations have a formal drought plan.
- The most common component of these organizations' drought plans is guidance on how water use will be restricted during a drought.
- Most organizations—with or without a drought plan—respond to droughts by proportionately reducing water deliveries to all users.
- In 2019, about 4 percent of irrigation organizations engaged in managed aquifer recharge and collectively recharged more than 1 million acre-feet.
- Irrigation organizations rely heavily on snowpack reports and streamflow monitoring for short-run management decisions and on long-range weather forecasts and reservoir reports for long-run management decisions.
- Flow rate metering and canal lining are the most common water conservation investments made by irrigation organizations.
- Managing water supply risk and drought risk is the primary reason that organizations make water conservation investments.

Overview of Irrigation Organizations and Drought Resilience

Water, soil, seeds, and sun are the basic ingredients for agricultural production. For an estimated 17 percent of U.S. harvested cropland and 1 percent of U.S. pasture and rangeland, irrigation provides at least a portion of the water necessary to meet crop requirements (See appendix for details). Irrigation water can come from off-farm water suppliers, directly from streams or rivers, on-farm groundwater pumping, or on-farm storage such as large ponds. The amount of water available from all sources varies widely across the country and seasonally. While on-farm surface water can be managed almost exclusively by individual farmers, off-farm surface water and on-farm groundwater often require some level of regional or local coordination. This coordination occurs within the context of irrigation water rights, which are defined differently across States (see box titled "Water Rights").

Off-farm surface water is delivered to farms through a series of canals, ditches, pipes, and reservoirs. This infrastructure is often built, maintained, and managed by a water delivery organization such as a ditch company, an irrigation district, or an acequia. Ditch companies, which are sometimes referred to as "mutuals," are typically organized as a business that sells shares that entitle the owners to delivery of water (Goodman and Howe, 1997). Some ditch companies are formally incorporated, while others are unincorporated. Irrigation districts are typically authorized by their State government to assess fees for provision of water within specified service areas (Leshy, 1982). Acequias, which are common in the Southwest, are a form of cooperative management of irrigation delivery systems (Rivera, 1998).

On-farm groundwater pumping can require local coordination since farms influence each other's water availability through their long-run pumping decisions. In these cases, it is increasingly common for some level of coordination and management to be accomplished through a groundwater district or similar entity (Cody et al., 2015, Megdal et al., 2015). The responsibilities of a groundwater management organization can vary widely from a simple information-gathering role to direct regulation of groundwater withdrawals.

The USDA's 2019 Survey of Irrigation Organizations (SIO) provides a nationally representative look at these water delivery and groundwater organizations (see the box titled"2019 Survey of Irrigation Organizations"). Water delivery organizations were last surveyed on a national scale in the 1978 U.S. Census of Irrigation Organizations. Groundwater organizations have never been subject to a comprehensive Federal data collection effort.

While irrigation serves as a buffer against the impacts of drought on crop production, the water sources used for irrigation are all subject to varying degrees of drought vulnerability. Surface water supplies are typically reduced, sometimes considerably, during prolonged drought events. Groundwater supplies are often pumped at greater rates during drought, which can lead to aquifer depletion and reduced long-term availability. There are large geographic differences in regional exposure to drought risk, reflecting the likelihood or historical frequency of drought. Drought risk is also expected to increase in most regions due to climate change, particularly in the Southwestern and Western States (Strzepek et al., 2010). Irrigation organizations play a critical role in determining how this exposure to drought risk is translated into farm-level outcomes. The management decisions of irrigation organizations are one important driver of agricultural drought resilience which is the ability of farms and ranches to reduce and absorb the impacts of drought.

2019 Survey of Irrigation Organizations

The 2019 Survey of Irrigation Organizations collected data on irrigation organizations in 24 States within the United States, where these organizations are most common (see appendix for the list of States). The SIO was a collaboration between the U.S. Department of Agriculture's Economic Research Service (ERS), National Agricultural Statistics Service (NASS), and the Office of the Chief Economist (OCE). 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, and irrigation mutuals. Organizations that influence on-farm groundwater use include groundwater management districts, natural resource districts, and groundwater sustainability agencies, depending on State-enabling legislation. Some irrigation organizations engage in both on-farm groundwater management and water delivery.

The 2019 SIO was the first nationally representative Federal data collection effort aimed at irrigation organizations since the U.S. Census Bureau conducted the 1978 Census of Irrigation Organizations (CIO). The 1978 CIO did not collect information on organizations that influence groundwater use, as 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.

Water Rights

The legal institutions defining the rights to use of water differ across States.[1] In the Eastern United States, the ownership of surface water follows the riparian doctrine which assigns water rights based on the ownership of land adjacent to streams and rivers. Generally, in the Western United States, the ownership of surface water is based on the doctrine of prior appropriation where water rights are granted based on historical, beneficial use of water rather than the ownership of riparian land (Haar and Gordon, 1958; Huffaker, Whittlesey, and Hamilton, 2000).

Under prior appropriation, water rights are assigned "seniority" or "priority" based on the first documented diversion of water for an approved beneficial use. In times of water scarcity, junior water withdrawals are restricted or "curtailed" based on seniority, meaning that the most junior rights holders are the most likely to face water supply shortages during drought. When regions using the riparian doctrine face water scarcity, an individual's use is limited to an amount of water that does not materially injure downstream users' access to water. As such, the riparian doctrine proportionally allocates water curtailments in times of drought and water scarcity. In contrast, prior appropriation curtails water use in time of scarcity according to seniority imposing the bulk of the costs of water scarcity on the junior water rights holders.

Where prior appropriation applies, many water users hold a portfolio of senior and junior water rights (Payne et al., 2014). Water rights may be held by either individuals or private irrigation organizations (e.g., ditch companies, mutual irrigation companies, etc.) and often specify an allowed location of use as well. When an organization holds the rights, irrigators with access to the canals and ditches can buy shares in the organization that entitles the owner to a percentage of the organization's total water supply each year (Rice and White, 1987). In many basins, particularly those with fully adjudicated and well-defined water-use property rights, water rights are transferrable and active markets have developed for irrigation organization shares and individual water rights (Goodman and Howe, 1997).

Legally, in an important variation on the idea of water rights, many irrigators and irrigation organizations hold long-term "contract entitlements" rather than "rights" to water (Hanak and Stryjewski, 2012). In these arrangements, local public irrigation organizations purchase their water under terms specified in contracts with the State or Federal agencies that operate large-scale water conveyance and storage infrastructure. Since some irrigators held prior appropriation rights that were established before the development of these large irrigation projects, the terms of their agreements for water delivery are set under adjudicated "settlements" rather than the standard contracts, which effectively creates a tier of seniority within these projects.

The doctrines governing groundwater-use rights also differ significantly across the United States.[2] Laws governing groundwater use can be classified into one of five categories: absolute dominion, the reasonable use doctrine, correlative rights, appropriative rights, and regulated riparianism (Dellapena, 2012). Relatively uncommon in the United States, the absolute dominion doctrine[3] allows unlimited withdrawals of water beneath the owner's land regardless of the impact on other nearby groundwater users (Bryner and Purcell, 2003). The reasonable use doctrine modifies the absolute dominion rule in that groundwater extraction must be "reasonable" and applied in a beneficial manner on land overlying the groundwater source. Correlative rights for groundwater are similar to the riparian doctrine of surface water law in that each owner of property overlying a groundwater source has an equal right to groundwater and all owners must proportionally reduce their use in times of scarcity. The doctrine of prior appropriation is also applied to groundwater law where priority in use is given to those property owners that first extracted water for a beneficial use. Regulated riparianism grants the right to use water through a State permitting process that outlines water-use rules designed to protect other users' rights. In some areas, groundwater and surface water are managed jointly through a process known as conjunctive management, in which the hydrological interactions between aquifers and streams are considered in setting rules about allowable water withdrawals.

[1]See Richardson and Aloi (2017) for a comprehensive review of State-level laws regarding surface and groundwater.

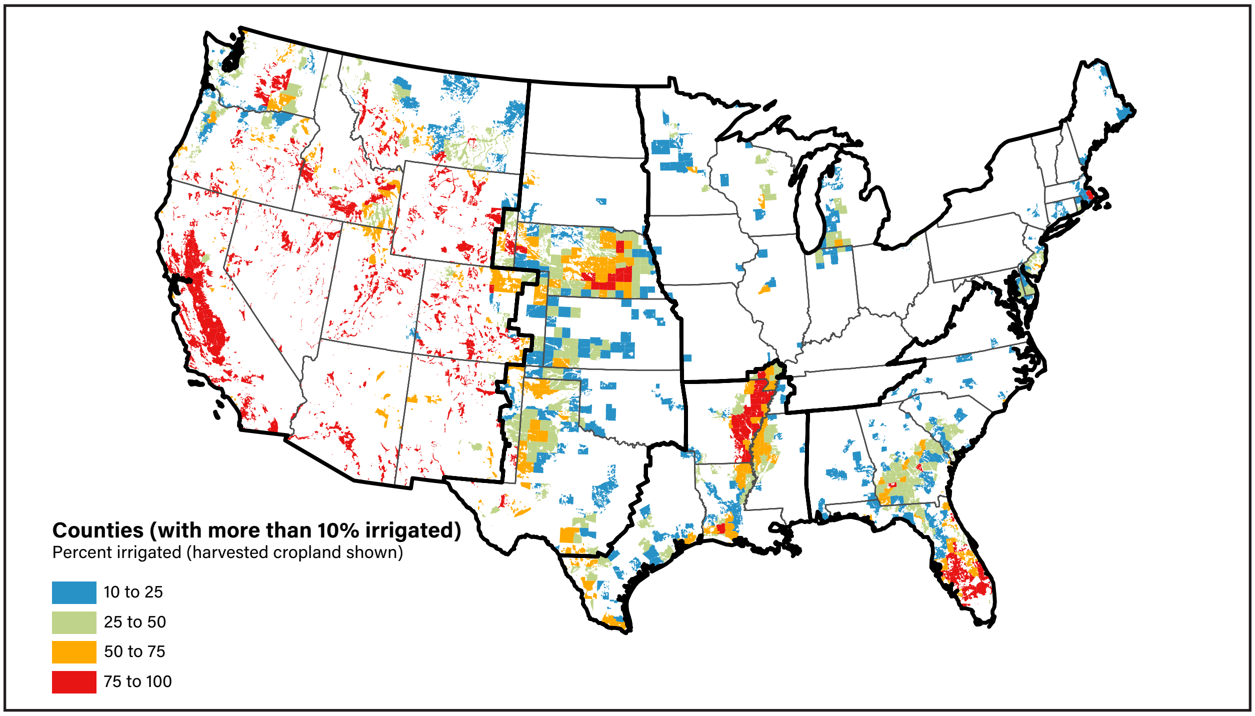
[2]See Dellapena (2012) and USDA-FS (2005) for a complete treatment of groundwater laws and State-level variations in their implementation.

[3]Absolute dominion doctrine is also referred to as the absolute ownership rule or the rule of capture. Variants of the absolute dominion doctrine define groundwater law in Indiana, Maine, and Texas.

The Geography of Irrigation

- In the Western United States, the large majority of cropland is irrigated, often with off-farm surface water that is transported over long distances through canals and pipes. Many of these areas also have complex groundwater resources that hydrologically interact with surface water resources and uses.
- In the Central Plains, most irrigation is dependent on groundwater. These aquifers are often slow to recharge in many areas, which can lead to significant overdraft, particularly in the central and southern portions of the Ogallala aquifer.
- In the Mississippi Delta region, irrigation is also largely dependent on groundwater. While these aquifers, such as the Mississippi Embayment and the coastal aquifers in Texas and Louisiana can recharge at much more rapid rates than the Ogallala, groundwater overdraft is a major concern in some locations (Konikow, 2013).
- In the Southeast region, most irrigation relies on groundwater. With the exception of Florida, these groundwater systems tend to store limited amounts of water while also benefitting from higher rates of natural recharge than other aquifers.
- In the Midwest, Lake States, and Northeast region, there are significant pockets of irrigated area where resources allow, but the overall scale is limited.

Figure 1
Irrigated cropland in the United States, 2017



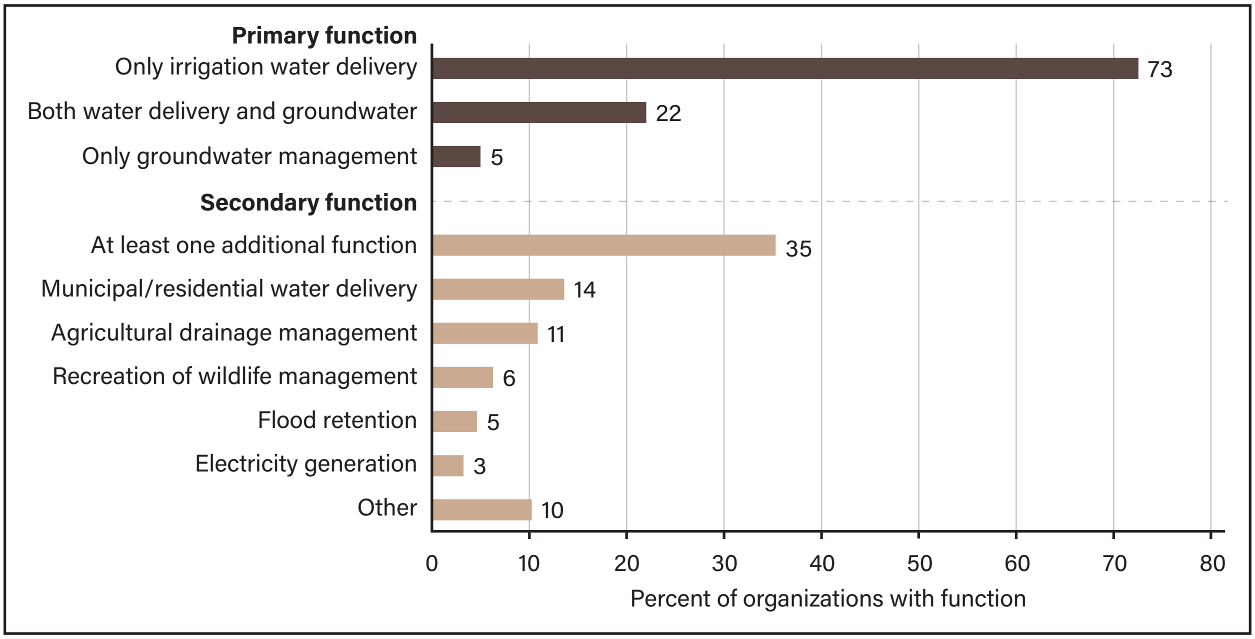
Notes: The regions used in this figure are based on USDA, Economic Research Service analysis of irrigated acreage and major aquifer boundaries. These regions do not directly correspond to other regions used for economic analysis such as Farm Production Regions or Farm Resource Regions. Regions as shown in the figure are: the Western United States (Washington, Oregon, California, Nevada, Arizona, Idaho, Montana, Utah, and the majority of Colorado, New Mexico, and Wyoming); the Central Plains (North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, Western Texas, and eastern portions of Wyoming, Colorado, and New Mexico); the Mississippi Delta region (Eastern and Southern Texas, Louisiana, Arkansas, Southeastern Missouri, West Tennessee, and Mississippi); the Southeast Region (Alabama, Georgia, Florida, South Carolina, North Carolina, Virginia). The Midwest, Lake States, and Northeast regions are grouped together as an area with limited areas of mostly supplemental irrigation. Irrigated areas in Alaska and Hawaii are not shown.

Source: USDA, Economic Research Service analysis of county-level irrigated and total harvested cropland acres data for 2017. Missing county-level estimates for 2017 are replaced with an average of estimates from 1997 to 2012.

The Functions of Irrigation Organizations

- The 2019 SIO collected information on organizations that, as their primary function, interact directly with irrigating farms and ranches either through delivery of water or through groundwater management. The SIO data represents an estimated 2,677 irrigation organizations in the United States.
  - About three-quarters of irrigation organizations have only water delivery as their primary function.
  - About one-fifth of irrigation organizations have both water delivery and groundwater management as their primary functions.
  - Only 5 percent of irrigation organizations have only groundwater management as their primary function.
- About one-third of irrigation organizations perform at least one secondary, water-related function such as delivering water to municipal or residential users, managed agricultural drainage or recreation and wildlife, flood retention, or electricity generation. The most common secondary function (14 percent of organizations) is delivery of water to municipal or residential users.

Figure 2
U.S. irrigation organizations by function



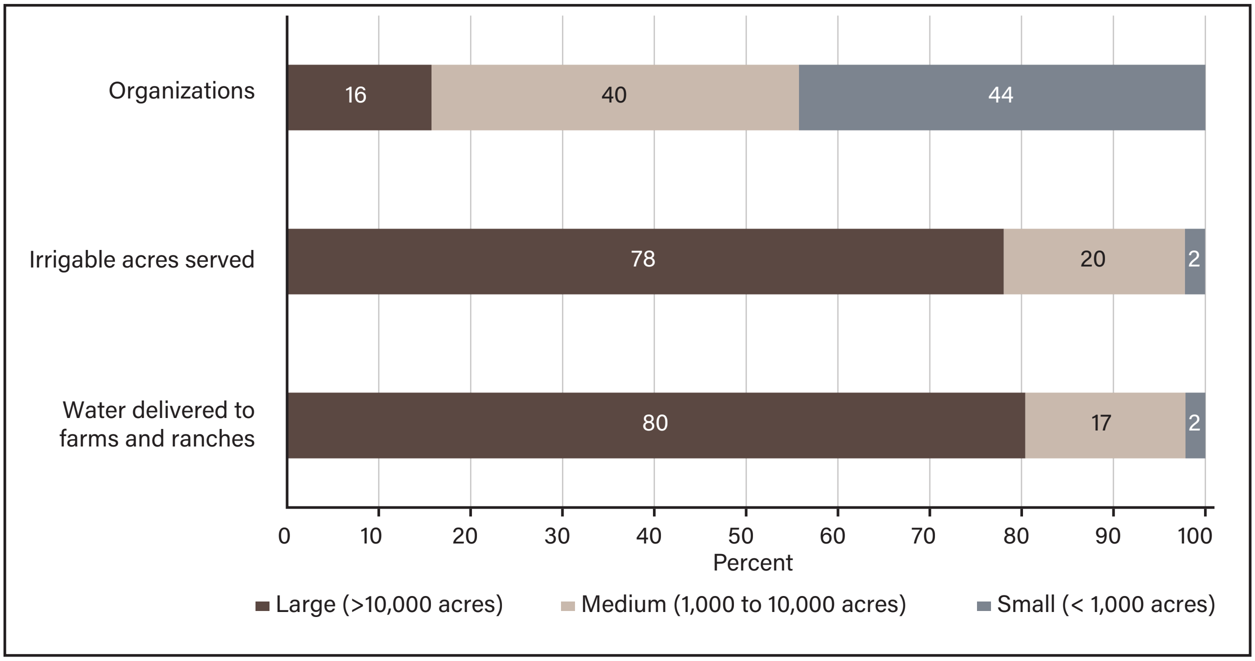
Note: Irrigation organization as defined in this study can have multiple secondary functions or not secondary functions.

Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

The Scale of Irrigation Organizations

- This report groups water delivery organizations according to the number of irrigable acres served by the organization. Irrigable acres are farmland that could have received water 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.
- Large delivery organizations accounted for 16 percent of all delivery organizations in 2019 but also accounted for the bulk of acres served and water delivered. In 2019, the large delivery organizations served 78 percent of irrigable acres and delivered 80 percent of the off-farm water to farms and ranches.
- Medium delivery organizations accounted for 40 percent of all delivery organizations. They served 20 percent of irrigable acres and delivered 17 percent of off-farm water to farms and ranches in 2019.
- Small delivery organizations accounted for 44 percent of all delivery organizations. They served 2 percent of irrigable acres and delivered 2 percent of off-farm water to farms and ranches in 2019.

Figure 3
Delivery organization size and scope



Note: Due to rounding, percentages may not add to 100.

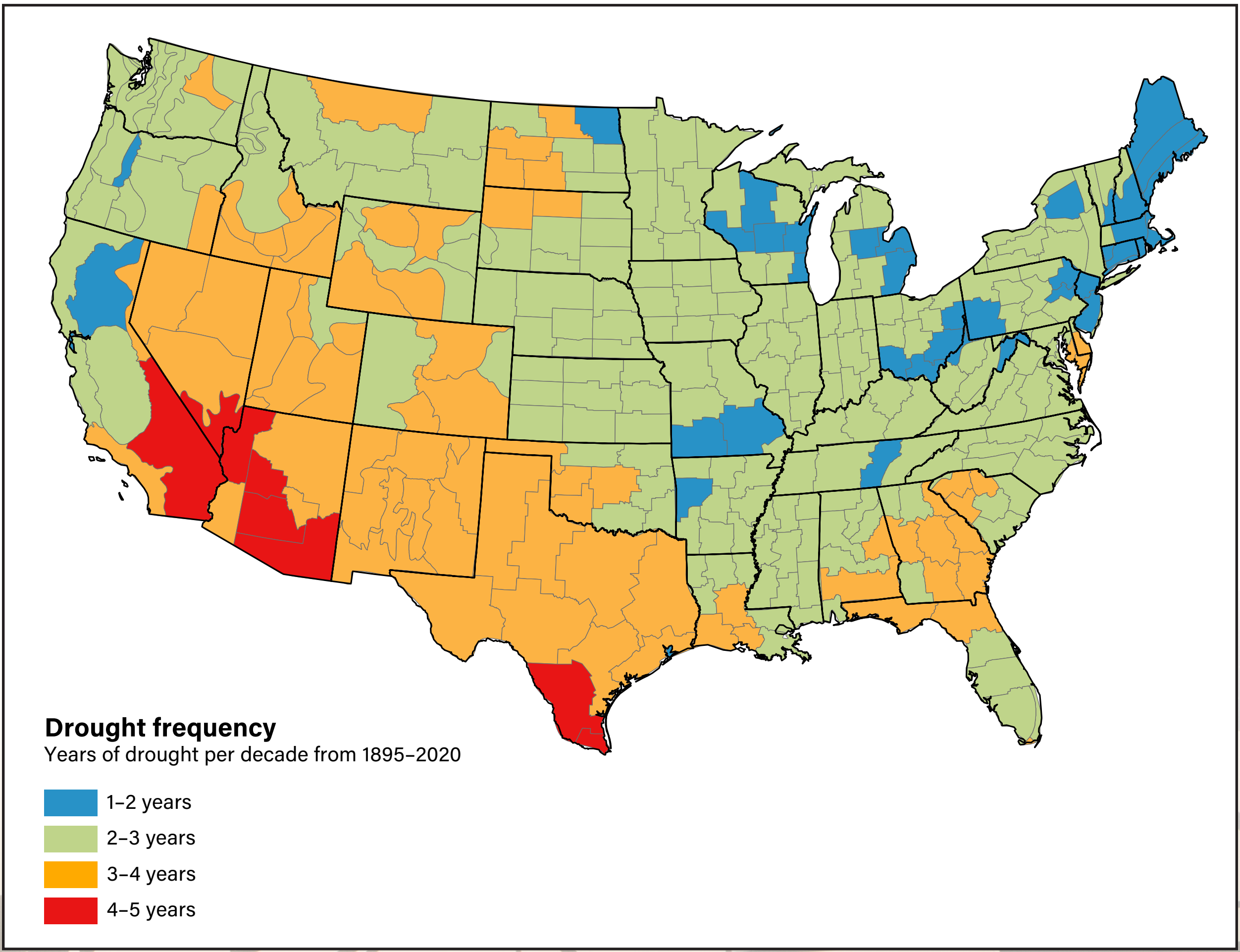
Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

The Geography of Drought Risk

- One useful measure of drought risk is based on the Palmer (Modified) Drought Index (PMDI) which converts temperature and precipitations over a chosen time period into a measure of drought severity (Palmer 1965, Wallander et al., 2013, Diffenbaugh et al., 2015).
- The historical frequency of moderate or worse drought during the summer growing season illustrates broad regional differences in exposure to drought risk. In many mountainous areas of the Western United States, drought risk over winter months and its impact on snowpack is a better measure of their risk of water supply reductions during the growing season. Since these areas and others are obtaining off-farm supplies from great distances, their exposure to risk is more strongly determined by the drought frequency in their supply watershed rather than where the farms and ranches are located. Lastly, water rights are an important component of drought risk. Senior water-rights holders will face lower risk than junior-rights holders.
- The Southwestern United States has the highest drought exposure with an average of four to five droughts per decade.
- The second highest risk areas, with three to four droughts per decade, are the Central Rocky Mountains, the Southern Plains, and parts of the Southeast.
- The mid-range risk areas, with two to three droughts per decade, include much of the Midwest and Appalachian regions.
- The lowest measures of drought risk, with one to two droughts per decade, are the Northeast, the Lake States, and part of Northern California.
- As a result of climate change, drought risk is expected to increase in many parts of the United States (Strzepek et al., 2010, Cook et al., 2015, Diffenbaugh et al., 2015)

Figure 4

Regional variation in drought risk



Notes: Drought intensity is measured using the Palmer Modified Drought Index (PMDI). Drought frequency is the number of years per decade in which at least 1 summer month (June, July or August) had moderate to extreme drought severity (PMDI less than or equal to -2.00).

Source: USDA, Economic Research Service analysis using National Oceanic and Atmospheric Administration historical data by climate district.

Drought Planning and Response

Given that all regions of the country face some degree of drought risk, advance planning for how to respond to drought can be an important source of improved drought resilience. Drought planning can occur at the individual farm or ranch level (Haigh et al., 2021), at the county level (California Department of Water Resources, 2021), and at the State level (Wilhite et al., 2000, Fu et al., 2013). Drought planning can also occur at the level of the irrigation organizations, although very little research has been done on planning at that level. A formal drought plan specifies measures and strategies for how individuals and organizations will respond prior to and during a drought. Often these plans specify actions to be taken at each level of governance or decision making based on measures of drought severity such as the Drought Monitor, which was developed in part to facilitate such planning and response (Wilhite et al., 2000).

Many individual States also have drought plans outlining State-level responses to drought conditions and/or plans to mitigate the impact of future droughts. The National Drought Mitigation Center reports that 45 of the 48 States in the contiguous United States have a formal State-level drought plan (NDMC 2021). State drought plans can involve recommendations or policies that will influence how irrigation organizations respond to drought. For example, Colorado's drought plan promotes tools to facilitate water transfers between agricultural users and municipal users and suggests increased funding for irrigation ditch maintenance (CWCB 2018). Almost all State drought plans (98 percent) specify drought responses that require intergovernmental coordination, which may include interaction between the State and local entities such as irrigation organizations (Fu et al., 2013). In some cases, State laws require certain types of organizations to have drought plans or similar formal assessments of water scarcity. For example, both Texas and California require groundwater districts to engage in formal planning.

Since droughts often reduce water supply availability, irrigation delivery organizations typically have to restrict water deliveries when insufficient supplies are available. These reductions in deliveries are commonly referred to as "curtailments" and can be implemented in different ways (Burt et al., 1996, Velpuri et al., 2020). In some cases, groundwater withdrawals can also be restricted during drought, often due to interactions between groundwater and surface water. This interaction is referred to as conjunctive management (Galloway et al., 2003). Drought plans can provide farms and ranches with advance information about what sorts of curtailments will be expected under different levels of drought (Coppock, 2011).

Other methods of dealing with drought-induced water supply shortfalls include changes in water pricing—the use of higher water delivery charges during drought—and land fallowing. Increases in water pricing during drought has a dual effect of incentivizing farms and ranches to reduce demand and offsetting revenue losses for the irrigation organization during drought (Johansson et al., 2002). Land fallowing programs involve reducing deliveries by temporarily taking some land out of irrigated production during a drought. The concept of land fallowing is that it can be lower cost, either in terms of total production or administratively, to totally eliminate deliveries on a small set of land rather than have small reductions in deliveries across most or all of the served land (Zilberman et al., 2002).

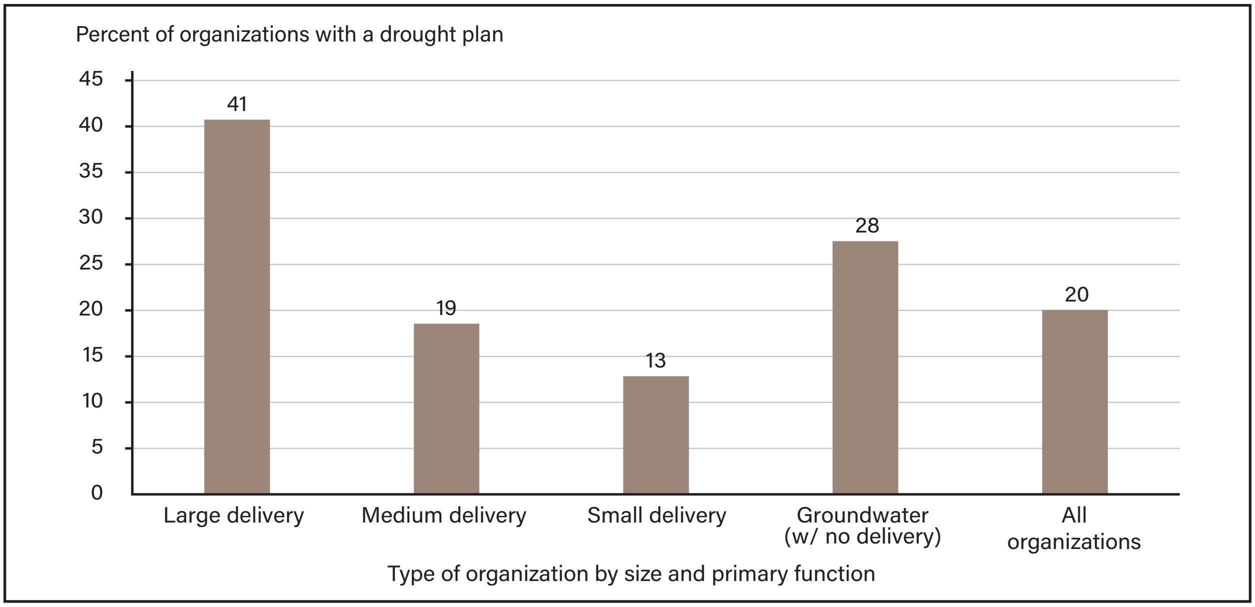
Supply augmentation is an alternative approach to these demand management strategies. In some cases, as a short-run response, irrigation organizations can temporarily acquire additional water supplies during a drought through transfer of water-use rights through tools such as water leases (Hanak and Stryjewski, 2012). Some irrigation organizations can use their reservoirs or managed aquifer recharge to store "excess" water during nondrought years and draw on that storage during drought years (Scanlon et al., 2016, Tran et al., 2020). Since both water purchases and water storage can involve significant capital investment, drought plans can provide important information for an irrigation organization's customers about the extent to which the organization is pursuing alternatives to curtailments and other demand management policies.

Adoption of Formal Drought Plans

- Only one-fifth of organizations report having a formal drought plan.
- Adoption of plans among delivery organizations varies by organization size and type. Large delivery organizations, which have the capacity to deliver water to more than 10,000 acres, are three times as likely to have a drought plan as small organizations, which only have the capacity to deliver water to 1,000 or fewer acres (41 versus 13 percent).
- About 28 percent of those groundwater organizations with no water delivery role have a formal drought plan.

Figure 5

Percentage of organizations with drought plans by size and type

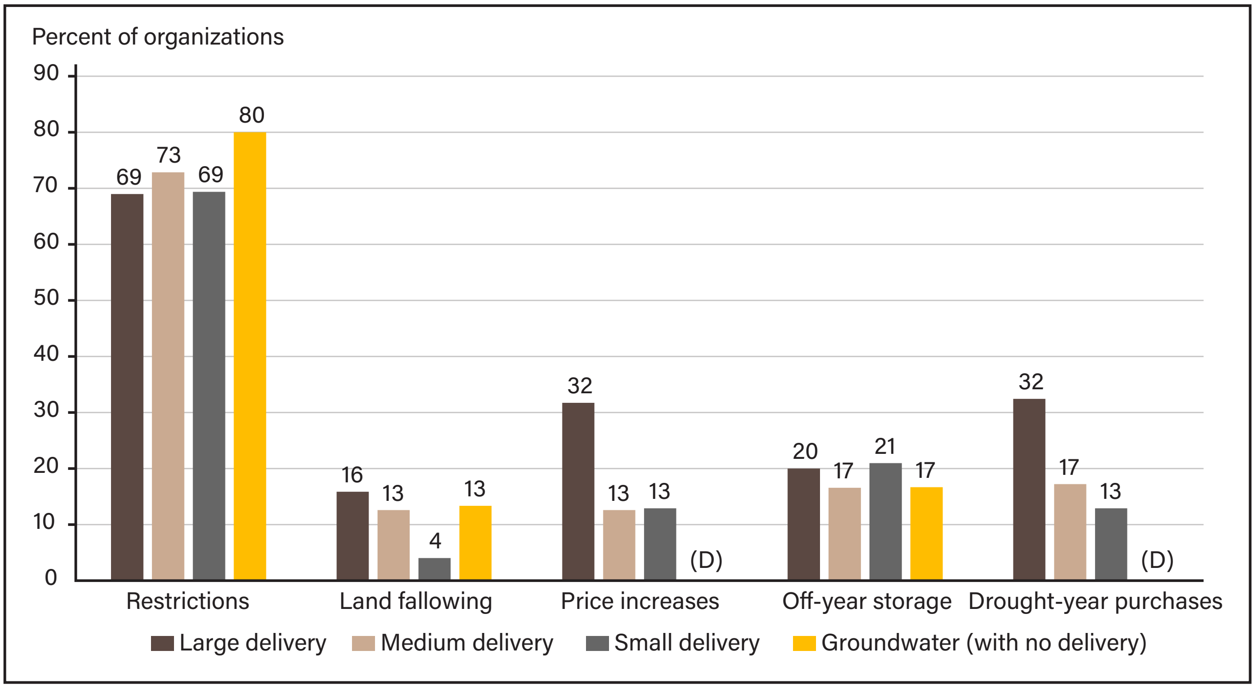


Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Drought Plan Contents

- Most organizations with plans (69 to 80 percent by type and size) specify how water delivery will be curtailed or pumping will be restricted during drought.
- Provisions to increase water supply during drought years through acquisition of additional water is included in about 32 percent of the plans of large delivery organizations but only about 13 to 17 percent of other organizations' plans.
- Drought pricing—the use of higher water delivery charges during drought—are included in about 32 percent of the drought plans of large organizations but only about 13 percent of other organizations' plans.
- Between 17 and 21 percent of organizations' plans include provisions to increase water storage during nondrought years as a buffer against supply shortfalls in drought years.
- Land fallowing is the least common component of formal drought plans, included in only 13 to 16 percent of plans for most types of organizations and just 4 percent of the plans of small organizations.

Figure 6
Drought plan components by irrigation organization type



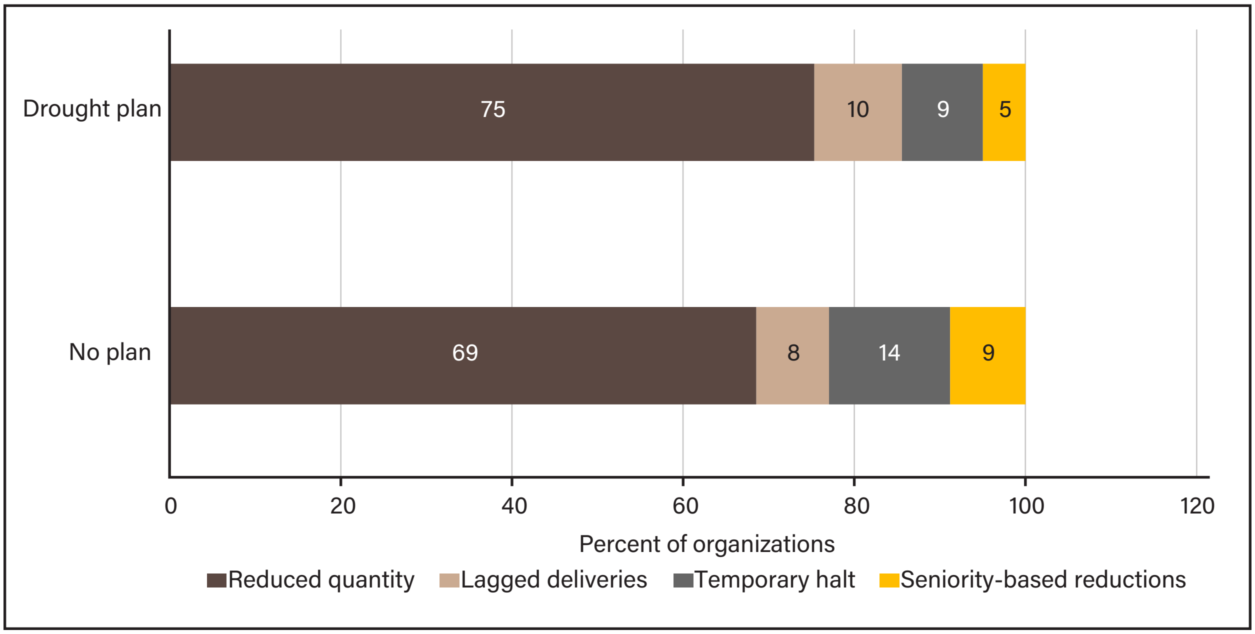
Note: (D) Withheld to avoid disclosing data for individual operations.

Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Methods for Reducing Water Deliveries During Drought

- Water available to delivery organizations can be reduced due to larger suppliers, such as State or Federal water projects, curtailing their deliveries or due to another water user within their water basin placing a “water call” that requires other users with more junior water rights to reduce their withdrawals. When these supply reductions occur, water delivery organizations can use different approaches to curtail deliveries within their service area.
- The most common approach for reducing water deliveries during drought is to proportionately reduce the quantity for all diversions from the irrigation delivery system. Organizations with drought plans are slightly more likely to utilize this approach.
- Three other approaches to curtailments: reducing the frequency of deliveries by introducing lags to the delivery schedule; imposing a temporary halt to all deliveries; and varying the reductions in water deliveries based on seniority of water rights within the service area.
- Delivery organizations without plans are more likely to use either the approach of a temporary halt to all deliveries or seniority-based reductions.

Figure 7
Approaches for implementing water delivery curtailments



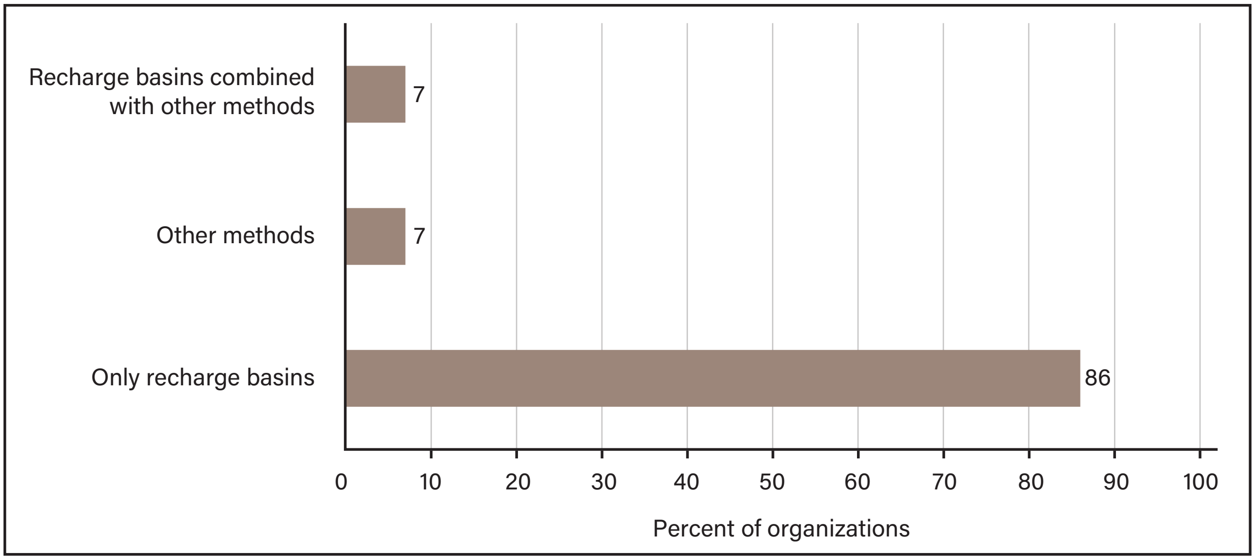
Note: Due to rounding, percentages may not add to 100.

Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Managed Aquifer Recharge

- Irrigation organizations use several different methods to intentionally recharge aquifers, including recharge basins (also known as infiltration basins or percolation ponds), injection wells, on-field water spreading, and other methods.
- In 2019, only 4 percent of irrigation organizations reported using managed aquifer recharge (MAR) to intentionally augment groundwater supplies in 2019.
- Irrigation organizations using MAR in 2019 recharged about 1.1 million acre-feet of water. Most organizations engaged in MAR relied exclusively on recharge basins (86 percent), while smaller shares relied on exclusive use of on-field spreading or other methods (7 percent) or a combination of recharge basins and other methods (7 percent).

Figure 8
Methods of managed aquifer recharge by irrigation organizations in 2019



Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Information Use

Drought planning, drought response, and even regular operations by irrigation organizations all rely on different information sources. Drought plans commonly draw on information such as the Drought Monitor and long-range weather forecasts (Wilhite and Svoboda, 2000). Information can influence farm and ranch decision making in response to drought (Shrum et al., 2018). However, many users continue to operate without the benefit of longer range information (Marshall et al., 2011).

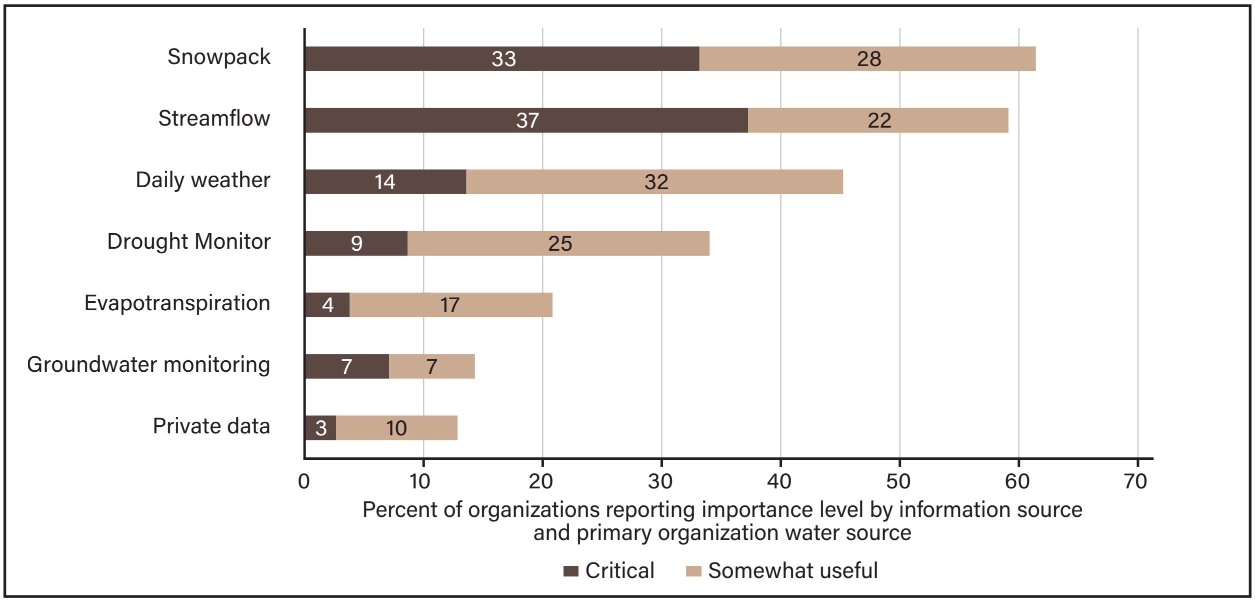
A wide range of data sources are available for irrigation organizations to use for short-run management decisions. For organizations that rely on water delivered from reservoirs that catch runoff from snowpack, the USDA, Natural Resources Conservation Service (NRCS) produces regular updates from a complex snow monitoring program (Pierce, 2010, Manning et al., 2017). For systems that rely on surface water flows, the U.S. Geological Survey (USGS) maintains an extensive stream gauge monitoring network (Erwin and Hamilton, 2005). Daily weather forecasts, available from many sources, can provide useful, indirect information on likely crop water requirements. More refined estimates of crop water requirements can be obtained from a variety of evapotranspiration monitoring networks, many of which are managed by State universities in collaboration with USDA and other partners (e.g., Colorado State University, 2021). For groundwater organizations, the USGS maintains a network of groundwater monitoring wells, and many States have similar, complementary networks.

The information sources used for long-run management decisions such as capital investment are similar but often involve more modeling and forecasting. Long-run weather forecasts can be highly useful for both farm-level production decisions and water-demand projections for organizations. These forecasts are improving in accuracy based on new insights about drivers or seasonal and regional weather patterns (Jones et al., 2000). Water allocation from Federal water projects is based on a combination of reservoir reports and water forecasts for a given “water year” (e.g., USBR, 2019; see appendix). For management decisions that span many years, climate change information and water supply forecasts can be important (Lemos et al., 2012). For groundwater organizations, the long-range information equivalent to well-based monitoring networks is the use of groundwater models to simulate aquifer conditions under alternative extraction and recharge scenarios (Johnson et al., 2011).

Information Sources for Short-Run Management

- More than half of irrigation organizations rely on information about snowpack, such as the snow telemetry (SNOTEL) monitoring network managed by USDA, and streamflow levels, such as those provided by USGS, for their short-run management decisions.
- For the use of snowpack monitoring, restricting the population analyzed to irrigation delivery organizations in the Western States slightly increases the share of organizations using such information, to 64 percent from the 61 percent shown in figure 9.
- More than one-third of organizations rely on daily weather forecasts, which are produced by National Oceanic and Atmospheric Administration (NOAA), and the Drought Monitor, a weekly report on regional drought severity produced as a partnership by USDA, NOAA, and the National Drought Mitigation Center, as a compilation of multiple drought metrics.
- For use of streamflow monitoring, restricting the population analyzed to all irrigation delivery organizations increases the share of organizations using such information to 60 percent from the 59 percent shown in figure 9.
- The least commonly used information sources are evapotranspiration monitoring and groundwater monitoring.
- For use of groundwater monitoring, restricting the population analyzed to all groundwater organizations (including those that also deliver water) increases the share of organizations to 39 percent from the 14 percent shown in figure 9.

Figure 9
Importance of information sources for short-run management decisions



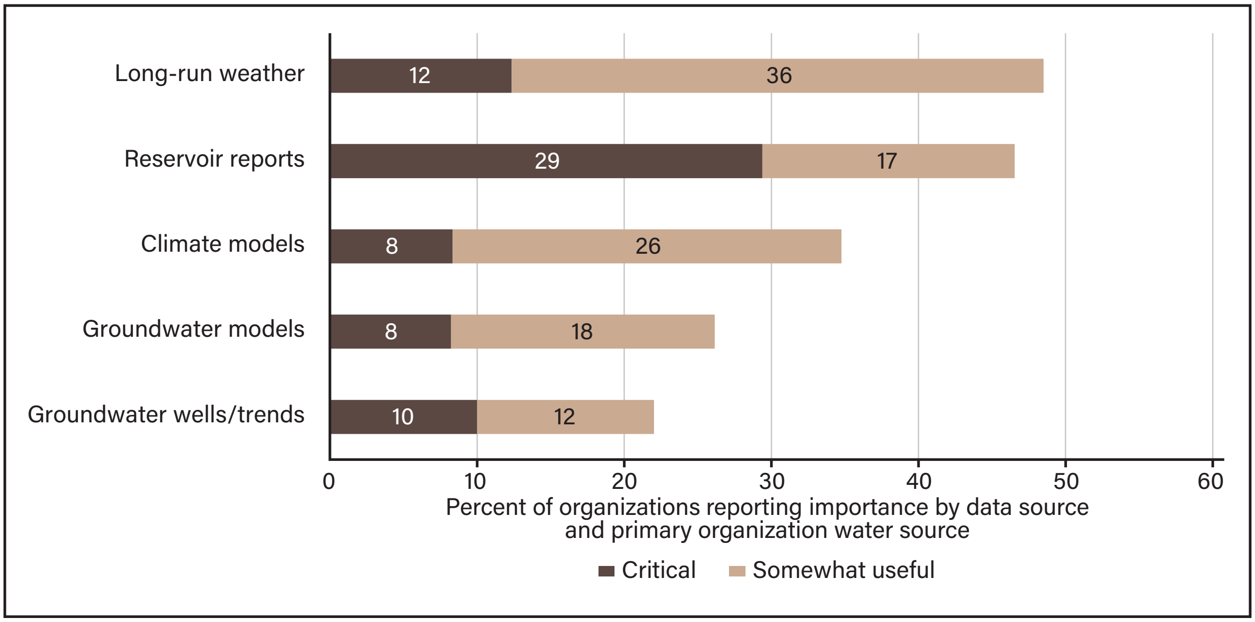
Note: Organizations indicated whether each information source was of critical use, somewhat useful, or not used for purposes of short-run planning and decision making in 2019.

Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Information Sources for Long-Run Planning

- For long-run planning and management, almost half of organizations rely on long-run weather forecasts and reservoir reports. Reservoir reports have the highest level of critical importance among organizations (almost 30 percent).
- For use of reservoir reports, restricting the population analyzed to irrigation delivery organizations that receive water from Federal or State water projects increases the share using such information to 69 percent from the 46 percent shown in figure 10.
- About one-third of organizations rely on climate models for long-run planning and management.
- Almost one-fourth of organizations rely on groundwater monitoring wells or analysis of trends in groundwater levels.
- For the use of groundwater models, restricting the population analyzed to all groundwater organizations (including those that also deliver water) increases the share using such information to 43 percent from the 26 percent shown in figure 10.
- For the use of groundwater wells and trend analysis, restricting the population analyzed to all groundwater organizations (including those that also deliver water) increases the share using such information to 46 percent from the 22 percent shown in figure 10.

Figure 10
Importance of information sources for long-range planning and management



Note: Organizations indicated whether each information source was of critical use, somewhat useful, or not used for purposes of long-run planning and decisions making.

Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Conservation Investment

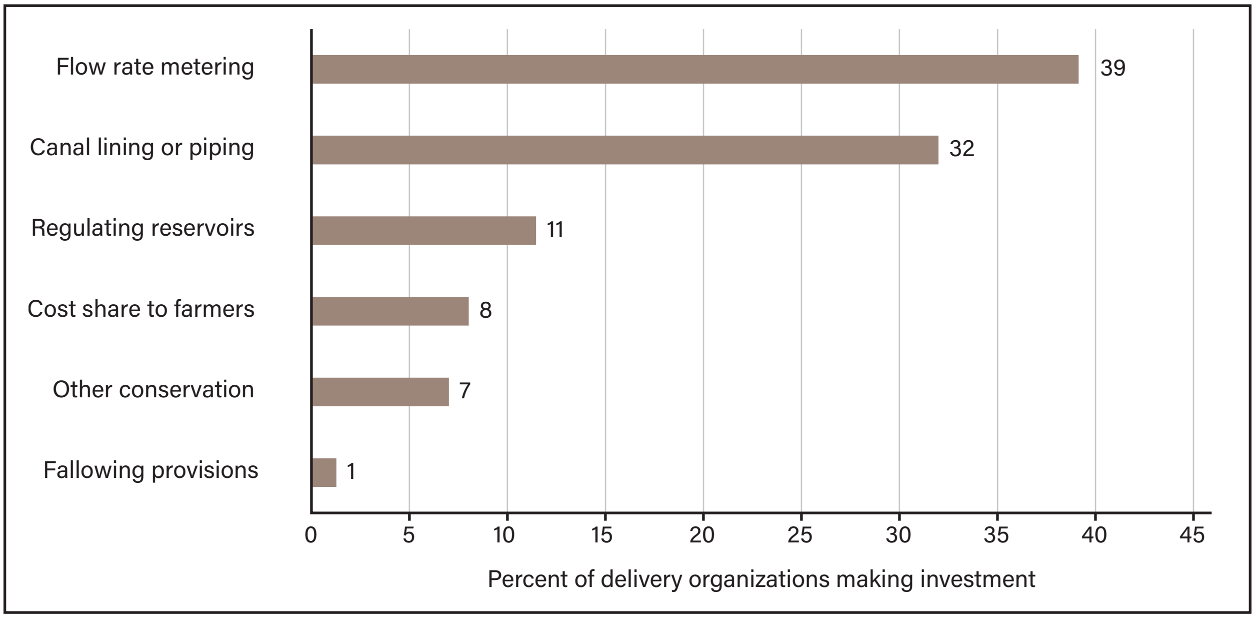
In addition to investing in the infrastructure needed to deliver water or manage groundwater, irrigation organizations can also make several types of water conservation investments. One of the most basic types of investment involves improved tools to measure water throughout the system, such as flow rate metering (Turner et al., 2011). To address conveyance losses through canals and laterals, irrigation districts can pursue canal lining or piping (Scherberg et al., 2018). During times of water shortages, irrigation organizations or States can engage in temporary fallowing of irrigated land, sometimes in exchange for incentive payments (Israel and Lund, 1995). Since land fallowing is temporary, these programs require different incentives than water conservation programs that target the permanent retirement of water rights (Rosenberg, 2020).

Irrigation organizations may face multiple reasons for investing in water conservation (Burt et al., 1996). Drought risk, as discussed above, can vary both across and within regions based on water rights' priorities and other factors. Water scarcity can apply to both surface water sources or groundwater. Competing water uses, including requirements to maintain flows or releases for environmental concerns such as wildlife habitat or water quality, can be the driver of water conservation investments. In some cases, the primary motivation for conserving water at the organization level is the same as the motivation for conserving water at the farm level: increasing productivity and yield through improved water-use efficiency. However, water conservation, and the related measures of irrigation efficiency, can have different outcomes at different scales since conserved water in one location can reduce water availability elsewhere in a watershed or groundwater basin (Scheierling et al., 2014).

Extent of Water Conservation Investments by Irrigation Organizations

- Flow rate metering is the most popular form of conservation investment with more than one-third of irrigation organizations making an investment.
- The second most popular form of conservation investment is lining of canals or replacement of canals with pipes.
- Other types of conservation investment (e.g., regulating reservoirs, cost share payments to farmers, and "other" conservation measures) are less common, each representing about 10 percent of investing organizations.
- Fallowing programs are extremely rare, with less than 2 percent of investment organizations that report conservation investments choosing this approach. This suggests that most observed fallowing is due to direct reaction to curtailments rather than response to incentive payments.

Figure 11
Frequency of conservation investments by irrigation organizations



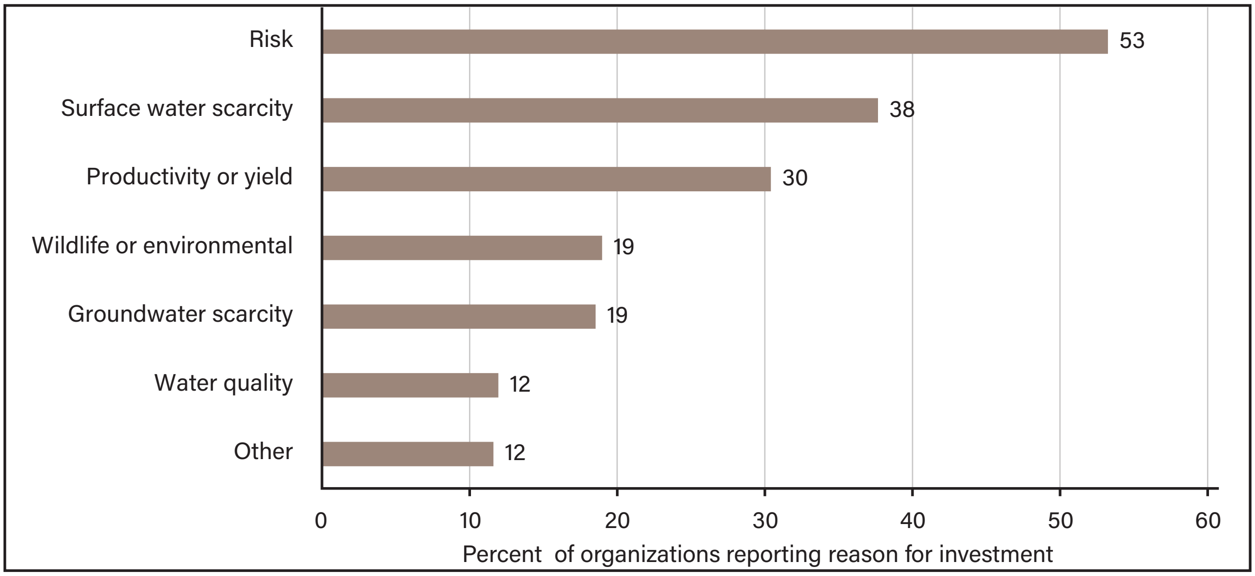
Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Reasons for Water Conservation Investment

- Over half of irrigation organizations making water conservation investments cite "water supply variability and production risk" as a reason for those investments.
- Other important reasons for water conservation are surface water scarcity (38 percent of organizations reporting investments), productivity and yield improvements (30 percent), wildlife and environmental concerns (19 percent) and groundwater scarcity (19 percent).
- Water quality concerns and other (unspecified) reasons are each only cited by 12 percent of organizations making conservation investments as a reason for those investments.

Figure 12

Reasons for conservation investments by irrigation organizations



Source: USDA, Economic Research Service analysis of 2019 Survey of Irrigation Organizations data.

Conclusion

Drought can reduce the availability of water for irrigation. Irrigation organizations cite drought risk ("irrigation water supply variability and production risk") as the most significant reason for making water conservation investments. Across the United States, exposure to drought risk can vary significantly. In much of the Southwestern and parts of the Southeastern United States, moderate or worse summer season droughts occur between three and five times per decade. In the rest of the country, these types of droughts occur between one and three times per decade.

Despite the broad exposure to drought risk and growing frequency of drought in response to climate change, only one-fifth of irrigation organizations have formal drought plans. Such plans are most common for larger water delivery organizations and groundwater management organizations. The most common component in those plans are details about how reductions in water deliveries or withdrawals ("curtailments") will be handled. While all organizations can potentially face the need to impose curtailments, the advanced notice to farmers provided by drought plans can be a useful source of information for farm-level drought planning and resilience.

Information on water availability involves a mix of monitoring and trend data, short-run and long-run forecasts, and climate predictions. Many of these data sources are provided by Federal agencies such as USDA, USGS, and NOAA. Irrigation organizations rely on these information sources to make short-run management decisions and long-run investment plans.

Many of the expenditures made by irrigation organizations aim to cope with water supply constraints and variability through water conservation investments. The most common such investments are improved flow-rate metering and lining of water canals and laterals. Water conservation investments have the potential to partially mitigate some of the adverse effects of water supply curtailments experienced during drought for the investor but also have the potential to change water available for other users. Although less common as a component of drought plans, some organizations also invest in water supply augmentation through use of water transfers or managed aquifer recharge. As such, these conservation and supply investments, along with the associated drought plans, are an important aspect of creating a more resilient irrigated agricultural sector.

The numbers presented in this report provide an important foundation for future research on the impacts of drought planning. Relevant research questions include: How does a drought plan influence an organization's drought response and investment in water conservation efforts? How does a formal drought plan influence on-farm irrigation decisions? Why do some organizations adopt plans while most do not adopt them?

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Appendix

Estimating irrigation shares by land use

In the 2017 U.S. Census, an estimated 17 percent of harvested cropland acres were irrigated in 2017 (53.96 million acres of irrigated harvested cropland/320 million acres of harvested cropland; the former is reported in table 10, and the latter is reported in table 1).

To estimate the share of irrigated acreage in pasture and rangeland, we combine numbers from the 2017 U.S. Census of Agriculture and the 2018 U.S. Irrigation and Water Management Survey (IWMS). In the 2018 IWMS, 6 percent of irrigated acres on U.S. farms and ranches was pasture and rangeland (3.42 million acres of irrigated pasture and rangeland/55.94 million acres of irrigated land; both reported in table 3). From this, there were an estimated 3.55 million acres of irrigated pasture and rangeland in 2017 (0.06 x 58.01 million acres of irrigated land). (Note: this compares to the reported 4.05 million acres of irrigated "pastureland and other land" reported in table 10 of the Census.) Based on these estimates, about 1 percent of pasture and rangeland was irrigated in 2017 (3.55 million acres irrigated pasture and rangeland/400.77 million acres of pasture and rangeland; the former is the ERS estimate, and the latter is reported in table 8).

States included in the 2019 U.S. Survey of Irrigation Organizations

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

Key Definitions

Conveyance losses: Conveyance losses refer to water that is lost to seepage or evaporation during storage or conveyance. Conveyance losses are not an actual loss of water as the water system is a closed system. Water seepage from main and lateral canals is stored in aquifers 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 original intended use.

Water year: The U.S. Geologic Survey (among other Federal and State agencies, as well as regional and local water management entities) refers to the "water year" as the 12-month period beginning on October 1 and ending on September 30. The "water year" is designated to the calendar year in which it ends.

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