ISSUE BRIEF

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Agricultural Water Conservation and Efficiency Potential in California

Agriculture uses about 80 percent of California's developed water supply. As such a large user, it is heavily impacted by the availability and reliability of California's water resources. Agriculture can also play an important role in helping the state achieve a more sustainable water future. The challenge is to transition to an agricultural sector that supplies food and fiber to California and the world and supports rural livelihoods and long-term sustainable water use.

Water efficiency—defined as measures that reduce water use without affecting the benefits water provides—has been shown to be a cost-effective and flexible tool to adapt to drought as well as to address longstanding water challenges in California. Moreover, today's investments in efficiency will provide a competitive advantage in the future and ensure the ongoing strength of the agriculture sector in California. California farmers have already made progress in updating and modernizing irrigation practices. More can and should be done.

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Since 2000, several research studies—including two sponsored by the CALFED Bay-Delta Program and a third by the nonprofit Pacific Institute—have shown that there is significant untapped agricultural efficiency potential in California (CALFED, 2000 and 2006; Cooley et al., 2009). Although the studies varied in their geographic scope and in their approach, the researchers came up with remarkably similar numbers: Agricultural water use could be reduced by 5.6 million to 6.6 million acre-feet per year, or by about 17 to 22 percent, while maintaining productivity and total acreage irrigated. Part of these savings are reductions in consumptive use, ranging from 0.6 million to 2 million acre-feet per year, which represents additional supply that can be allocated to other beneficial uses. The rest of the savings reflect a reduction in water required to be taken from rivers, streams, and groundwater, with improvements in water quality, instream flow, and energy savings, among other benefits. Additional water savings could be achieved by temporarily or permanently fallowing land or switching crop types, although we do not include them in this analysis.

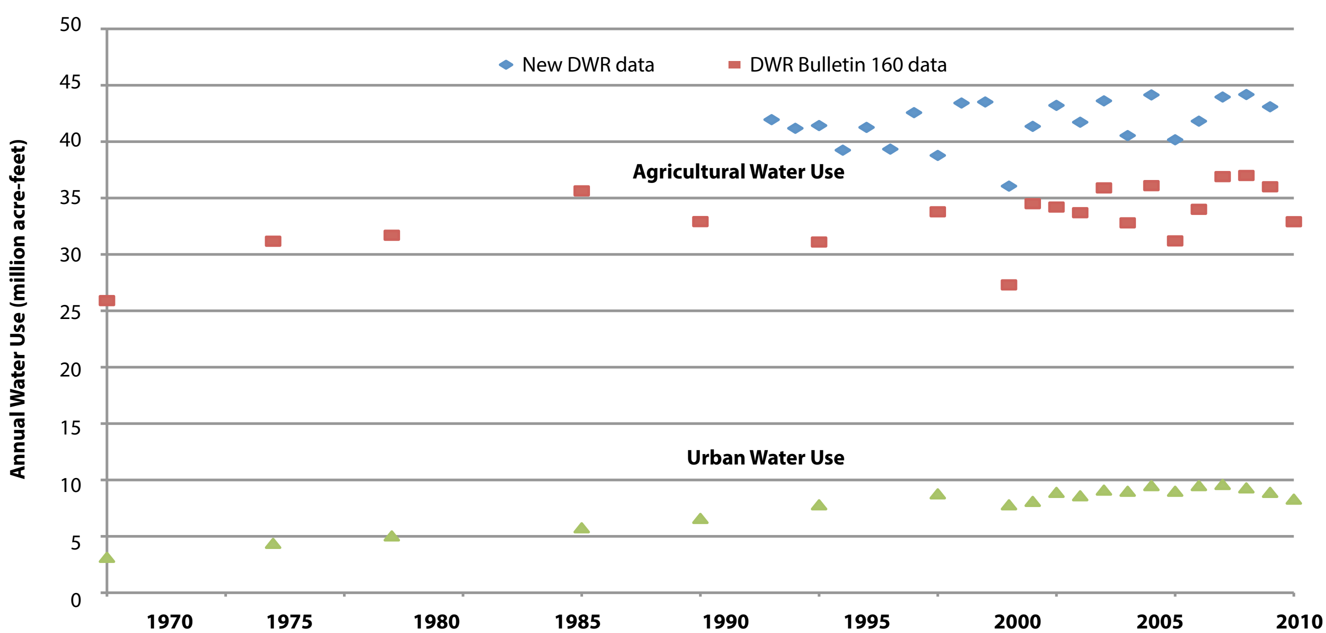
CALIFORNIA AGRICULTURE TODAY

California is one of the most productive agricultural regions in the world, producing more than 400 different farm products. The state is the nation's largest agricultural producer, supplying both U.S. and international markets. In 2012, California farm output was valued at a record $45 billion, or about one-tenth of the total for the entire nation. Additionally, California is the nation's largest agricultural exporter, with exports reaching a record $18.2 billion in 2012 (CDFA, 2013). California's rich agricultural production has been made possible in part by irrigation supplied by a vast water infrastructure network; however, much of that infrastructure is not easily compatible with efficient on-farm irrigation technology and needs to be updated. For example, in some areas, water is not available to farmers on demand, making it difficult to implement some efficiency measures.

AGRICULTURAL WATER USE

Water managers use a variety of terms to describe agricultural water use, including water use, water withdrawals, and consumptive use. *Water use* and *withdrawals* are used synonymously here to refer to water taken from a source and used for agricultural purposes, such as crop irrigation, frost protection, and leaching salts from soil. It includes conveyance losses, i.e., seepage or evaporation from reservoirs and canals. Water sources include local groundwater and surface water as well as water imported via large infrastructure projects like the federal Central Valley Project and State Water Project.

Figure 1. Agricultural water use, 1960–2010



Sources: DWR (1964, 1970, 1974, 1983, 1987, 1993, and 2014) and Orang et al. (2013).

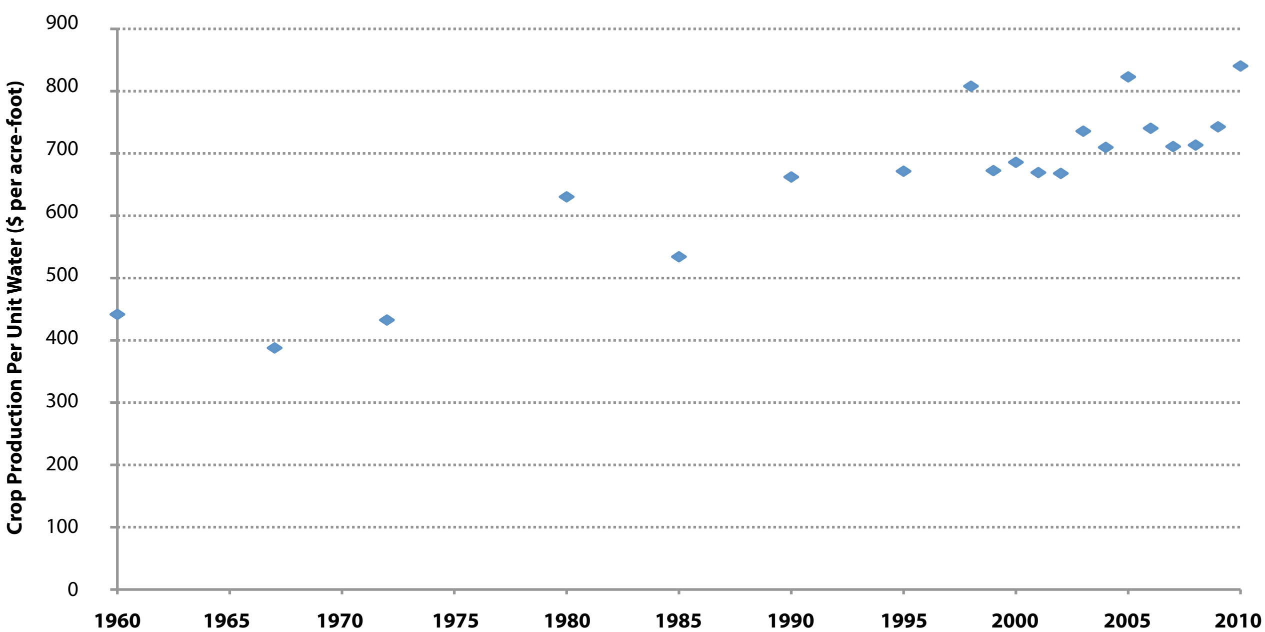
Agricultural water use can be further divided into two water-use categories, consumptive and non-consumptive. *Consumptive use* is sometimes referred to as irretrievable or irrecoverable loss. The term consumptive use or consumption typically refers to water that is unavailable for reuse in the basin from which it was extracted, due to evaporation from soils and standing water, plant transpiration, incorporation into plant biomass, seepage to a saline sink, or contamination. Non-consumptive use, on the other hand, refers to water available for reuse within the basin from which it was extracted, such as through return flows. Non-consumptive use is sometimes referred to as recoverable loss. This water usually has elevated levels of salts and other pollutants.

There are large uncertainties regarding actual water use in the agricultural sector due to a lack of consistent measurement and reporting of water use.[1] Estimates are produced by the Department of Water Resources (DWR) and are used in long-term planning efforts. According to data from the DWR's water plan update (Bulletin 160), agricultural water use steadily increased during the 1960s and 1970s. Since the mid-1960s, agricultural water use has generally ranged from about 30 to 37 million acre-feet per year (Figure 1). More recent estimates, also produced by DWR and described in Orang et al. (2013), suggest that agricultural water use may be 20 to 30 percent higher than previous estimates, ranging from 35 million and 45 million acre-feet per year between 1998 and 2010, but the same general trends apply.[2] Agricultural water use is variable, and this variability is driven by several factors, including weather, the types of crops grown, water costs, and total crop acreage.

AGRICULTURAL EFFICIENCY IMPROVEMENTS

Over the past 50 years, California agriculture has made significant water-use efficiency improvements. There are a variety of ways to evaluate these efficiency improvements. As one example, we analyzed the economic productivity of water. Figure 2 shows the value added to the U.S. economy for crop production in California per acre-foot of water between 1960 and 2010.[3] All values have been adjusted for inflation and are shown in year 2009 dollars. During the 1960s, the economic productivity of water averaged $420 per acre-foot. Economic productivity increased considerably in the 1970s and 1980s but remained consistently below $700 per acre-foot. In every year since 2003, however, it has exceeded $700 per acre-foot. This trend was driven by several factors, including a shift toward higher-value crops and the increased adoption of more-efficient irrigation technologies and practices (see Box 1 for a description of some of these efficiency measures). For example, the total and percentage of cropland using flood irrigation has steadily declined, replaced by precision drip and micro-sprinkler irrigation systems (Figure 3).

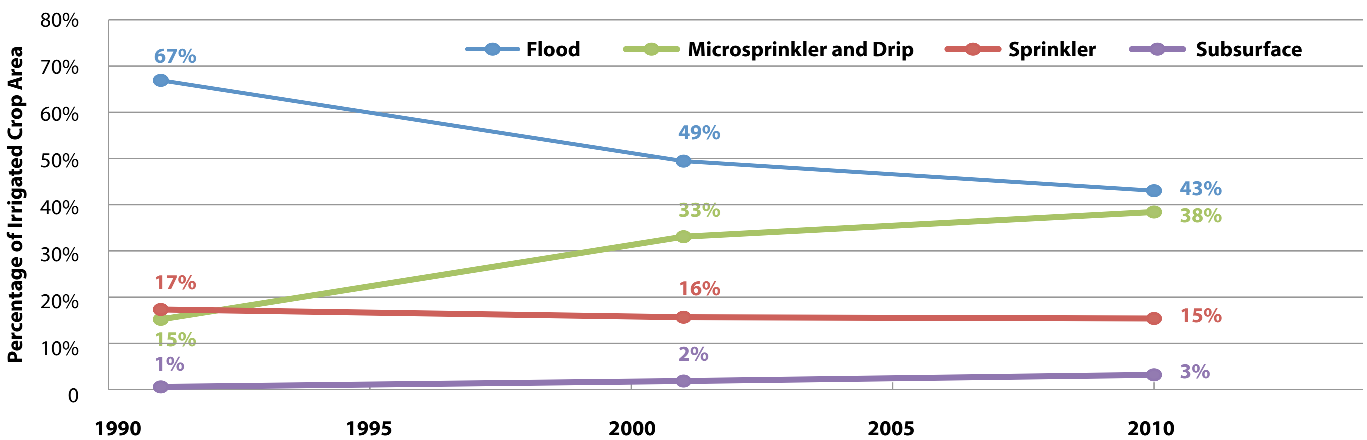
Figure 2. Economic productivity of water in California agriculture, 1960–2010



Note: All values shown in year 2009 dollars.

Source: Crop production values are based on figures from U.S. Department of Agriculture (2014). Values for agricultural water use for 1960 – 1995 are based on estimates from DWR Bulletin 160 (DWR 1964, 1970, 1974, 1983, 1987, and 1993). Water use values for 1998 – 2010 are based on DWR Statewide Water Balances data (DWR, 2014).

Figure 3. Irrigation methods for irrigated crops grown in California in 1991, 2001, and 2010



Note: These data do not include rice acreage, which is grown using flood irrigation. If rice acreage were included, the percent of crop land using flood irrigation would be higher.

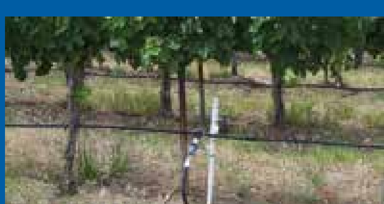
Source: Tindula et al. (2013).

AGRICULTURAL EFFICIENCY POTENTIAL

Water efficiency improvements can provide a number of important benefits to farmers. In particular, they can increase yields and improve crop quality while at the same time reducing fertilizer, water, and in some cases, energy costs, resulting in higher profits. Additionally, efficiency can improve the reliability of existing supplies and reduce vulnerability to drought and other water-supply constraints.

Water efficiency improvements can result in reductions in both consumptive and non-consumptive water use. Reductions in consumptive use provide additional water supply that can become available for other uses, but there are also compelling reasons to seek reductions in non-consumptive use. In particular, any reduction in demand lessens the amount of water taken from ecosystems or pumped out of the ground, and the need for investment in new infrastructure to capture, store, and distribute that water. It can also allow greater flexibility in managing water deliveries and reduce vulnerability to drought. Furthermore, improvements in water use efficiency can improve the timing and maximize the amount of water left in the natural environment, providing benefits to downstream water quality, the environment, recreation, and even upstream use.

Over the past 15 years, several studies have quantified the agricultural efficiency potential in California, including



Many options are available for improving the efficiency of water use in California agriculture, including efficient irrigation technologies, improved irrigation scheduling, regulated deficit irrigation, and practices that enhance soil moisture. For example, **weather-based irrigation scheduling** uses data about local weather conditions to determine how much water a crop needs. The California Department of Water Resources maintains the California Irrigation Management Information System (CIMIS) to provide this information to growers. This service is free and available online to the public, but other kinds of weather-based systems are also available from irrigation consultants who may set up additional weather stations to provide even more precise local information.

Additionally, **regulated deficit irrigation** imposes water stress on certain crops that have drought-tolerant life stages, e.g., wine grapes and some nuts. This approach is widely practiced in many Mediterranean and semi-arid climates around the world, including more and more applications in California, providing improvements in crop quality and/or yield along with significant water savings (Cooley et al. 2009). Furthermore, certain irrigation technologies, such as **sprinkler and drip irrigation systems**, tend to have higher distribution uniformities and water-use efficiencies than traditional flood, or gravity, irrigation systems. Drip irrigation, for example, slowly releases low-pressure water from plastic tubing placed near the plant's root zone, allowing for the precise application of water and fertilizer to meet crop needs. Realizing the full water savings from these irrigation technologies requires proper management and maintenance.

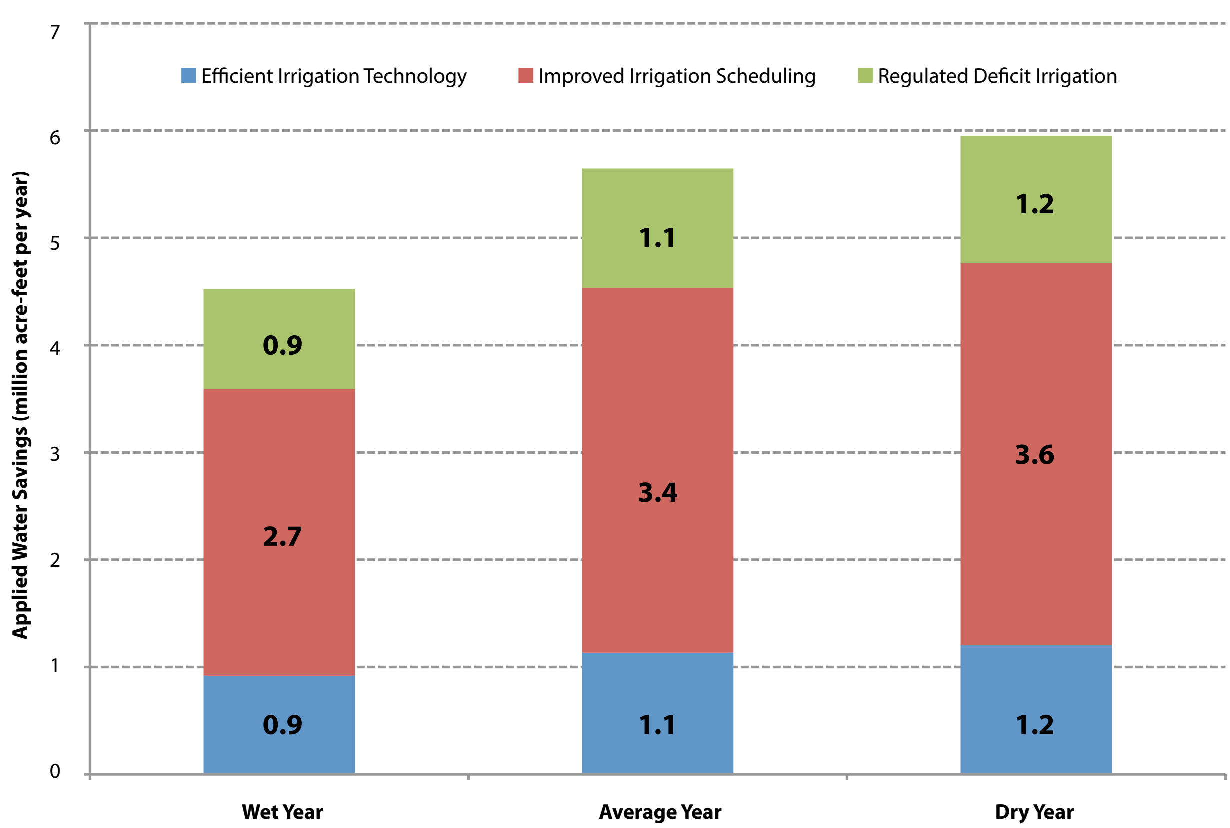
two studies in support of the CALFED Bay-Delta Program and a third study by the Pacific Institute. All of these studies examined efficiency improvements, i.e., measures that reduce water use without affecting the benefits water provides, and did not include any changes in crop type or irrigated acreage. The first of these, the CALFED *Water Use Efficiency Program Plan*, was released in 2000; it had a limited geographic scope, including only those areas that would affect Bay-Delta water supplies. Further, the analysis was designed to capture 70 percent of the efficiency potential in the region and to include only those efficiency practices that were "locally cost-effective" or for which CALFED could provide financial incentives. The study found that on-farm and district-level efficiency measures could reduce agricultural water use by 4.3 million acre-feet per year. Of that amount, 0.4 million acre-feet were reductions in consumptive use that could be available to other uses. Expanding this analysis to the entire state and including opportunities to capture the full percent of the efficiency potential, we estimate that the technical efficiency potential is 6.6 million acre-feet per year, of which 0.6 million acre-feet is a reduction in consumptive use.[4]

In 2006, CALFED released its *Water Use Efficiency Comprehensive Evaluation*. This study focused on the entire state and evaluated efficiency actions under different policies and investment levels. One scenario examined the statewide technical potential in agriculture, defined as all of the technically demonstrated practices that could be implemented regardless of cost. The authors estimated that irrigation water use in California could be reduced by 6.3 million acre-feet per year, of which 2.0 million acre-feet per year would be reductions in consumptive use, freeing up water that could be available to other uses.

In 2009, the Pacific Institute released *Sustaining California Agriculture in an Uncertain Future*, a comprehensive analysis of the water savings potential of increased adoption of three on-farm technology and management practices:

- **Irrigation technology:** shifting nearly 1.1 million acres of land currently irrigated by flood to drip and 2.2 million acres of land irrigated by flood to sprinklers;
- **Irrigation scheduling:** expanding to all California farms the application of irrigation scheduling, using local climate and soil information to determine crop water requirements.
- **Regulated deficit irrigation:** applying less water to all wine grape, raisin, almond, and pistachio acreage in California during drought-tolerant growth stages to save water and improve crop quality.

Figure 4. Potential reductions in agricultural water use (in million acre-feet) in wet, average, and dry years



Source: Cooley et al. (2009).

The authors did not examine the full technical efficiency potential (e.g., a scenario in which all farmers use drip irrigation), but used assumptions consistent with a more rapid uptake of proven efficiency measures. The combined potential savings from these three technology and management scenarios was between 4.5 million acre-feet in a wet year and 6.0 million acre-feet in a dry year (Figure 4). In total, these scenarios would reduce agricultural water use by 17 percent in all year types. While all practices produced considerable water savings, the greatest savings were associated with better irrigation scheduling (2.7 to 3.6 million acre-feet per year). The authors did not distinguish between reductions in consumptive and non-consumptive use due to data limitations, but there is evidence that significant consumptive savings are possible, especially with regulated deficit irrigation. Adopting this practice on California's entire wine grape, almond, and pistachio acreage would reduce consumptive use by 1.1 million acre-feet per year. Reductions in consumptive use would also result from the other practices.

CONCLUSIONS

Agriculture can significantly improve water-use efficiency while maintaining or even increasing productivity. Improved technology and management practices are already contributing to a trend toward improved efficiency, but much more can be done. On the basis of a review of previous efficiency studies, we estimate that agricultural water use could be reduced by 5.6 million to 6.6 million acre-feet per year, or by about 17 to 22 percent, while maintaining productivity and total irrigated acreage.[5] Part of these savings are reductions in consumptive use, ranging from 0.6 million to 2.0 million acre-feet per year, which represents additional supply that can become available for other beneficial uses. The rest reflect a reduction in water required to be taken from rivers, streams, and groundwater, with improvements in water quality, instream flow, and energy savings, among other benefits. In addition to reducing water use, efficiency improvements can increase crop yield and quality while reducing input costs, resulting in higher profits.

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Endnotes

1 Under state legislation passed in 2009, referred to as SBx7-7, agricultural water suppliers providing water to 25,000 irrigated acres or more (excluding acres that receive only recycled water) are required to measure the volume of water delivered to their customers. While these requirements went into effect on July 1, 2012, many water districts are not yet providing that information to the state.

2 Note that all studies described in this paper developed examined the efficiency potential based on the DWR Bulletin 160 water use estimates and thus percent reductions are based on these data.

3 The value of crop production is the gross value of the commodities produced within a year.

4 The CALFED Record of Decision examined the potential to capture 70 percent of the efficiency potential in a region that accounted for approximately 93 percent of the state's agricultural water use. We estimated the full technical potential (100 percent efficiency potential for the entire state) for reducing agricultural water according to the following: 4.3 million acre-feet/(0.7*0.93) (or 6.6 million acre-feet). Likewise, we estimate the full technical potential to reduce consumptive use by the following: 0.4/(0.7*0.93) (or 0.6 million acre-feet).

5 Additional water savings could be achieved by temporarily or permanently fallowing land or switching crop types.

Authors and Acknowledgements

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