

5. AGRICULTURAL WATER USE EFFICIENCY

Despite higher agricultural water demand compared to urban water uses, very little attention is driven towards agricultural water use efficiency. To a certain extent this is explained by the fact that over 90 percent of the population in California and Spain lives in urban areas and therefore people are obviously more exposed to urban water issues including conservation and water quality (California Rural Health Policy Council – RHPC, 2007; Asociación para la investigación y el desarrollo educativo en Extremadura- aidex.es, 2001). It is my sincere belief that the media should (partly) change their focus towards water for irrigation purposes and thus increase awareness about the importance of the agricultural sector within the national/state water balance. Hopefully pressure generated by public opinion would encourage farmers to adopt more efficient irrigation methods and thus contribute to general water conservation.

This report will review agricultural water demand in California and Spain and conservation measures in both regions.

5.1. Agricultural Water Use

California is the largest producer of agricultural goods and ranks first among the 50 states providing 45 percent of the nation's fruits and vegetables (USDA, 2005; Barraqué 2002 and 2004). Moreover, California is the sole producer of 12 different commodities including almonds, artichokes, dates, figs, raisins, kiwifruit, olives, persimmons, pistachios, prunes and walnuts (Office of Water Use Efficiency - DWR). In 2005 agricultural activities benefits added up to \$31.9 billion, 2% of the State's GSP and 13.3% of national agricultural revenue (CDFA, 2007).

Along with France, Germany and Italy, Spain has one of the four largest agricultural industries in the European Union, accounting for 13.2% of the EU's production in 2004 (MAPA). Spanish agricultural business generated \$54 billion (€40 billion) in gross income in 2005 or 4.4% of national GDP. After costs and taxes, agricultural gross benefits totaled \$35 billion - €23.5 billion (INE).

However, a large portion of the generated income comes from livestock in California and Spain, which is often fed with animal feed and therefore does not use irrigated pasture areas. Thus, in order to calculate economic productivity (generated income per unit of applied water) we will only take into account revenue and water use linked to vegetable production. It should be noted that income generated by vegetable business includes production within irrigated as well as nonirrigated croplands. Thus economic productivity will be actually higher than if only irrigated farmland were taken into account. Unfortunately, this has not been possible due to lack of available data.

Two indicators of agricultural water efficiency are applied water per unit of irrigated area and agricultural production per unit of applied water. As shown in Table 12, agriculture water use in California is two times higher than it is in Spain, yet both regions have similar irrigated crop area. Hence, for every hectare of irrigated cropland, the Golden State applies 1.8 times more water than Spain does. Unfortunately, such intensive water demand cannot be justified by increased productivity. In fact per unit income in California is as little as \$0.639/m³ whereas in Spain is 3.2 times higher, \$2.041/m³. Despite California's low values, between

1980 and 2000 the productivity in terms of tons per applied water increased by 38% for 32 important California crops while statewide gross crop revenue per unit of applied water grew by 11 percent.

Table 12. Agricultural water use and generated income

	California	Spain
Total agricultural water use (hm ³ /year)	34,462	18,596
Irrigated crop and pasture area (thousand ha)	3,583	3,790
Vegetable products generated income (Billion \$*)	19.8	33.7
Vegetable products income as % of GSP/GDP	1.2%	2.7%
Total applied water per irrigated crop area (m ³ /ha)	9,617	5,394
Income per unit of applied water for crops (\$/m ³)	0.639	2.041

* € 1 = \$ 1.3664

Data from DWR, INE, Banco de España, US Department of State

In regards to the type of crops, due to a likeness in climate, both countries grow similar species including mostly herbaceous plants, but also fruits and vegetables (see Table 13).

Table 13. Agricultural water use by kind of crop

	California	Spain
Herbaceous	41%	46%
Fruits	5%	19%
Potatoes and vegetables	31%	9%
Vine and olives	6%	14%
Other	17%	12%

Source: DWR 2003, INE 2005

Rice and alfalfa are the highest water-consuming crops in California, using 15,460 m³/ha and 15,690 m³/ha respectively. Not only is alfalfa the biggest water user, but it is also the most important crop in terms area with 467 thousand hectares accounting for 13% of total irrigated area in the State. Yet alfalfa -- harvested mostly for hay to feed dairy livestock -- is a low-value crop that accounts for only 4 percent of state farming revenues (NRDC, 2001). In contrast, alfalfa crops in Spain only use 7,300 m³/ha (WWF, 2005) while they only overly 5% of national irrigated area. California could save 3,915 hm³ annually only if the State's alfalfa crops used the same amount of water per unit than Spain's alfalfa.

It is note worthy that 40 percent of California's agricultural water is used for irrigation of low-value crops, including rice, alfalfa and pasture that require between 12.2 and 15.7 thousand cubic meters of water per hectare (data from DWR 2003). Despite their low economic productivity, these produce are among the heaviest subsidized crops in California. In 2002, only cotton and rice within the Central Valley Project delivery area received 92 percent of the crop subsidies in the system and one-fourth of the irrigation water, according to the Environmental Working Group (EWG). The EWG (2004) carried out an investigation that calculated, for the first time, federal water subsidies to each of more than 6,800 farms in the Central Valley Project (CVP). The study found out that Central Valley farmers received subsidized water worth between \$60 million and \$416 million annually, depending on how the market value of the water is defined. The report also points out that the largest beneficiaries of water subsidies are a few multimillion-dollar agribusiness operations — not the small family farmers whom federal water projects were originally intended to benefit.

Moreover, analysis of federal, state and local data showed that about one-fifth of all agricultural water in California goes to CVP farmers at rates that, by any measure, are far below market value. In 2002, the average price paid for irrigation water from the CVP was \$0.0139/m³ or less than 2 percent of what residents of Los Angeles pay for drinking water.

Efficiency of agricultural water management in Spain has also been questioned due to large agricultural surpluses that are eventually subsidized by the Spanish government or the European Union's Common Agricultural Policy (CAP). The WWF's report (2005) *Los excedentes agrícolas "se beben" el agua de 16 millones de españoles: Un análisis de la sobreproducción en el regadío* severely criticizes public subsidies policies and the use of water to irrigate surplus crops. The WWF estimates that in FY 2003/04 combined water demand from surpluses of corn, cotton, alfalfa and rice totaled 995.8 hm³, equivalent to over 16 million people's annual municipal water use. True though this may be, the WWF report does not specify what is the purpose of surplus crops, whether they are exported or simply thrown away in order to maintain the produce's market price.

As occurs with urban water, agricultural water use performance may be achieved as a result of combining various activities including improvement of delivery and irrigation systems, reduction of non-beneficial evapotranspiration and optimization of on-farm management.

5.2. Irrigation Methods

Performance of irrigation is measured in several different ways although uniformity and efficiency are two of the most frequently used indices.

Under identical soil, temperature, sunlight, etc. conditions crops within the same area should be uniformly irrigated in order to receive equal amounts of water and thus avoid over –or under- watering (Solomon, 1988). Besides being important for water conservation, uniformity is strongly correlated with crop yields. Solomon (1988) presents data on sugar cane yields that are maximized with perfect uniformity.

Irrigation efficiency responds to the intuitive idea of profit over investment. J. Irrig. and Drain (1997) define irrigation efficiency (IE) as:

$$IE = \frac{\text{vol. irrig. water beneficially used}}{\text{vol. irrig. water applied} - \text{change in storage of irrigated water}} \times 100\%$$

When irrigation water is applied to a certain crop area, water may remain temporally stored in the root zone before leaving by percolation, evapotranspiration or runoff. After a certain amount of time, if water contained within the irrigated area is the same as it was at start, change in storage is zero. Thus, IE could be calculated as the ratio between applied water beneficially used over water beneficially plus non-beneficially used. Beneficial uses include consumptive use (water absorbed by the plant), leaching of salts, freeze protection, seedbed preparation, and maintenance (Dukes, www.agen.ufl.edu).

On the other hand, non-beneficial uses, also referred to as losses, include percolation, drainage, evapotranspiration and runoff without significant environmental enhancement. Major losses are usually due to overwatering beyond the crops' needs. As a consequence, not only are large amounts of water squandered, but soil quality and thus crop yield can also be affected. In addition, irrigation water often contains dissolved pesticides and other chemicals that could contaminate nearby water bodies when surplus irrigation water percolates into underlying aquifers or reaches surface streams.

However, as it occurs in the Red Rock Ranch in the Central Valley (see water recycling chapter in this thesis) in some cases runoff or drainage can be captured as “tailwater” and reused for further irrigation. The DWR estimates on-farm water savings at 10-15 % by reuse of tailwater. Reuse has certain limitations, though, due to increased concentration of salts and other products such as pesticides.

Besides overwatering, surface irrigation losses are due to evapotranspiration. Water may evaporate from the wet soil or it may even evaporate before reaching the ground when using sprinklers.

Much has been said about advantages and drawbacks of different irrigation systems: gravity, drip, sprinklers, furrow, etc. Overall performance is, however, difficult to compare because some methods may have higher efficiency but lower uniformity or vice-versa. Dukes (www.agen.ufl.edu) provides data on overall efficiency (storage, conveyance and application) in Florida, considering design and installation but not management (see Table 14).

Table 14. Efficiency of different irrigation methods in Florida

Irrigation method		Efficiency range
Sprinkler	Solid set	70-80 %
	Portable or traveling guns	60-75 %
Micro	Surface and subsurface drip	70-90 %
	Spray or jet	70-85 %
Surface	Continuous and crown flood	25-75 %
Seepage	Open ditch	20-80 %

Source: Duke. University of Florida

As shown in Table 14, micro-irrigation is the most efficient system ranging from 70 to 90 percent. Drip and micro-jet irrigation minimize evapotranspiration because water is applied close to the plant roots and therefore is not exposed to sunlight or wind unlike when using large sprinklers. Research on drip irrigation of alfalfa has shown an increase in productivity of 30 percent with the same amount of applied water (DWR, 2005).

Nevertheless, sprinklers can also achieve high efficiency rates of up to 80%, Overall performance however, can be much lower due to poor uniformity. In order to improve irrigation uniformity, sprinkler manufactures have developed special rotary nozzles that allow watering within a larger radius, even in the area close to the jet and also reduce overlapping areas. In contrast, flood and seepage are the least efficient methods with rates that can reach as low as 20%. This kind of method is based on the use of open ditches or buried perforated tubing (drain tile) to maintain the water table near the bottom or just below the crop root zone.

Despite the well known water conservation advantages of sprinkler and micro-irrigation, gravity flow irrigation is the most common irrigation system in California and Spain, as shown in Figure 6. Low volume irrigation methods include micro-sprinklers as well as buried and surface drip irrigation. Gravity irrigation consists of water flowing in the surface due to gravity forces without circulating through any pressurized pipeline systems. Some gravity methods are flood, basin, border, furrow, hand-moved or side-roll watering.

It should be pointed out that data regarding California water irrigation methods refers to surface of cropland whereas data for Spain is based on applied water volumes. At the time this research was conducted, no data was available using the same parameters for both regions.

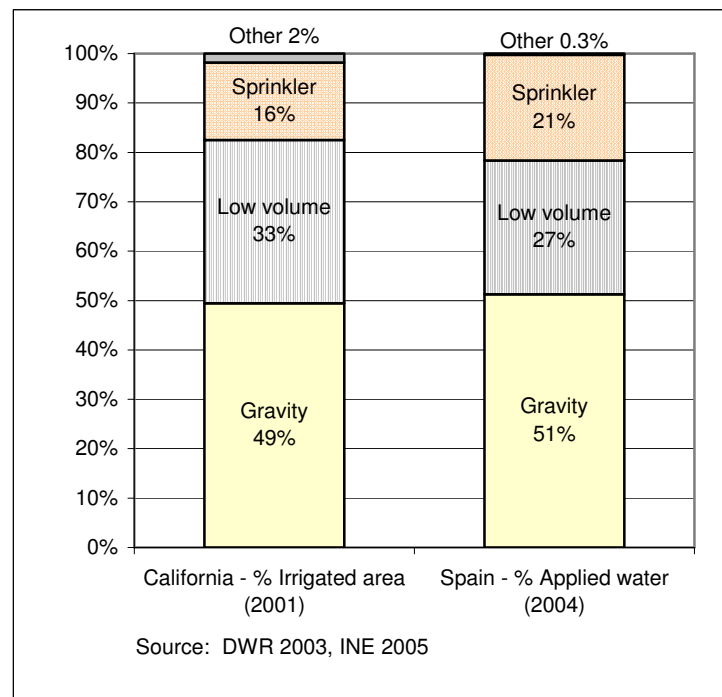


Figure 6. Irrigation methods

The reason for using higher water-demanding methods versus pressurized systems such as drip or micro-spray systems, relies on the fact that flood irrigation requires lower investment, energy (pumping) and maintenance costs. Moreover, low water rates or even rate systems per surface (not per used volume) lead to overuse of agricultural water. Although agricultural water marketing is no doubt a key tool in efficient water management, this paper will not get into the details of pricing and trading due to its economical, political and social complexity. However, we strongly encourage reviewing studies carried out by Barraqué, Chesnutt, Verges and Green, among many others.

As far as water demand and productivity goes, applied water volume for agricultural use in Spain has remained relatively constant over the past decade, yet gross income has followed a growing trend up to +66% since 1990 (oldest data available). In fact, between 1999 and 2005 water use dropped by 7% whereas gross income due to vegetables products increased by 17%. Consequently, productivity rose by 25% from €1.19/m³ to €1.49/m³.

As regards irrigation methods, Spain has significantly increased the use of sprinklers and drip irrigation techniques in recent years, as shown in Figure 7. Between 2003 and 2005 gravity applied volume dropped by 22%, whereas drip irrigation increased by 19% during the same period. Pressurized irrigation methods are supposed to be more water efficient than gravity, which means that while applying the same amount of water, less water is lost while more is absorbed by the plants. Assuming that crop water needs remain unchanged, there should be a certain degree of correlation between the implementation of low-volume irrigation methods and total water use as a result of cut down in losses. Although water use dropped by 7% between 2004 and 2005 it is still early to determine whether such reduction is indeed due to increased irrigation efficiency resulting from the switch from gravity to drip irrigation that started in 2003.

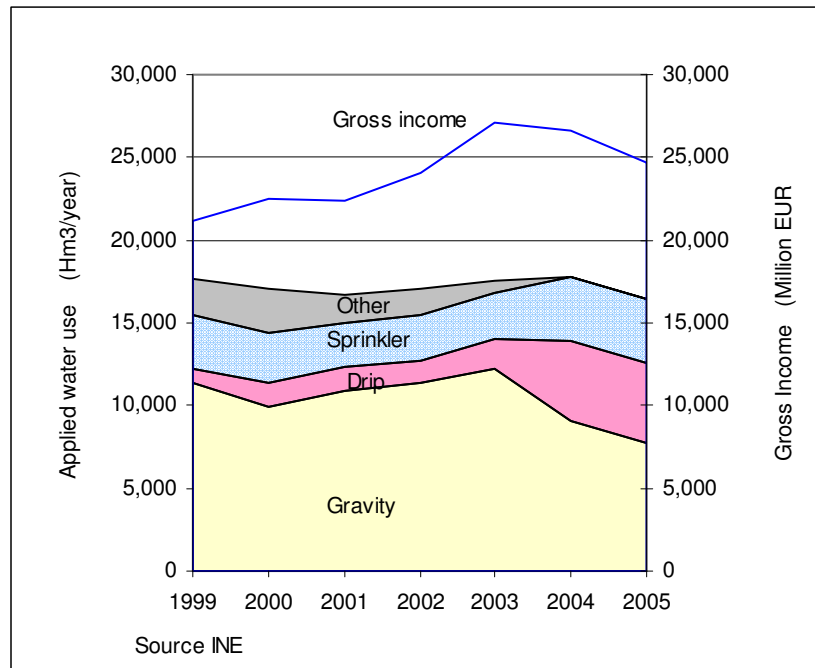


Figure 7. Trends in irrigation methods in Spain and agriculture gross income

Between 1990 and 2000, the crop area under micro-irrigation in California grew from 324 to 769 thousand hectares, which translates into an 11% increase with regards to total irrigated land. In contrast, gravity irrigation lost 16% of its area, from 2.6 million hectares in 1990 to 2.0 million hectares in 2000 (DWR, 2005). As referred to in the California Plan Update 2005, the California Polytechnic State University, San Luis Obispo, Irrigation Training and Research Center estimates that an additional 3.8 million acres could be converted to precision irrigation such as drip or micro-spray irrigation. This would enhance uniformity and reduce non-beneficial evapotranspiration and therefore result in an overall increase in performance.

Around 70 percent of irrigated croplands in Spain receive surface water while the remainder supplied with groundwater. However, surface water applied volume is equivalent to five times that of groundwater, 20 thousand hm^3 for the former and 4 thousand hm^3 for the latter (Llamas, 2004). Thus, applied water per hectare is over two times higher when surface water is provided ($8,200 \text{ m}^3/\text{ha}$) compared to groundwater use ($3,800 \text{ m}^3/\text{ha}$). One of the reasons that explain such difference is the higher cost of groundwater. When water becomes expensive, growers have an additional incentive to conserve their resources and also to implement efficient irrigation systems whose investment can be easily recovered due to large savings in the water bill. Llamas (2004) also points out that many farmers using flood irrigation systems still pay their water bill based on the size of the irrigated area, at a rate close to $\text{€}100/\text{ha}$ per year, instead of being charged for the amount of applied water. It stands to reason that from the growers' point of view, when water is unmetered flood irrigation represents a great economical advantage versus low-flow pressurized methods, which entail higher maintenance and energy costs.

5.3. On-farm Management

One of the major challenges for growers is irrigation scheduling, which is the decision-making process for determining irrigation dates and/or how much water should be applied to the field for each irrigation (CIMIS, 2007). A good irrigation planning should include a year-

round schedule specifically built for each crop and field based on historical weather data. However, weather may vary from year to year and therefore farmers must readjust their schedules on a short-term basis. Due to large extensions of croplands and weather variability growers are often unable to manually monitor water demand and control water supply. New technologies such as data acquisition systems and automatic irrigation can provide flexibility and accuracy to deliver water at the optimal time, duration and quantity. Today many growers use satellite weather information and forecasting systems to schedule irrigation. In addition to water savings, efficient on-farm water management may also reduce operation and maintenance costs as well as energy use.

5.3.1. California Irrigation Management Information System (CIMIS)

The California Irrigation Management Information System (CIMIS) is a network of 120 automated weather stations that make information useful in estimating crop water use available to the public, free of charge. The system was created in 1982 by the Department of Water Resources (DWR) and the University of California at Davis and today is managed by DWR's Office of Water Use Efficiency (OWUE). Although irrigation scheduling continues to be the main use of CIMIS, its uses have been constantly expanding over the years and today include pest management, hydrological research, water resources planning, fire fighting and air pollution monitoring among several others. After 25 years of use, today there are approximately 6,000 registered CIMIS users who make in average 70,000 information requests per year.

The CIMIS works as follows: 1) Each weather station measures parameters such as solar radiation (R_s), air temperature (T), relative humidity (RH), wind speed (u), etc. on a minute-by-minute basis. 2) Hourly and daily vales are calculated and stored in the station's data logger. 3) A computer at the DWR headquarters in Sacramento calls every station starting at midnight and retrieves each day's data. 4) The central computer calculates reference evapotranspiration (ET_o - for grass reference and ET_r - for alfalfa) for each stations which represents its local microclimate 5) ET_o/ET_r is made available at the CIMIS website www.cimis.water.ca.gov. 6) Users convert ET_o/ET_r into an actual evapotranspiration (ET_c) by a specific plant by applying correction factors, known as crop coefficients 7) Growers may calculate the amount of water that their crops need. When soil moisture has dropped below the desired level, irrigation should be applied with a net amount equivalent to the accumulated ET losses since the last irrigation.

5.3.2. Spain's Sistema de Información Agroclimática para el Regadío (SIAR)

The Spanish Ministry of Agriculture and Fishery manages a network of weather stations similar to the CIMIS throughout seven of the seventeen Autonomous Communities (AACC) including Andalucía, Canarias, Castilla-La Mancha, Castilla y León, Extremadura, Murcia and Valencia. The *Sistema de Información Agroclimática para el Regadío (SIAR)* system was implemented between 1998 and 2001 within the European Union framework about drought mitigation. Weather stations were first installed in those areas considered priority in terms of water scarcity and the system is currently under expansion to another five AACC.

The SIAR has 367 local weather stations, through 12 AACC: 87 in Andalusia, 49 in Aragón, 45 in the Region of Valencia, 43 in Castilla-La Mancha, 42 in Castilla y León, 20 in the Canary Islands, 20 in Extremadura, 18 en Murcia, 16 in Navarra, 11 in the Balearic Islands, 6 en Madrid and 4 in Galicia. There are also 12 Local Centers –one per Autonomous Community and one National Center. The SIAR captures and processes data in a very similar way to that of the CIMIS. Each station calculates reference evapotranspiration based on measures of air temperature and moisture, speed and direction of the wind, solar radiation and

precipitation. Data on local water demand is then sent to the Local Centers and then to the National Center, which centralizes and coordinates data of the entire network.

Data for every station and for each of the measured parameters is publicly available at www.mapa.es/siar without any kind of registration being required.

5.4. Agricultural Water Conservation Measures

In addition to improving irrigation methods and on-farm management, California is carrying out important institutional efforts in order to increase agricultural water use efficiency throughout the state. The DWR's Office of Water Use Efficiency works to identify and help develop agricultural water use efficiency technologies, as well as to transfer information on enhanced irrigation (www.owue.water.ca.gov).

As a non-governmental and non-profit organization, the Agricultural Water Management Council (AWMC) gathers water stakeholders who voluntarily sign a Memorandum of Understanding (MOU) and therefore commit to implement a series of defined Efficient Water Management Practices (EWMPs) that are locally cost-effective. The Council was established in 1996 and today its members represent 1.9 million hectares throughout California. The signatories are divided into three groups: 1) 74 agricultural water suppliers, 2) three environmental interest groups, 3) other interested parties (non-voting). The third group includes several Universities and research centers, as well as state and federal agencies such as California Department of Water Resources, U.S. Bureau of Reclamation, CALFED Bay-Delta Authority, California Department of Food and Agriculture and California Irrigation Institute.

The Council is funded through a variety of sources including state and federal grants. In 2005 the Council received \$462,700 from the USBR to support the Best Management Practices implementation and also signed a \$1.2 million Cooperative Agreement with DWR and the USBR.

The EWMPs cover a wide variety of water use efficiency measures, some of which are mandatory for all participants, whereas others are subject to financial feasibility. The council recommendations focus on enhanced coordination among the different water stakeholders and development of water management plans. In addition, it is suggested to increase the use of recycled water, beneficial transfers and conjunctive use as well as funding for capital and construction improvements. A full list of all EWMPs is available at the AWMC's website (www.agwatercouncil.org).

In addition to the management practices, the Councils website provides a large amount of information resources. First, the Online Resources Directory includes over 170 reports regarding agricultural water management and related technologies. Moreover, the Monitoring Protocols help irrigation districts and water agencies estimate the volume of water conserved by a water use efficiency project through canal seepage, drainage and spillage reduction and on farm water management. The Council also publishes information about DWR's grant programs, legislative calendar and the CALFED Agricultural Water Use Efficiency Program. Finally, the AWMC provides valuable information on training programs, efficient water management planning, irrigation scheduling (CIMIS), DWR Mobile Laboratories, professional irrigation consultants, financial assistance through the USDA and drought mitigation.

Separate from the information freely available to the public, members can also access an online application for the net benefit analysis (NBA) that helps them evaluating the benefits and costs of implementing the efficient water management practices established in the MOU.

However, despite the large amount of information made publicly available by the Council's and unlike the California Urban Water Conservation Council (CUWCC), there is no data on savings achieved as a result of the Efficient Water Management Practices.

5.5. Land Fallowing

Land fallowing is a key tool in water management since it allows users to allocate water wherever it is more needed (or productive) by transferring water from irrigators to other water users. Fallowing requires that growers withhold irrigation water in order to free the resource and transfer it to a different user. Due to agricultural water demand higher elasticity, occasionally growers may be able to give up farming and transfer their water to needy urban areas that in exchange would pay for the water at the agreed price. Fallowing can be either seasonal or permanent. It is worth pointing out that fallowing does not necessarily require physical water conveyance, since it is often a question of establishing agreements on water rights over a certain source. As shown in Figure 8, during the 1987-1991 drought, California agriculture water use per unit of irrigated area dropped by 13%. During the dry periods aggressive conservation was called on agriculture in order to free resources to urban areas where the potential of water use reduction is much lower.

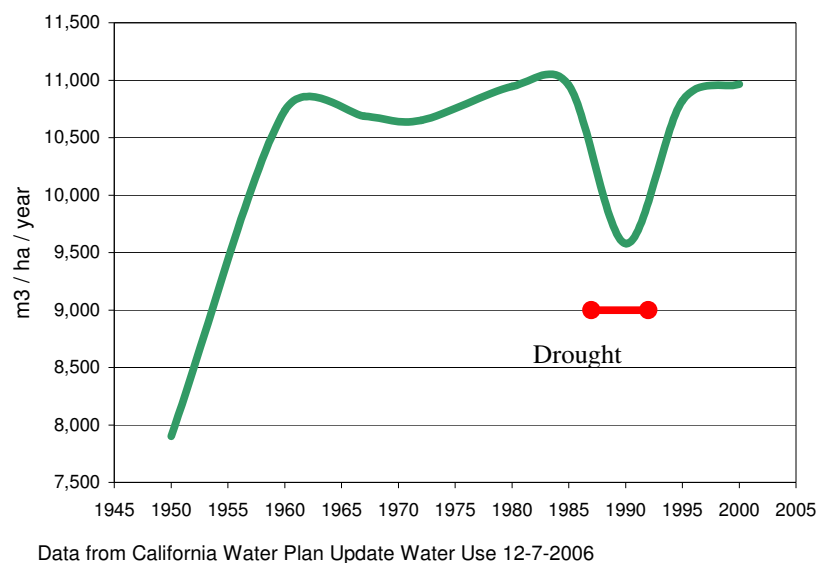


Figure 8. California Agricultural Applied Water Use per unit

In addition to fallowing, irrigators can also transfer water to urban users by implementing conservation measures and trading the extra water that is available as a result of increased savings. Over the past decade, the Imperial Irrigation District (IID) in Southern California has signed several agreements to transfer conserved water to local water agencies including Metropolitan Water District of Southern California (MWD) and San Diego County Water Authority (SDWCA). The IID is the largest irrigation district in the US delivering up to 1,600 hm³ of the Colorado River water annually (IID).

In 1988 the IID and the MWD established the Water Conservation Program to build 15 new projects that would help IID increase its agricultural water use efficiency. The new 15 projects included canal lining, systems' automation and enhanced water management and were paid for by MWD in return for having this additional amount of Colorado River water available for diversion through the Colorado River Aqueduct. Initially, projected water conservation was 131 hm³/year at an average capital and O&M cost of \$0.103/m³ (\$ 1988). In 2003 the price of raw water was \$0.2027/m³ to which SDCWA had to add another \$0.073/m³ for conveyance, with a total cost of \$0.3487/m³ (Pezon, 2003). Today the IID/SDCWA agreement is still in force and in 2006 delivered over 100 hm³ to MWD.

Ten years later, in 1998, IID signed a similar long-term agreement with San Diego County Water Authority (SDWCA) to transfer 160 hm³ to 247 hm³ annually obtained through water savings. The agreement has been amended four times however. The transfer's terms of agreement were revised for the last time in the 2003 in order to modify certain aspects that would lessen the environmental impacts of the transfer of the Conserved Water from the IID to SDCWA. Recent studies have shown that transferring water out of the Imperial Valley may lead to increased salinity in the Salton Lake. In July 2007 IID started a 15-year Fallowing Program in order to conserve additional water and thus make up for the transfer needs. Within the first 10 years transferred water will come mostly from fallowed land, whereas during the last five years increased water use efficiency measures are expected to provide enough water to supply SDCWA (IID, 2007). As a result of 2003 amendment, transferred volumes were reduced to the point where in 2006 SDCWA received less than 50 hm³ (MWD, 2006), although this amount is scheduled to increase up to 247 hm³ by 2020.

5.6. Cost and Potential Savings of Agricultural Water Use Efficiency

Two major studies have been conducted in California to estimate the costs and savings of the implementation of agricultural water use efficiency measures. The CALFED Water Use Efficiency Technical Appendix of the CALFED Record of Decision (ROD) calculates expenditure and water savings based on on-farm improvements of 85 percent within each hydrologic region and considers total irrigated crop area, crop water use and applied water. The California Bay Delta Authority's (CBDA) Year Four Comprehensive Report (Year Four Report) takes into account on-farm and water supplier improvements at six levels of funding based on a 27-year implementation horizon (2003-2030).

Savings are divided into two groups, recoverable and irrecoverable flows. The DWR defines recoverable flows as "the portion of applied water that would return to a usable surface or groundwater body, making it available for reuse". This means that even without water conservation measures recoverable flows would still have a beneficial use. Conversely, irrecoverable flows (also referred to as net water use) would evaporate or return to an unusable surface or groundwater body and would not be available for reuse. Combined recoverable and irrecoverable flows are referred as applied water.

The ROD estimates reduction in irrecoverable flows ranging between 150 and 660 hm³/year by 2030 at a cost ranging from \$0.028 to \$0.730 per cubic meter. In addition, the study identified almost 2,000 hm³/year potential savings in applied water. The total cost of this level of agricultural water use efficiency to year 2030 is estimated at \$0.1 billion to \$2.5 billion. Moreover, another \$220 million will be invested to save up to 116 hm³/year within the Colorado River Hydrologic Region by lining the All American Canal (84 hm³/year) and the Coachella Branch Canal (32 hm³/year).

The Year Four Report water savings estimates results from enhanced on-farm irrigation methods, typically pressurized systems, as well as infrastructure improvements such as regulated reservoirs, canal lining and spill prevention. Each level of investment correspond to different annual state spending ranging from \$2.9 Million (Level 1) to \$150 Million (Level 6) for both on-farm and water supplier improvement projects combined.

For every level of investment, there are different estimates of recoverable/irrecoverable flows and on-farm/water supplier savings. It should be pointed out that potential savings from recoverable flows are always larger than irrecoverable flows, usually between 3.5 and 5.5 times more. However, reduction of recoverable flows is limited since they are often being reused downstream and thus supply could be affected by a drop in upstream return flows. Figure 9 shows marginal costs for on-farm and water supplier efficiency improvements. Investing in water supplier projects appears to be less cost-efficient compared to on-farm improvements, especially for low levels of expenditure.

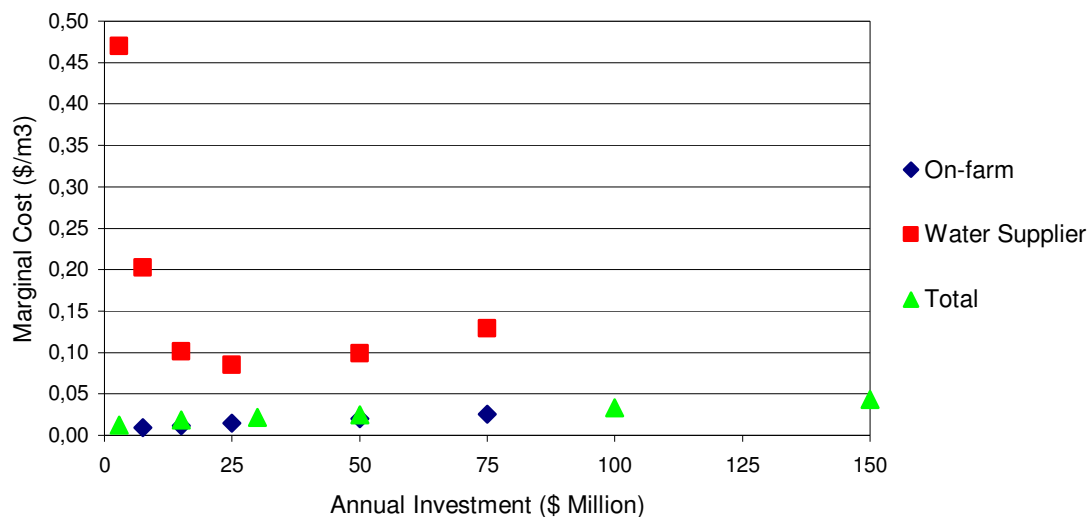


Figure 9. Marginal cost of agricultural water use efficiency measures

Despite the apparent great advantage of on-farm investment versus water supplier programs, both areas of investment must be managed conjunctively. In fact, there is a strong correlation between water supplier improvements and on-farm savings and therefore, much of these savings would not be achieved without the corresponding water supplier level spending. Moreover, around 90 percent of on-farm potential savings correspond to recoverable flows, which as previously mentioned, may only be reduced to a certain level as they serve as beneficial supply further downstream.

As regards total investment, achieving the maximal irrecoverable flow savings (766 hm³/year) would require about \$3.75 billion of State spending over 25 years, which translates into a unit cost of \$0.196/m³.

5.7. Challenges Facing Agricultural Water Use Efficiency Measures

Funding is usually one of the major issues that planners have to deal with while looking into innovative strategies and agricultural water use efficiency practices is no exception. The DWR's Agricultural Water Conservation Program of the 2003– Proposition 13 made \$28

million available in loans for agricultural water conservation and water use efficiency projects (DWR, 2003). Local public and mutual water agencies were eligible to obtain up to \$5 million per project that may include ditch lining, canal automation, tailwater recovery, purchase of measurement devices, etc. Besides, the California Proposition 50 (2002) made available \$3.4 billion in obligation bonds that include agricultural water use projects.

Despite Proposition 13 and Proposition 50 financial assistance, the State's public expenditure in this area in the past seven years has felt short of the estimates of the 2000 CALFED Record of Decision that prescribed an investment of \$1.5 billion to \$2 billion from 2000-2007. Within the CALFED Framework for Agreement it was established that the state and the federal governments would fund the implementation of water use efficiency measures at a level of 25% each, while local agencies would be responsible for the remaining 50%.

Small and less resourceful agricultural water customers often struggle to adopt innovative water management practices and retrofit their existing irrigation systems. In such cases, local agencies are often unable to provide the required 50% funding for the designed projects.

Besides technical feasibility and cost-effectiveness, water use efficiency practices need to be correctly implemented and managed to achieve their maximal potential savings. Therefore, education and willingness of farmers play a key role in agricultural water efficiency programs. For example, a weather-based irrigation station requires additional installation and maintenance labor versus a traditional time-automated system.

Many growers and irrigation districts are reluctant to adopt water efficiency practices because they believe that conserved water may be made available to other users who eventually could start claiming a certain right over the water. This is the reason why numerous irrigators fear that conserving, and thus sharing, their water could lead to a loss of their water rights. Again, it is a question of education and regulatory efforts that must be carried out in order to help farmers and other water users to cooperate and reach win-win agreements.

One of the major impediments for optimal water management and planning is lack of data on crop water use, land use, irrigation systems, irrigation efficiency, etc. Also there is no comprehensive state-wide guidance plan to assist the regions and water suppliers to collect and transfer the data needed to elaborate the future California Water Plan Updates (DWR, 2005). The Independent Panel on the Appropriate Measurement of Agricultural Water Use (www.calwater.ca.gov) makes specific recommendations for accurate measurement and registration regarding water supply, groundwater use, crop water demand as well as water quality, stream and return flows.

5.8. Summary and Conclusions

With regards to agricultural water use efficiency measures in California and Spain we highlight the following conclusions:

- Agricultural water use accounts for 80% of applied water in California and Spain. The Golden State is the major producer of agricultural goods in the United States, while Spain has one of the top four agricultural industries in the European Union. However, the production from the agricultural sector only accounts for a small portion of total gross income, 2.0% of California's GSP and 4.4% of Spain's GDP. This data include generated income by livestock as well as irrigated and unirrigated farming activities.
- Agriculture in California and Spain are very similar in terms of kind of crops and irrigated area (3.6 and 3.9 thousand hectares respectively). Surprisingly, California

consumes twice as much agricultural water as Spain. Unitary water use in California is 9.6 thousand cubic meters per irrigated hectare, while in Spain it is 4.6 thousand m³/ha. As regards economic productivity, every cubic meter of applied agricultural water in Spain generates \$2.04, unlike California where agricultural productivity is as low as \$0.69/m³.

- In California 37% of irrigation water is used in low-value and high-water consuming crops including cotton, alfalfa and rice, whereas the same variety of crops only account for 17% of total applied irrigation water in Spain.
- An investigation carried out by the Environmental Working Group (EWG) concluded that Central Valley growers receive subsidized water worth \$60 million to \$415 million annually. If such amount of money was invested in agricultural water use efficiency measures, California could achieve water savings ranging from 1.4 billion m³ to the maximal State potential of 3.5 billion cubic meters, considering the highest cost of water efficiency practices \$0.043/m³.
- Despite higher water use efficiency of low-flow systems (drip and micro-sprinklers), gravity methods are the most largely used due to low energy and maintenance costs. Moreover, low water prices and billing by surface instead of by volume do not stimulate water use efficiency measures.
- In Spain croplands that are irrigated with surface resources consume twice as much water per hectare than those supplied with groundwater. Groundwater is usually kept privately and thus becomes more expensive due to pumping costs and lack of public subsidies. This proves that higher water costs entail a more rational use of the resource.
- In addition to low-flow irrigation methods, agricultural water use can be optimized by improving on-farm and water suppliers water management. Weather stations in California and Spain help farmers optimizing their irrigation schedules according to real water demand. Furthermore, land fallowing frees large amounts of agricultural water that are made available for other uses, mostly urban.
- Marginal cost of water savings resulting from combined on-farm and water suppliers efficiency grows with the level of investment, from \$0.013/m³ to \$0.043/m³.

In terms of recommendations, there are several guidelines that could help California and Spain increase agricultural water use efficiency.

- Spain should serve as an example to California on how in a Mediterranean climate region it is possible to grow larger amounts of cereals and vegetables with half of the water the State uses now and yet keep economic productivity 50% higher. California should reduce production of low-value and high-water consuming crops, while increasing that of high-productive plants.
- On the other hand, an organization similar to the Agricultural Water Management Council (AWMC) would improve coordination among Spanish farmers and water authorities and eventually would help the implementation of water use efficiency measures. Moreover, the Spanish Ministry of Agriculture, Food and Fishery should increase expenditure in research on agricultural water conservation as well as stimulate growers to adopt water use efficiency practices through funding programs as DWR does.

The following recommendations apply to both California and Spain:

- The Governments should encourage production of low-water intensive and high value crops whenever the market could support it. Also, they should cut water subsidies especially for surplus and unprofitable crops.
- Billing by volume of applied water should substitute billing by surface of irrigated area in order to reduce water squandering. Moreover, water rates should reflect the true cost as required by the Principle of Full Cost Recovery in the EU-Water Framework.
- Implementation of low-flow irrigation systems should become mandatory wherever it was cost-effective, as it occurs with urban water conservation devices.
- An accurate statewide database should be created on amount of water applied by different irrigation methods and for every different kind of crop, as well as crop economic productivity. Data should be detailed enough to make inefficient water use farms rapidly identifiable.
- Information on agricultural water use should be made easily available to the public in order to educate all water users on the importance of agricultural water use efficiency. Not only do urban water users pay 50 times more for their water than irrigators, but also 95% of Californian and Spanish workers are contributing with their taxes to water subsidies for the farming industry, which only employees 5% of total work force. The media and public opinion should take a step forward and put pressure on the farming business to increase agricultural water conservation.