Agricultural Water Use Efficiency Resource Management Strategy

CALIFORNIA WATER PLAN UPDATE 2023

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Agricultural Water Use Efficiency Resource Management Strategy

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Lead Author:
Jennifer Morales

Contributing Authors:
Julia Roldan
Sarah Ko
Michelle Pombrol
Ryan Bailey
Sabrina Cook

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Acronyms and Abbreviations

AWMC	Agricultural Water Management Council
AWMP	agricultural water management plans
CIMIS	California Irrigation Management Information System
CWUF	crop water use fraction
DWR	California Department of Water Resources
ET	evapotranspiration
EWMP	efficient water management practices
GHG	greenhouse gases
maf	million acre-feet
RDI	regulated deficit irrigation
TWUF	total water use fraction
WMF	water management fraction
Water Code	California Water Code

1. Introduction

The contributions of California's agricultural sector are crucial to the state and national economy. In 2021, despite a year plagued by drought, wildfires, supply chain disruptions, and a worldwide pandemic, California's farms generated more than $50 billion in cash receipts (California Department of Food and Agriculture 2022) and supported a significant portion of regional income and employment in many areas of the state. California's agriculture supports worldwide food security, exporting more than $22 billion in products in 2021, a 7 percent increase from 2020. Supporting this level of production requires significant management of natural resources. Approximately 80 percent of statewide developed water goes to agricultural uses and, as the impacts of a warming atmosphere continue to increase the frequency and severity of drought, further water use efficiency improvements will help agricultural water users ensure a resilient and sustainable food system.

Quantifying Agricultural Water Use Efficiency

Agricultural water use efficiency describes the use and application of scientific processes and best management practices to control agricultural water delivery and use to achieve a beneficial outcome. It includes an estimation of net water savings or increased production resulting from implementing efficiency measures as expressed by the ratio of output to input.

Water use efficiency is defined by California Water Code (Water Code) Section 10817 as "the efficient management of water resources for beneficial uses, preventing waste, or accomplishing additional benefits with the same amount of water." Improvements in agricultural water use efficiency can be expressed as yield or net revenue improvements for a given unit of water and can be estimated over individual fields or entire regions. Improvements in water use efficiency can also result in net water savings. Net water savings is the reduction in the amount of water applied while maintaining or improving crop yield and agricultural productivity.

Important aspects to recognize when quantifying water use efficiency:

1. The uptake and transpiration of water for crop water use.
2. The role, benefits, and quantity of applied water that is recoverable and reusable in the agricultural setting.

3. The quantity of irrecoverable applied water that flows to salt sinks, such as the ocean and inaccessible or degraded saline aquifers, or that evaporates to the atmosphere and is unavailable for reuse.

Agricultural water use efficiency does not necessarily mean a reduction in the amount of water used to grow crops. Often, increased water use efficiency – along with other management practices – allow for an increase in crop yield without increasing the amount of irrigation water. For the same amount of water used, an increase in crop yield translates into increased water productivity. In addition to advances in irrigation technology and improvements in water management, crop yield and water productivity can also be enhanced through fertilizer technology, crop selection, and advanced crop breeding.

In the absence of specific crop yield or economic return measurements, agricultural water use efficiency can be expressed as fractions that are the ratios of the amount of water going toward beneficial use(s) compared to how much water was applied (e.g., the ratio of crop evapotranspiration [ET] use to the amount of water used to irrigate the crop). Water Code Section 10825 specifies methodology for quantifying water use efficiency that accounts for crop water use, agronomic water use, environmental water use, and recoverable surface flows to be included in agricultural water suppliers' agricultural water management plans (AWMPs).

Agricultural water use efficiency does not necessarily mean a reduction in the amount of water used to grow crops. Often, increased water use efficiency – along with other management practices – allow for an increase in crop yield without increasing the amount of irrigation water. For the same amount of water used, an increase in crop yield translates into increased water productivity. In addition to advances in irrigation technology and improvements in water management, crop yield and water productivity can also be enhanced through fertilizer technology, crop selection, and advanced crop breeding.

Determining Crop Water Use

Determining the amount of water required by the crop to produce the ideal yield can be a complex undertaking. Crop water requirements during various growth stages can be modeled for most common crops. Models typically use a "crop coefficient" (k_c) factor that is the ratio of the amount of water the crop needs compared to what a standardized grass surface needs (reference crop evapotranspiration, [ET_o]). But the accuracy of these models can be hampered by incomplete or low-quality datasets and the difficulty of accounting for real-world problems including disease, insect infestations, nutrient management, poor irrigation systems, microclimate conditions, and lack of uniform soils. Nevertheless, when used correctly, these models have provided valuable information for better decision-making. Recent approaches to estimating crop water requirements employ satellite imagery, often in conjunction with local weather stations, to estimate crop transpiration on a 30x30-meter grid of cells. The finer the grid, the better the accounting for the spatial non-uniformity of crop water use. Spatial non-uniformity of crop ET can be the result of many factors such as spatial variability of soil hydraulic characteristics, variability of field conditions, irrigation system non-uniformity, wheel traffic compaction, variability in growers' cultural practices (e.g., pesticide and fertilizer applications), and varying effects of different populations of insects, nematodes, and denitrifying bacteria.

Co-benefits of Improved Agricultural Water Use Efficiency

Agricultural water use efficiency aims at increasing or maintaining productivity. Using less water to provide the same or increased productivity can save water that may then be available for other beneficial uses downstream or in future years. Other co-benefits may include water quality improvements, environmental benefits, improved stream flow and timing, and increased energy efficiency. While pursuing efficiency in agricultural water use, it is important not to isolate the agricultural operations from the environment. With a holistic view, agricultural water use efficiency efforts must go beyond the simplistic irrigation efficiency approach to embrace a management system that enhances the co-benefits of water use in agriculture. This approach aims at ensuring sustainable food production while protecting and restoring the natural and human built environments.

Improving Agricultural Water Use Efficiency

Improving agricultural water use efficiency involves making changes in at least some agricultural management practices including, the types of crops grown; crop operational management (e.g., fertilization, weed control, and cover crops); technology used (e.g., precision farming, remote sensing, soil moisture sensors, on-demand delivery systems, and irrigation system type); and water management (e.g., irrigation scheduling, deficit irrigation, and irrigation system maintenance). The ability to improve water use efficiency is influenced by a wide variety of factors, including labor, crop market conditions, demographics, education, government policies, funding availability, the impacts of climate change, environmental stressors, production goals, cultural practices, energy, water supply source and availability, water delivery systems, economics, and land use issues. For irrigation system water use efficiency, opportunities may be identified through irrigation and pump system evaluations.

It is also important to consider the scale used to evaluate agricultural water use efficiencies – at the farm level, the water supplier level, or at the regional and state levels. For example, an apparent lack of efficiency at a farm-level may not mean lack of efficiency at the regional level if that "wasted" water is recoverable and used by a downstream user or provides environmental benefits. Conversely, improved water use efficiency at the farm level may mean less water is available for downstream users or environmental benefits at the regional level. Water use efficiency opportunities may be identified through irrigation and pump system evaluations. The ability to improve water use efficiency is influenced by a wide variety of factors, including labor, crop market conditions, demographics, education, government policies, funding availability, the impacts of climate change, environmental stressors, production goals, cultural practices, energy, water supply source and availability, water delivery systems, economics, and land use issues.

In some circumstances, increasing water use efficiency may lead to increased costs (e.g., infrastructure investments for more efficient irrigation systems or precision management of fertilizer and water applications) and energy use (e.g., automated or pressurized delivery systems instead of gravity flow systems). As a result, potential impacts should be fully considered before implementing any significant water conservation or efficiency measures.

Agricultural Water Use Efficiency Efforts in California

California growers and water suppliers implement state-of-the-art design, delivery, and management practices to increase production efficiency and conserve water. As a result, they continue to make great strides in increasing the economic value and efficiency of their water use. Among the indicators of agricultural water use efficiency improvement is the inflation-adjusted gross revenue for California agriculture, which increased 103 percent between 1967 and 2020, from $24.2 billion to $49.1 billion (both in year 2020 dollars). While the state's agricultural revenue more than doubled, the total water applied to crops in California only increased by 8 percent during the same period, from 31.2 million acre-feet (maf) in 1967 to 34 maf in 2020, likely because of an increase in total irrigated acres across the state (California Department of Water Resources 2021). As a result, the "economic efficiency" of agricultural water use in California has almost doubled in the same period, from $756 per acre-foot (year 2020 dollars) in 1967 to $1,444 per acre-foot in 2020 (California Department of

Food and Agriculture 2021), meaning less water is being used to produce greater gross revenues.

It is important to note that the economic output of California agriculture, expressed either as crop yield or the dollar value of produced crops, is a function of many variables. These include water quality, soil fertility, fertilizer applications, insect infestation, plant diseases, cultural practices, management, crop selection, and crop variety, as well as many other physical, biological, and socioeconomic factors (e.g., crop market, trade and market conditions, and weather conditions). Given the complex factors affecting agricultural productivity, any economic output indicator can only be used as an overall gauge of the efficiency and competitiveness of California's agriculture and its agribusiness establishment, in general. By no means can it be linked exclusively to water use efficiency.

The Agricultural Water Management Planning Act has identified 16 efficient water management practices (EWMPs) that agricultural water suppliers can implement to further improve agricultural water use efficiency. These practices are covered in Section 2, "Current and Historic Regulations and Legislation Related to Agricultural Water Use Efficiency."

California Agricultural Water Use Efficiency Efforts: Case Studies

Recycled Water at Ocean Mist Farms

Since 1998, Ocean Mist Farms, located in the Salinas Valley of California, has been irrigating a wide variety of crops with recycled water, using approximately 9 billion gallons for irrigation annually. Facilitating the use of recycled water is listed as one of the California Water Code EWMPs agricultural water suppliers are to implement if technically feasible and locally cost-effective (conditional EWMP). As a result of using recycled water from the Monterey County Water Resource Agency, Ocean Mist Farms has been able to reduce the amount of well water used to irrigate their crops, minimizing the negative effects of saltwater intrusion and increasing the reliability of its water supply. In addition, the implementation of drip irrigation and soil sensor technologies have allowed them to further optimize their water usage (Ocean Mist Farms 2022).

Dry Irrigation Farming in California Vineyards and Farms

Dry irrigation farming methods have been used historically by growers and Indigenous peoples. Depending solely on annual rainfall, no irrigated water is applied to crops. This method relies on soil moisture and calculated soil management practices. Dry irrigation farming is commonly seen among grape growers, not only in California, but globally. Vineyards such as Tablas Creek Vineyard and Frog’s Leap Winery, have been able to successfully produce their wine with dry irrigation farming methods, citing a higher quality and taste because of the stress endured by the fruit during growth (Tablas Creek Vineyard 2022, Frog’s Leap Winery 2022). Not only is this a common practice for wine makers but it can also be used by commodity growers. Growing a wide variety of crops, San Juan Bautista grower, Jim Leap, has been farming since the early 1990s without the use of irrigation water. Instead, relying on annual rainfall, Leap has been able to avoid using groundwater while still producing high quality crops (East Bay Times 2019).

2. Current and Historic Regulations and Legislation Related to Agricultural Water Use Efficiency

The Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 (Assembly Bill [AB] 3616, Water Code Sections 10900–10904) and the federal Central Valley Project Improvement Act of 1992 established guidance for improving agricultural water use efficiency. Per AB 3616, the Agricultural Water Management Council (AWMC) was formed through a memorandum of understanding in 1996. Between its establishment and its dissolution in 2013, the AWMC enlisted approximately 80 agricultural water suppliers and four environmental organizations to improve agricultural water use efficiency through the implementation of efficient water management practices. The AWMC worked in a voluntary and cooperative manner with agricultural water suppliers, environmental interest groups, government agencies, and other agricultural interest groups to establish a consistent endorsement process for agricultural water suppliers to demonstrate how they are managing water efficiently. Through a review and endorsement procedure, the AWMC helped with water suppliers' water management planning and the tracking and implementation of cost-effective, efficient water management practices. The signatory agricultural water suppliers voluntarily committed to implementing locally cost-effective management practices and submitted agricultural water management plans to the AWMC.

As part of a comprehensive package of water legislation in the 2009–2010 legislative session, Senate Bill (SB) X7-7 of 2009 [Friedman] incorporated agricultural water management planning and sustainable water use practices into the Water Code. The Agricultural Water Management Planning Act (AWMP Act) (Water Code Sections 10800–10853) requires agricultural water suppliers who provide water to 10,000 or more irrigated acres to develop and adopt a water management plan with specified components. Division 6, Sustainable Water Use and Demand Reduction (Water Code Sections 10608–10609.42), requires agricultural water suppliers who provide water to 10,000 or more irrigated acres to implement two EWMPs and 14 other EWMPs if cost-effective and technically feasible. Agricultural water suppliers providing water to less than 25,000 irrigated acres are exempt from these requirements unless sufficient funding has been provided to implement the provisions.

The Water Code requires:

1. Agricultural water suppliers to prepare and submit water management plans to the California Department of Water Resources (DWR) every five years.
2. Agricultural water suppliers, on or before July 31, 2012, to implement EWMPs including the following critical EWMPs:
   - A. Measure the volume of water delivered to customers with sufficient accuracy to comply with provisions of the bill.
   - B. Adopt a pricing structure for water customers based, at least in part, on quantity of water delivered.
3. Agricultural water suppliers use a standardized form to report which EWMPs have been implemented and are planned to be implemented, an estimate of water use efficiency improvements that have occurred since the last report, and an estimate of water use efficiency improvements estimated to occur five and 10 years in the future. If an agricultural water supplier determines that an EWMP is not locally cost-effective or technically feasible, the supplier shall submit information documenting that determination.
4. DWR, in consultation with the State Water Resources Control Board, was to submit to the Legislature (in 2013, 2016, and 2021) a report on the agricultural EWMPs that have been implemented, and are planned to be implemented, and an assessment of the way the implementation of those EWMPs has affected and will affect agricultural operations, including estimated water use efficiency improvements.
5. DWR to make available all submitted water management plans on the DWR website.
6. DWR, in consultation with the AWMC, academic experts, and other interested parties, to develop a methodology for quantifying the efficiency of agricultural water use. Alternatives to be assessed shall include determination of efficiency levels based on crop types or irrigation system distribution uniformity.

Following the passage of AB 1668 in 2018, each AWMP must also contain the following:

1. An annual water budget, on a water-year basis, based on the quantification of all inflow and outflow components for the service area.
2. Identification of water management objectives based on the water budget to improve system efficiency or to meet other water management objectives.
3. Quantification of water use efficiency using the appropriate method(s) from

DWR's 2012 report to the Legislature, *A Proposed Methodology for Quantifying the Efficiency of Agricultural Water Use*. In quantifying the efficiency of agricultural water use, all water uses must be accounted for, including crop water use, agronomic use, environmental use, and recoverable surface flows.

4. A drought plan for periods of limited water supplies describing actions for drought preparedness (resilience planning) and management and allocations of water supply during drought conditions (response planning).

Agricultural Efficient Water Management Practices per California Water Code Section 10608.48

Critical EWMPs are to be implemented by all agricultural water suppliers and conditional EWMPs are to be implemented by all agricultural water suppliers if technically feasible and locally cost effective.

Critical EWMPs

1. Measure the volume of water delivered to customers with sufficient accuracy to comply with Water Code Section 531.10(a) and to implement EWMP #2.
2. Adopt a pricing structure for water customers based, at least in part, on quantity delivered.

Conditional EWMPs

1. Facilitate alternative land use for lands with exceptionally high-water duties or whose irrigation contributes to significant problems, including drainage.
2. Facilitate use of available recycled water that otherwise would not be used beneficially, meet all health and safety criteria, and do not harm crops or soils.
3. Facilitate the financing of capital improvements for on-farm irrigation systems.
4. Implement an incentive pricing structure that promotes one or more of the following goals:
    A. More efficient water use at the farm level.
    B. Conjunctive use of groundwater.
    C. Appropriate increase of groundwater recharge.
    D. Reduction in problem drainage.
    E. Improved management of environmental resources.
    F. Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.

5. Expand line or pipe distribution systems and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance, and reduce seepage.
6. Increase flexibility in water ordering by, and delivery to, water customers within operational limits.
7. Construct and operate supplier spill and tailwater recovery systems.
8. Increase planned conjunctive use of surface water and groundwater within the supplier service area.
9. Automate canal control structures.
10. Facilitate or promote customer pump testing and evaluation.
11. Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress reports.
12. Provide for the availability of water management services to water users. These services may include, but are not limited to, all of the following:
    A. On-farm irrigation and drainage system evaluations.
    B. Normal year and real-time irrigation scheduling and crop evapotranspiration information.
    C. Surface water, groundwater, and drainage water quantity and quality data.
    D. Agricultural water management educational programs and materials for growers, staff, and the public.
13. Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.
14. Evaluate and improve the efficiencies of the supplier’s pumps.

These EWMPs may be updated by DWR as per SB X7-7, Water Code Section10608.48(h).

Drought Plans per California Water Code Section 10626.2

The drought plan must include resilience planning, including information to determine the water supply availability levels of drought severity, identification of potential vulnerability to drought, a description of the opportunities and constraints for improving drought resilience planning and policies. The drought plan must also include response planning including policies and process for declaring a water shortage and for implementing water shortage allocations among other requirements.

Most agricultural water suppliers report that they have plans in place to implement their water shortage allocation policies and drought resilience and response actions. Policy components and actions are ever evolving as new technology and knowledge are made available regarding drought response and resilience. Agricultural water suppliers often allocate little to zero allocation for all or many customers during periods of limited water supplies. This means that growers must adapt by reducing irrigated area, deficit irrigating crops, or using alternative water sources like groundwater.

Robust water use and supply projections, as affected by climate change, are not required of or typically incorporated into agricultural water suppliers' AWMPs or drought plans, but could improve water use efficiency through the identification of local or regional infrastructure needs, water management decisions, and the ability to accommodate customer needs, along with providing a tool for customers to consider long-term changes in types of crops grown and irrigation systems used in light of overall future water supply conditions.

DWR Agricultural Water Use Efficiency Implementation Guidance and Assistance

DWR provides guidance and technical assistance to agricultural water suppliers who are developing their AWMPs and implementing EWMPs.

2020 AWMP Guidebook

DWR updated and made available a 2020 agricultural water management plan guidebook to assist agricultural water suppliers in the preparation of their plans.

Water Use Efficiency Data

DWR developed and hosts the Water Use Efficiency Data (WUEdata) portal for agricultural water suppliers to submit their 2020 AWMPs and associated data to DWR and to access DWR-related tools. The data provided by agricultural water suppliers is populated into a database. All associated data are made available to the public.

Methodologies for Calculating Agricultural Water Use Efficiency

The Water Conservation Act directed DWR to develop technical methodologies and criteria to ensure consistent implementation of the act and to provide guidance to agricultural water suppliers in determining agricultural water use efficiency.

Technical Assistance

DWR provides direct technical assistance and tools to agricultural water suppliers in determining components of their annual water budget, including effective precipitation, drought planning, and crop evapotranspiration through DWR's regional offices, California Simulation of Evapotranspiration of Applied Water (CalSIMETAW) model, California Irrigation Management Information System (CIMIS), and Spatial CIMIS.

3. Status of 2020 Efficient Water Management Practices Implementation

Summary of EWMPs Implemented by Agricultural Water Suppliers Who Submitted Required 2020 Plans

Fifty-two agricultural water suppliers were required to submit a 2020 AWMP to DWR that addressed EWMPs; DWR received 49. In addition, DWR received 10 voluntary plans that addressed EWMPs, that are not included in the statistics below.

- 98 percent (48 of 49) of those reporting have implemented both of the critical EWMPs (“Water Measurement” and “Volume Based Pricing”).
- 100 percent (49 of 49) of agricultural water suppliers who submitted required 2020 plans implemented the conditional EWMPs that were deemed cost-effective and technically feasible. Of those:
    - The most implemented conditional EWMPs found in 2020 plans were “Conjunctive Use of Groundwater” and "Water Management Services,” with implementation from 48 suppliers each.
    - The least implemented conditional EWMPs found in 2020 plans were “Recycled Water Use,” with implementation from 26 suppliers, and “Facilitate Alternate Land Use,” with implementation from 15 suppliers.
    - "Facilitate Alternative Land Use” was the most common EWMP to be listed as not locally cost-effective by agricultural water suppliers.

It should be noted that some EWMPs may have competing effects. For example, lining or piping canals reduces transportation losses for improved water use efficiency, but also reduces groundwater recharge for improved water use efficiency. Identification and implementation of locally specific water management objectives enables agricultural water suppliers to implement appropriate EWMPs to improve overall service area water use efficiency and resilience.

Estimates to quantify water use efficiency improvements may be feasible if more comprehensive and consistent data are available and when these practices have been implemented, assessed, and reported over a longer period of time and by a consistent group of agricultural water suppliers, with similar climate conditions and crop types.

Agricultural Water Use Efficiency Quantification in 2020 AWMPs

Agricultural water suppliers submitting an AWMP were required to calculate their water use efficiency with one of four approved methods described in DWR's report to the Legislature, *A Proposed Methodology for Quantifying Efficiency of Agricultural Water Use* (2012):

- Crop water use fraction (CWUF), which assesses the efficiency of applied water compared to how much water crops use.
- Agronomic water use fraction (AWUF), which assesses the efficiency of applied water compared to how much water it takes to grow the crop(s) including other necessary water uses such as leaching for soil salinity.
- Total water use fraction (TWUF), which assesses the efficiency of applied water when considering agronomic uses and environmental uses, such as agricultural spills to support wetland functions.
- Water management fraction (WMF), which assesses the efficiency of crop water use and the amount of water leaving the service area (surface flows or deep percolation) that can be recovered for beneficial uses.

Table 1 displays the average, maximum, and minimum water management fractions reported in 2020 AWMPs. Because agricultural water suppliers were only required to use one of the calculations, the number of agricultural water suppliers reporting in each category is different.

Table 1 Water Use Efficiency Fractions Reported in 2020 Agricultural Water Management Plans

Category	Crop Water Use Fraction	Agronomic Water Use Fraction	Total Water Use Fraction	Water Management Fraction
Average	0.75	0.83	0.89	1.04
Maximum	0.91	0.96	1.17	1.35
Minimum	0.42	0.70	0.70	0.91

A value of 1.0 means all the applied water was, or could be, beneficially used. Overall, agricultural water use efficiency ranged from an average of 0.75 to 1.04, depending on which of the four metrics was used. It should be noted that the CWUF can tell an incomplete story about agricultural water use efficiency because it does not address the fact that much of the water not used by the crops is recoverable; it can be used again as it percolates to groundwater or by downstream growers. For example, for two water suppliers that calculated CWUF and WMF, the CWUFs were 0.53 and 0.42, whereas the WMFs were 1.0 and 0.91, respectively. This means that even though the crops, themselves, only used half the irrigation water, the remainder was still available for beneficial uses.

EWMP Effectiveness

Quantifying EWMP effectiveness is especially complicated because there are multiple factors that affect water use, such as weather, farm prices, and water supply restrictions. EWMPs also have competing effects, such that lining canals can prevent water losses but impede groundwater recharge. Regardless, agricultural water suppliers have implemented or plan to implement EWMPs in the future to continue conserving water resources.

4. Additional Benefits of Agricultural Water Use Efficiency

Regenerative Agriculture

By shifting management objectives toward a regenerative agricultural approach, growers can increase artificial and natural water supplies above and below ground. Regenerative agriculture methods can integrate agriculture and natural processes to promote environmental health. Methods such as earth-lined canals can facilitate water recharge in the soil subsurface, while sprinkler and micro-irrigation systems reduce water evaporation losses through precise applications. Shifting management objectives to naturally recharge surface and groundwater supplies results in many benefits: preventing saltwater intrusion, mitigating subsidence, providing habitat for birds, reducing flood risks, and storing water for droughts. Diversifying crop selection and investing in new irrigation technologies can also provide beneficial ecosystem services which include improvements to water quality and quantity.

On farm management practices like cover cropping, no-till, reduced-till, mulching, compost application, and diversified crop plantings can all help to improve soil health, which can sequester greenhouse gas emissions, improve water holding capacity, and improve crop outcomes. The California Department of Food and Agriculture offers grants, when available, to incentivize such practices through their Healthy Soils Program and Statewide Water Efficiency and Enhancement Program.

Groundwater Use

Surface water supplies are becoming more unreliable because of increasing demands and climate change. As a result, many growers are more often turning to groundwater reserves to irrigate their crops. The efficient use of water could result in lower water demand and reduced groundwater pumping. But highly efficient use of surface water on the farm could mean less water percolating into groundwater aquifers, reducing groundwater recharge rates.

Sustainable Agriculture

Sustainable agriculture meets the food, fiber, and energy needs of existing generations without compromising the ability of future generations to do the same. Agricultural sustainability is built on the pillars of profitability, environmental health, and social and economic equity. Principles of sustainability for food and agriculture include maintaining productivity, protecting and enhancing natural resources, and communities (Food and Agriculture Organization of the United Nation 2022), all of which benefit from water use efficiency.

5. Potential Costs and Barriers to Implementation

Energy and Water Relationship

The relationship between water use efficiency and energy use is complex and needs to be thoroughly studied and understood. Improved agricultural water use efficiency might help to reduce energy use, and thus reduce greenhouse gases (GHGs). In some circumstances, the increased use of water efficiency measures, such as precision irrigation, can increase energy use. By considering the embedded energy of irrigation water, which is the energy required to deliver water to the field, California State University, Fresno's Center for Irrigation Technology showed in its 2011 report that water use efficiency may reduce or increase energy use. By reducing irrigation water through water use efficiency, generally the embedded energy would be decreased. The water-use-efficiency method employed might require a change in the irrigation system (e.g., converting from flood to drip). In such a case, even though the embedded energy is reduced, the energy required to apply the water to the field is increased. Determining whether water use efficiency results in a net decrease or increase in energy use depends on the amount of water saved, the level of embedded energy, and the additional energy required to pressurize the irrigation system.

Energy and Water Relationship: Case Study

The California Energy Commission conducted a study in its report, *Energy Efficiency and Water Savings in Agriculture by Innovative Plant-Aware Irrigation* (February 2021), based on viticulture (wine-grape crops) to develop a plant-based approach to irrigation called plant-aware irrigation (PAI). Sap flow sensors were used to integrate soil moisture, climate, and seasonal leaf area data to inform the timing of an irrigation event without sacrificing yield quality and quantity. Although the study focused on grapes, this technology could also be applied to perennial crops such as citrus trees and almonds. Precise timing of water application can benefit growers with water and energy savings for their operation.

The report found there was an average water and energy savings of 61 percent per designated area of the vineyard, or block (as designated in the study), and as much as 100 percent savings when no irrigation was needed. Additionally, grape quality improved substantially. Plants that were monitored by PAI methods were more drought-resistant and yield remained about the same, even though grapes received less water. The California Energy Commission projects that if PAI technology is applied to California's 880,000 acres of viniculture, water savings could be as much as 297 billion gallons per year statewide, without having to sacrifice detrimental yield losses. This amount of water savings corresponds to about 403 million kilowatt-hours of electricity saved, because pumping demands are reduced as less water is needed to irrigate (assuming a power need of 440 kilowatt-hours per acre-foot). By reducing agriculture's carbon footprint, growers could potentially reduce GHG emissions statewide.

There are multiple benefits to managing energy within an agricultural operation, including climate change mitigation benefits. Preserving agricultural land can also mitigate GHG emission outputs, as urban landscapes produce 70 times greater GHG emissions than agricultural land (CalCAN 2019). Energy efficiency in agricultural practices and operations are necessary in reducing GHG emissions statewide.

Water Rights

Agricultural water users have expressed concerns about existing and potential water use efficiency legislation they believe could affect their water rights. The concern is that they could lose their rights to use the water they conserve. This perception may impede implementing water use efficiency strategies.

Economic Factors

Infrastructure changes necessary for improved water use efficiency can result in substantial costs, depending on what changes are necessary (e.g., completing new on-farm irrigation systems, providing pressurized water for using efficient irrigation systems, water supplier on-demand delivery systems). After the COVID-19 pandemic, prices for supplies and labor increased. Inflation and access to resources, particularly for infrastructure projects, could be difficult to obtain in a timely manner. Increased prices may impede suppliers from being able to fund their own projects or customer projects, which will necessitate working with other organizations and agencies (State and federal) to obtain resources.

While increasing water costs could encourage water conservation at the district or regional level, it could hamper new efficiency projects at the farm-level. In 2022, water prices on the California Nasdaq Veles Water Index reached an all-time high of $1,144.14 per acre-foot and almost $2,000 per acre-foot in areas of the Westlands region (Chediak and Chipman 2022). Agriculture is susceptible to a myriad of financial losses that can affect various industries and groups of people.

Changing farm management practice for water use efficiency could result in substantial costs to implement water efficient technologies and practices or loss of investments. One means to increase water use efficiency is to alternate to less thirsty crops. But less thirsty crops may provide less economic return. Changing from one permanent crop to another, or to an annual crop, can result in loss of investment associated with the original permanent crop. Even though increasing water costs may make it sensible to change crop types from a high-water-using crop to a low-water-using crop, the short-term costs may be prohibitive.

Human Behavior and Water Use Efficiency

Human behavior plays a large role in water conservation, demand, and water use efficiency. From both individual and institutional levels, water use efficiency implementation can be greatly influenced by socioeconomic status (e.g., age, gender, race), availability of technology (e.g., data availability, technology readiness, development of water use efficiency [WUE] plans), and institutional infrastructure (e.g., performance of utilities, capacity to supply water demand, organizational structure) (Callejas et al. 2021). Behavioral factors that influence water use efficiency include trust in institutions (e.g., political atmosphere), values and beliefs (e.g., religion, culture, upbringing), attitudes and norms, and perceptions of risk (Callejas et al. 2021). Because of these factors, the ability to influence an individual or an institution to implement water use efficiency can be difficult.

Agricultural Water Use Data

To effectively implement agricultural water use efficiency, water suppliers, growers, and local, regional, and State agencies need to have an understanding of how much water is used and for what purposes; if it is not measured, it cannot be managed. First, there needs to be information on how much water is delivered to customers. Next, there needs to be information on how that water is used and if there were additional sources of water used to grow the crop. For example, if one grower uses a lot of water compared to another, it still may be efficient use if that grower is getting a higher yield than the second grower. Alternatively, the second grower may be using just as much water as the first grower, but the second grower is using a private groundwater well as well as the delivered water.

The Agricultural Water Measurement Regulation (California Code of Regulations Section 597.3) requires agricultural water suppliers serving more than 25,000 irrigated acres to measure their deliveries to customers with a specified degree of accuracy. This allows for water suppliers to understand the service area customer demands and uses. But many water suppliers are not big enough to meet this requirement and do not have to measure the deliveries to customers, and neither the smaller suppliers nor the bigger suppliers have information on private groundwater use or use of other supply sources. This makes understanding and management of agricultural water use efficiencies difficult at regional, service area, or statewide scales.

While all agricultural water suppliers providing more than 2,000 acre-feet of water per year must report their aggregated water deliveries each year by April 1 (Aggregated Farm Gate Delivery Reports, Water Code Section 531.1) often only the larger suppliers have measurements with a higher degree of accuracy; small to mid-size water suppliers are left to estimate their volume of deliveries using “best professional practices.” Additionally, many smaller water suppliers may not be aware of this requirement or the best methods to estimate deliveries and how to report their deliveries to DWR. The resulting aggregated water delivery estimates from smaller water supplies may have limited utility.

Technical Expertise

Implementing water use efficient management practices requires integrated knowledge of agricultural systems. Many farm operators and staff are highly knowledgeable about their systems but may not be as knowledgeable about the management of new systems or crops that may be implemented to improve water use efficiency. Irrigation scheduling software has been developed to assist growers with scheduling for efficient irrigation, but not all growers are familiar with the software or have sufficient data and knowledge to use the software. Changes in irrigation practices may also necessitate changes in fertilizer and pesticide management.

Additionally, with future climate change and aridification, California growers and agricultural water suppliers will need more technical information to help them adapt to the changing conditions. Information on the local or regional effects, the types of crops will be viable in their regions, future water supply conditions, and availability of alternative supplies and storage options would allow growers and agricultural water suppliers to use water more efficiently.

Regulated Deficit Irrigation

Regulated deficit irrigation (RDI) is an irrigation technique that purposely stresses crops at specific developmental stages as to not produce negative effects on the yield or marketability of the product, but to, in some cases, improve flavor, or conserve water. The water stress is normally imposed at stages of the season when reproductive growth is relatively low. Under the goal of water use efficiency, the objective of RDI is to maintain or increase farm profits while reducing the consumptive use of water. Reducing ET requires precise application of water, as water needs are not constant throughout the growing season. Stressing crops through RDI is one approach that requires careful scheduling and application of water and may have additional costs and could result in unintended adverse impacts on crop quality or soil salinity.

Soil Salinity Management

When plants use water, salts are left behind in the soil. The higher the salinity of irrigation water, the more chance there is for salt build-up. In areas with sufficient rainfall, these salts are naturally flushed out of the rootzone during winter. But, in many areas, extra water needs to be applied through irrigation to flush out the salts. Deficit irrigation or deficit irrigation techniques that only apply enough irrigation water to meet crop needs do not include an application of water to flush salts from the rootzone. RDI may contribute to salt build up in soils unless carefully managed.

Potential Adverse Ecosystem Effects of Agricultural Water Use Efficiency

Efficient agricultural water use may improve water quality, reduce pollution entering waterways, reduce groundwater overdraft, and protect drinking water sources. But under certain circumstances highly efficient irrigation can have potential negative ecosystem effects. High water use efficiency may lead to less water circulating in waterways, and if water has been used multiple times under a highly efficient cropping system, it may be warm and contain high levels of agricultural inputs, such as fertilizers, herbicides, and pesticides. These temperatures and constituents can adversely affect aquatic and riparian habitats and increase dissolved oxygen concentrations. In some cases, efficient irrigation can also mean less extra water in fields percolating to deep groundwater storage and shallow groundwater contributions to instream flows, although reduced extractions and diversions typically mitigate these potential adverse effects.

6. Costs If Not Implemented

If agricultural water use efficiency best management practices are not implemented, negative impacts may include:

- Reduced crop quality and yield.
- Increased operational costs from sub-optimal water application (e.g., water purchases, pumping and application costs).
- Environmental and drinking water impacts (e.g., agricultural inputs, such as fertilizer and herbicides flowing into wetlands, streams, rivers, and water bodies).
- Drainage issues.
- Reduction in surface and groundwater availability.
- Increased labor requirements for weed abatement and irrigation system maintenance.
- Increase in irrecoverable flows.
- Increased greenhouse gas emissions.
- Soil degradation.

Climate Change

Between 1998 and 2015, approximately 80 percent of California's developed water went to agricultural uses (California Department of Water Resources 2022). Climate change, which is projected to diminish the state's water supply by as much as 10 percent by 2040 (California Department of Water Resources 2022), is a critical threat to the state's agricultural water users. The projected increase in the frequency and severity of drought conditions in California means that climate change will continue to pose a major challenge to agricultural water users.

A critical impact of climate change on California agriculture may be the projected reduction in the Sierra Nevada snowpack, which is California's largest surface "reservoir." Snowmelt currently provides an annual average of 15 maf of water, which is slowly released from April through July each year. Much of the state's water infrastructure was designed to capture the slow spring runoff and deliver it during the peak of the agricultural water use season. Based on historical data and modeling, DWR projects that the Sierra snowpack will experience a 25–40 percent reduction from its historical average by 2050. Additionally, warmer temperatures can cause the snowpack to melt earlier in the season, decreasing the late-season runoff on which many agricultural water users depend. Warmer temperatures and increased atmospheric concentrations of carbon dioxide (CO_2) will also increase ET and crop water demand. In some areas, frequent drought conditions have already led to a decline in surface water availability and an increase in unsustainable groundwater pumping.

Implementation of agricultural water use efficiency strategies can increase the resilience of California's agricultural sector and reduce the adverse impacts of climate change on the agricultural economy. The development of AWMPs requires certain agricultural water users to quantify the efficiency of their water use, develop water management objectives, and develop a drought plan that includes resilience planning. The goal of these efforts is to ensure that agricultural water users are prepared for the changing conditions that climate change will bring. Increasing agricultural water use efficiency also supports the goal of the Sustainable Groundwater Management Act, enacted in 2014, which aims to bring California's overdrafted groundwater basins into balance by 2040.

Climate Change Adaptation

Increasing agricultural water use efficiency is one adaptive strategy that water suppliers and growers can use to increase their resilience in the face of climate change, but additional adaptive actions will likely be necessary to maintain agricultural output in the future. Some adaptation strategies could include:

- Improving soil health to increase water and carbon holding capacity.
- Fallowing or repurposing marginal agricultural land.
- Deficit-irrigating crops.
- Using drought-tolerant crop types.
- Conducting regular irrigation uniformity and efficiency field tests.
- Improving pump and irrigation system efficiencies.

Climate Change Mitigation

Certain water use efficiency improvements, such as pressurized irrigation systems, could require additional energy use or infrastructure that may lead to an increase in GHG emissions. But not all water use efficiency improvements require significant energy inputs. For example, adopting a pricing structure for water customers based, at least in part, on quantity delivered (one of the critical EWMPs per SB X7-7), may increase water use efficiency without requiring additional energy inputs. This EWMP may lead to greater efficiency and reduced pumping, thereby lowering GHG emissions and contributing to a more sustainable agricultural economy.

Social Costs

Disparities between socioeconomic groups are likely to be amplified without dynamic water use efficiency projects, resulting in the continued loss of economic opportunities, and increased environmental burdens for low-income, minority, and historically unrepresented groups. Decreases in agricultural productivity affects the socioeconomic status and employment of socially disadvantaged groups. Many low-income people of color tend to be workers in the agricultural sector, particularly Mexican and Central American immigrants. Latinos made up approximately 63 percent of the agricultural labor force in California from 2003 to 2011. Climate change is also expected to affect crop quality and quantity, and as a result, reduce crop market values. Areas such as California's Central Valley, where agriculture is a major commodity, and many low-income Latino communities reside, would be affected the most from financial losses in the agricultural sector. These groups are especially vulnerable as temperatures and water demand increase from climate change.

7. Agricultural Water Use Efficiency in the Water Resilience Portfolio

On July 28, 2020, Governor Gavin Newsom released a final version of the *Water Resilience Portfolio*, the administration's blueprint for equipping California to cope with more extreme droughts and floods and rising temperatures, while addressing long-standing challenges that include declining fish populations, over-reliance on groundwater and lack of safe drinking water in many communities. The following proposals were included in the *Water Resilience Portfolio* to detail how State agencies can support supply diversification and implementation of this RMS.

- 2. Drive greater efficiency of water use in all sectors.
    - 2.1 Implement existing "Make Conservation A Way of Life" laws (SB 606 and AB 1668, 2018), which create new efficiency standards for residential use and reporting requirements for agricultural use.
    - 2.3 Fund the State Water Efficiency and Enhancement Program and prioritize grants for water-saving irrigation system improvements to socially disadvantaged growers and ranchers in basins considered high priority under the Sustainable Groundwater Management Act.
    - 2.5 Promote consistent and effective conservation messaging in partnership with local water districts.
    - 2.6 Evaluate proposals for an exemption from state income tax any rebates, vouchers, or other financial incentives issued by a local water agency for participation in water efficiency or stormwater runoff improvement programs.
- 8. Protect and restore water quality by driving pollution reduction from a range of sources.
    - 8.8 Enhance dairy and livestock manure management programs to protect water quality, including activities that improve nutrient use efficiency and enable development of manure-based products, including bioenergy.
- 16. Improve soil health and conservation practices on California farms and ranches.
    - 16.3 Support research and technical assistance, such as through the UC Cooperative Extension Climate Smart Agriculture Advisors program and resource conservation districts, to support growers and ranchers with education about healthy soils, manure management, water and nutrient

efficiency practices, on-farm recharge, drought adaptation, and land management changes.

Making Conservation a California Way of Life

Although agricultural water suppliers are able to meet the challenges of using water efficiently, there are additional anticipated challenges to water availability and reliability because of climate change. The 2018 legislation (AB 1668 [Friedman] and SB 606 [Hertzberg]) mandates new reporting requirements for AWMPs to better address water use efficiency and improve local drought resilience and response planning. Climate change may bring hotter temperatures and drier conditions, as well as a higher evaporative demand. As a result, growers must consider securing alternative sources of water, increasing infrastructure to better store and capture water, and increasing water use efficiency starting at the farm level.

8. Recommendations

The following recommendations can help facilitate greater agricultural water use efficiency.

Implementation

- It would be beneficial for the State and applicable agencies to consider clarifying policy and improving incentives, assurances, and water rights protections to ease fears over the loss of water rights resulting from improved water use efficiency.
- Expand technical assistance to water suppliers to implement the Agricultural Water Measurement Regulation and report aggregate farm-gate deliveries to comply with the regulation.

Data Measurement and Evaluation

- Continue an analysis of the Aggregated Farm Gate Delivery Reporting to identify its utility in water use efficiency assessments.
- Conduct studies and develop models that evaluate climate change effects on crop production, particularly regarding drought and changes in the hydrologic regime, that can help water suppliers, water managers, and growers improve agricultural water use efficiency. Studies could consider factors such as:
    - Water supply conditions.
    - Population.
    - Future growth projections.
    - Demands on water supplies.
    - Crop markets projections.

  The studies may be able to use water measurement data, along with additional information, to evaluate water use efficiency on a watershed scale. Watershed-scale analysis may help identify regions most at risk from climate change. This may also provide the State and other agencies with important information for determining water allocations, storage options and needs, and development of alternative supply sources.
- The State and applicable agencies should consider supporting and expanding water use efficiency information, evaluation, and on-site technical assistance programs provided through agricultural extension services, resource

conservation districts, independent crop advisors, and other agricultural outreach efforts.

- Improve online data collection and dissemination to provide growers with on-demand meteorological and hydrological information on climate, soil conditions, and crop water needs.
- Work with the agricultural community to develop methods to quantify water savings and costs associated with hardware upgrades, water management, and ET reduction projects identified in this strategy.
- Support on-farm irrigation system evaluation program, such as mobile labs, statewide. Data and information from these on-farm efficiency improvements collected by mobile labs could be used to improve quantifying changes in irrigation system distribution uniformity.

Education and Training

- Increase training opportunities, such as workshops focused on using the WUEdata portal, Aggregated Farm Gate Delivery Reporting, and crop WUE measurement methods for agricultural water suppliers and interested parties.
- Support implementation of the EWMPs through expansion of CIMIS (including remote sensing technology and satellite imagery), mobile laboratory services, and other training and education programs to improve irrigation distribution uniformity, irrigation scheduling, and on-farm irrigation efficiency. These program expansions could aid improvements in pumping system efficiencies, remote control technologies and telemetry, canal automations, flexible water delivery systems, and irrigation system design.
- Based on long-term ET reduction studies and research, DWR could consider developing informational guidelines that define the crop water consumption reduction practices, identify how to implement them for each crop, and estimate the potential crop benefits and impacts, water savings, and costs for growers and water suppliers. DWR, with the participation of agricultural and water industries and environmental interests, could consider developing community educational and motivational strategies for conservation activities to foster water use efficiency.
- Facilitate or provide a platform where interested parties could share knowledge and ideas associated with crop and livestock water use efficiency improvement practices, with a focus on socially disadvantaged communities that lack access to resources, knowledge, and funding to address climate change challenges.

- Initiate collaboration with county governments to offer tax credits for installation of more efficient irrigation systems.
- Host workshops and forums to help agricultural water suppliers develop long-term drought mitigation and resilience plans. Tools could be developed and provided to the agricultural water suppliers to better assess vulnerabilities and solutions during periods of water shortages.

Dry-Year Considerations

- To support the drought resilience and response planning requirements of the AWMP Act, DWR, the California Department of Food and Agriculture and partners could consider compiling protocols currently used by growers and water suppliers to deal with water shortages and droughts and develop a comprehensive agricultural drought guidebook as a storehouse of information and procedures for drought mitigation, including new and innovative methods.
- Review and adopt standard water use efficiency approaches to meet water needs during dry years. Explore new approaches, such as regulated deficit irrigation, to cope with water shortages.
- During abnormally wet years, make water conservation a major management objective for agricultural water suppliers.

Reporting Requirements

- Agricultural water suppliers could include data on future water supplies and demand projections. This data would be helpful in developing the drought resilience and response plan by identifying future infrastructure needs and opportunities (e.g., conjunctive use, flood managed aquifer recharge, or use of recycled water).
- Robust water use and supply projections are not required for AWMPs or drought plans; but quantifying these values could improve identification of local or regional infrastructure needs, water management decisions, accommodating customer needs, and provide a tool for customers to relate various crop and irrigation systems with overall future supply conditions.

DWR Core Programs

- Continue improving the WUEdata portal for water suppliers to use in reporting water use data, EWMPs, and AWMPs, and improve the quality assurance checks to account for gaps and inconsistencies in the data.

Environmental

- Continue to collaborate with and support the California Department of Food and Agriculture with incentives for growers to facilitate projects that promote healthy soil organic matter and improve productivity. Projects could include hedgerow and cover crop establishment, tillage reduction, and change in cropping patterns. By enhancing the natural environment, the land can effectively store and capture water for groundwater recharge, as well as manage water movement during periods of flooding.

Related Resource Management Strategies

- Salt and Salinity Management.
- Matching Water Quality to Use.
- Pollution Prevention.
- Agricultural Land Stewardship.

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10. Useful Web Links

Agricultural Water Management Plan Handbook
https://water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/Water-Use-And-Efficiency/Agricultural-Water-Use-Efficiency/Files/Draft-2020-AWMP-Guidebook.pdf

A Proposed Methodology for Quantifying the Efficiency of Agricultural Water Use
https://wuedata.water.ca.gov/public/public_resources/3461454093/A%20Proposed%20Methodology%20for%20Quantifying%20the%20Efficiency%20of%20Agricultural%20Water%20Use.pdf

Methodologies for Calculating Agricultural Water Use Efficiency
https://wuedata.water.ca.gov/public/public_resources/3461454093/A%20Proposed%20Methodology%20for%20Quantifying%20the%20Efficiency%20of%20Agricultural%20Water%20Use.pdf

Sustainable Groundwater Management Act
https://water.ca.gov/Programs/Groundwater-Management/SGMA-Groundwater-Management

Water Resilience Portfolio
https://resources.ca.gov/Initiatives/Building-Water-Resilience/portfolio

Water Use Efficiency Data (WUEdata) Portal
https://wuedata.water.ca.gov/

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