Contribution of University of California Cooperative Extension to Drip Irrigation

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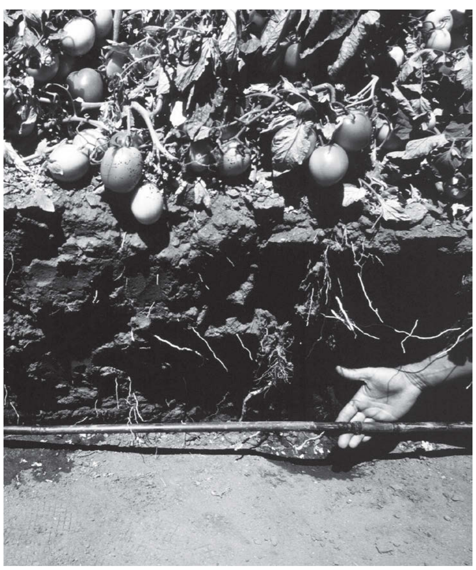
In the 100th anniversary year of University of California Cooperative Extension (UCCE), this study examines the role UCCE has played in the evolution and adoption of one noteworthy technology in California agriculture—drip irrigation. With UCCE personnel responsible for both introducing and continually adapting drip irrigation to numerous California crops and locations, we estimate the value of UCCE's work in drip irrigation brings the state $78 to $283 million annually in water savings and yield increases.



Soil cut away to expose a buried drip irrigation line in a tomato field.

Photo courtesy of Pete Mortimer, USDA ARS

The Cooperative Extension of the University of California (referred to as UCCE) is celebrating its 100th anniversary this year. UCCE is part of the Division of Agricultural and Natural Resources and comprised of 200 locally based farm advisors, 130 campus-based Extension specialists, 57 county offices throughout the state, and nine Research and Extension Centers. While UCCE's specific goals, methods, and name have changed over the last century, its basic vision has endured: "practical education for the people can lead to a better society for all."

In honor of 100 years of UCCE, we embarked on a study to assess the impact of Cooperative Extension in California, focusing on a handful of case studies. We chose a case-study approach because the literature on the distribution of benefits of Research and Extension Programs suggests that a small number of projects account for most of the effects of a research program.

We decided to start with drip irrigation for two reasons: At their fall 2013 meeting, an informal survey of County Directors identified drip irrigation as one of the major success stories of UCCE. Furthermore, it is timely to look at this technology during this period of severe drought in California. Moreover, the history of drip irrigation in California showcases the many roles UCCE plays: identifying, testing and disseminating new technologies, reducing adoption risk, training technology users, and continually collaborating with various clientele.

Drip Irrigation in California

Drip irrigation (and related low-volume irrigation technologies like trickle) requires investment in equipment that increases water-use efficiency (amount of water actually consumed by the crop), and improves the precision of water delivery in terms of the timing and location of irrigation. Its higher water-use efficiency tends to increase yields and frequently saves water used per acre. In choosing drip technology, farmers trade off higher equipment cost for better performance. The impact of drip technologies varies across locations and crops—for example, providing higher gains in sandy areas or on steep hills.

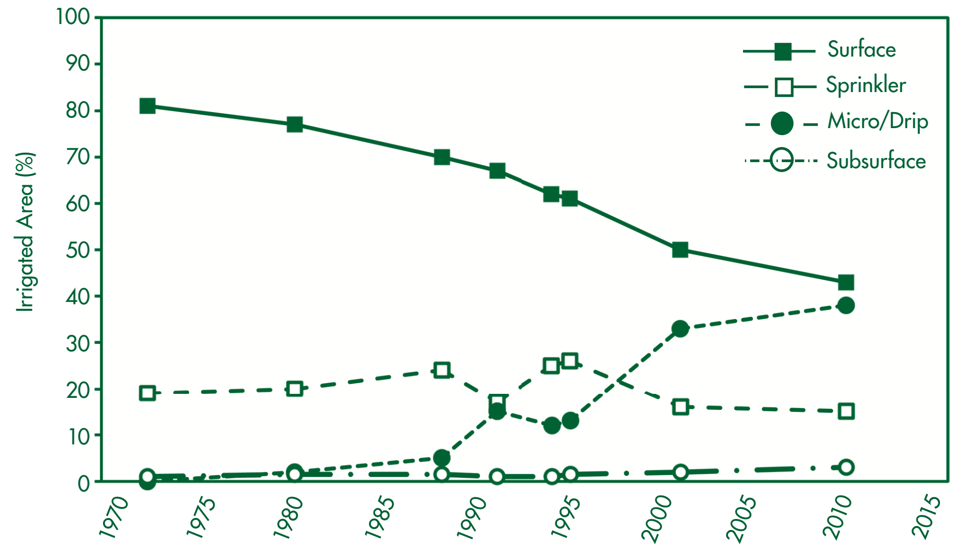
Drip was introduced to California agriculture in 1969, but its take-off was slow. By 1988, only 5% of irrigated acres in California were using drip irrigation, as switching to drip irrigation seemed costly and risky. From the beginning, UCCE farm advisors, specialists, and economists worked to provide information to improve these tough irrigation choices. UCCE initiated field experiments across the state and in numerous crops and raised awareness through research reports, demonstrations, and meetings.

UCCE efforts complemented that of drip manufacturers and distributors, with the private sector handling technical concerns and UCCE identifying how drip irrigation can improve economic and agronomic performance. Drip irrigation has since been widely adopted in the last 25 years, with almost 40% of the irrigated cropland in California now using drip. Below, we detail the different stages of its adoption.

Development, Introduction, and Early Adoption: 1965–1975

Israel introduced modern drip irrigation in 1965. Don Gustafson, a

Figure 1. Trends in Irrigated Area (Percent) by Irrigation System Category



Source: Tindula et al. (2013).

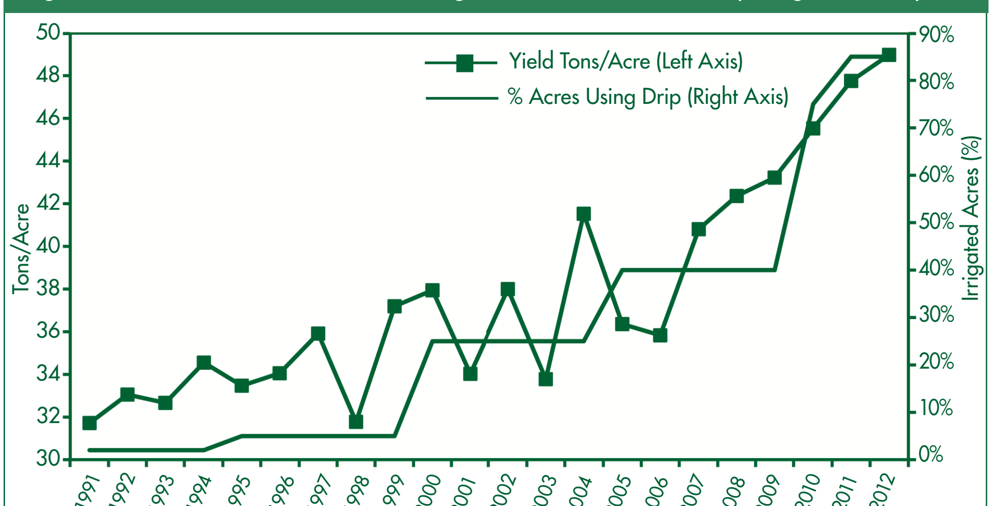
farm advisor in San Diego County, returned from a sabbatical in Israel in 1969 and initiated the drip irrigation movement in California, with a small, five-acre, experimental avocado orchard in San Diego County.

In 1970 the first drip irrigation seminar was held in Escondido, drawing 600 people and 18 equipment manufacturers. By 1974, only five years after drip's introduction into California, San Diego was invited to host the Second International Drip Irrigation Congress, drawing over 2,000 persons from 29 countries and 70 exhibitors.

Adoption of drip began to grow slowly in California. In 1976 there were about 60,000 drip-irrigated acres, in 1980 there were 305,000, and in 1985 there were 350,000. A major reason for the big increase between 1976 and 1980 was the drought of 1977–78.

Adoption of drip first occurred in avocados because of high water costs and hillside plantings. Another early application was in high-value strawberries, where UCCE farm advisor Bernarr Hall combined the use of drip irrigation and plastic mulching to grow strawberries on marginal land.

Figure 2. Trends in California Processing Tomatoes Yields and Drip Irrigation Adoption



Hall also introduced drip irrigation to fresh market tomatoes and is known for his promotion of drip tapes.

Technical Problems and Reputation Effects: 1980–1987

In the 1980s drip was mostly adopted in high-value fruit and vegetable production. However, its diffusion slowed. This was a period of low agricultural commodity prices and for most crops, the high cost of the technology—and several widely publicized failures in the design and service of new systems—made drip risky and unattractive.

The private and public sectors labored to reduce the perceived risks of adopting drip. Private-sector firms worked on improving the product and its reputation. Fresno State's Center for Irrigation Technology (CIT) and Cal Poly's Irrigation Training and Research Center (ITRC) assisted the private sector in testing, evaluating, and improving irrigation equipment. UCCE initiated field experiments with drip irrigation systems on many crops across the state in order to gauge where and under what circumstances drip irrigation would be most successful. Together, these efforts mended the reputation of drip irrigation and developed a viable product for growers.

However, knowledge and availability of a viable product do not mean immediate and widespread adoption. When assessing a new technology, individuals consider not only whether to adopt, but when to adopt; timing is important and, as shown in Figure 1, the turning point for drip was the drought of 1987–91.

California Drought: 1987–1991

Between 1987 and 1991, California suffered a severe drought with annual precipitation averaging less than 50% of normal. During the first two years of the drought, reservoirs maintained surface water supplies. However, by 1991 the Central Valley

Project's major reservoirs held less than 50% of their storage capacity.

This led growers to make a number of difficult decisions. One strategy was to fallow land with low-value crops. Another strategy was to expand the use of groundwater. The third strategy was to adopt water conservation technologies like drip. Between 1987–91, drip acreage in fruit production went up by more than 50%, and as much as 10% of vegetables were drip irrigated.

The fast adoption of drip took advantage of water management systems that were initiated by UCCE efforts—in particular, the California Irrigation Management Information System (CIMIS). From 1986 to 1991, the number of CIMIS users increased from 500 to 2000, and many more benefited from CIMIS indirectly by using information provided by consultants who were often trained by UCCE.

Adapting Drip to Other Crops and Regions: 1992–Present

After the drought years, private-sector innovation made drip systems more reusable, lowering the fixed costs associated with adopting drip and making it more economical. UCCE focused on researching methods for more effective water, fertilizer, and pest control management using drip, as well as training irrigators on how to operate and maintain drip systems.

The lower cost of equipment, combined with the high effectiveness of the technology, increased the range of crops and regions in which drip was profitable. A prime example is the work UCCE did in adapting drip technologies to processing tomatoes —a relatively large crop in California, with 317,000 acres in production, generating $984 million in revenue in 2010. Drip increased tomato yields, but canning companies were resistant to buy drip-grown fruits and vegetables because as yields go up, soluble solids and fruit sugars go down. UCCE Vegetable Specialist Tim Hartz identified a field sampling protocol for optimal ripening that increased yields with drip while maintaining high levels of soluble solids.

The adoption of drip in processing tomatoes also drastically increased because of efforts undertaken by Blaine Hanson and Don May to adapt drip irrigation to saline conditions, profitably increasing yields by up to 60%. Drip irrigation in processing tomatoes has gone from 0% of growers in 1987 to 5% in 1995, to 85% of growers in 2011. The trend in drip irrigation adoption among California processing tomato growers is shown Figure 2, alongside the trend in processing tomato yield. While there are other important factors likely at work in yield growth, the similarity between trends is striking.

Quantifying the Role of UCCE in Drip Irrigation

Quantifying the economic benefits from UCCE's contribution to the adoption of drip irrigation is a significant challenge. First, we must determine the value of drip irrigation to California, and second, decide the proportion of this value that accrues to UCCE. A common practice is to attribute 25% to the research and 25% to the development leading to a new technology. Since UCCE personnel are responsible for both introducing and adapting drip technologies to California crops, we believe it is fair and conservative to also attribute 25% of the value of drip irrigation to UCCE.

The value of drip irrigation in California has several dimensions—saving water, reducing chemical usage and increasing yield—leading to a net surplus for consumers and producers. Starting with water savings, though there are numerous farm-level studies showing that the water-saving effects of drip range from 5%–40%, they do not provide reliable aggregate estimates of impacts. Thus, to obtain an estimate of the water savings associated with using drip irrigation, we employ detailed data from Monterey Country.

According to the Center for Irrigation Technology, on average, 33.22 million acre-feet of water is used by the agricultural sector in California annually. Using 18 years of data on water extraction and irrigation methods from the Monterey County Water Resources Agency, we estimate that full adoption of drip irrigation in Monterey County is correlated with an 11.9% decrease in total agricultural water pumped per year.

Extrapolating the Monterey County estimates to the rest of the state, an increase in the percent of drip acres in California to 40% in 2010 would be associated with a 4.76% decrease in total water pumped (11.9% * 40%). Subtracting roughly 5% of the 33 million acre-feet used per year would mean 1.58 million acre-feet in annual water savings for California.

Table 1. Value of Water Savings from Drip Irrigation, Annually

Marginal Cost of Water ($/acre-foot)	Value of Annual Water Savings from Drip Irrigation ($millions)	Value of UCCE's Work in Drip with Respect to Water Savings ($millions)
80	$128	$32
150	$240	$60
220	$352	$88

Assumptions: Agricultural water use is 33.32 million acre-feet.
Percentage of irrigated crops adopting drip is 40%.
Percentage of agricultural water saved from adopting drip is 12%.
Percentage of water savings accredited to UCCE is 25%.

Table 2. Increase in Farm Income from Drip Irrigation, Annually

Yield Effect of Drip Irrigation	Increase in Farm Income from the Yield Effect ($millions)	Value of UCCE's Work in Drip with Respect to the Increase in Farm Income ($millions)
5%	$185	$46
15%	$508	$127
25%	$778	$195

Assumptions: Net farm income in crop production is $7.2 billion
Percentage of irrigated crops adopting drip is 40% (60% of high-value crops and 15% of low-value crops).
Percentage of agricultural crop value from high-value crops is 86%.
Percentage of yield effect accredited to UCCE is 25%.

To put this in monetary terms, the cost of an incremental unit of water varies across location and season, and it can be between $80/acre-foot to $220/acre-foot, with an average cost of $150/acre-foot for water use in drip (Table 1). Thus, using $150/acre-foot, the average water-saving effect of drip irrigation will be $240 million per year.

We realize these estimates reflect the impact of the adoption of drip within a water system that has been affected by other factors—such as water availability, consumer demand, and environmental regulation. However, when the water-saving effect of drip irrigation in different studies ranges from 5% to 50%, our estimate is quite conservative.

Drip irrigation has also been shown to augment crop yields; however, the estimated yield effects of drip irrigation vary. For instance, in the case of processing tomatoes, a major study found that drip irrigation increases yields by as much as 60%; while using aggregate country data, we find that drip adoption is correlated with a 41.6% increase in processing tomato yields.

In light of the variability of drip's effect on yields, depending on crop type, location and timing, the yield effect of drip is likely to be between 5% and 25%, with an average of 15% (Table 2). The yield effect is approximately equal to the effect on farm income from crop production (i.e., the total revenue excluding input costs).

Crop production comprised roughly 68% of California's $10.6 billion net farm income in 2010 (revenue excluding input costs, etc.), which equates to $7.2 billion. Given statewide adoption of 60% among high-value crops—which produce roughly 86% of the total agricultural income—and adoption of 15% among low-value crops, the value of the yield effect of drip in California lies between $185 million for a yield effect of 5% and $778 million for a yield effect of 25%, with an average of $508 million for a yield effect of 15%.

The sum of the value of water saving and the additional income from the yield effect lies between $313 million and $1.13 billion, with an average of $748 million. Accrediting UCCE one-fourth of this value means that UCCE's work in drip irrigation brings the state between $78 million and $283 million annually. Considering the entire UCCE budget in 2010 was $99 million, this is a remarkable return on investment. Furthermore, UCCE is involved in hundreds of projects every year, and drip irrigation is only one. Thus, these estimates are conservative with respect to the total value UCCE brings California.

It is important to note that these results do not take into account benefits of drip to consumers, as well as the environment, which may be substantial. The value of drip is also much higher in years of drought when water prices increase and water-use shifts towards high-value crops. In years of water abundance, we see the opposite effect. Lastly, our results do not include the quality-enhancing effects of drip irrigation in several crops, where deficit and precision irrigation lead to a superior crop quality.

Suggested Citation:

Taylor, R., D. Parker, and D. Zilberman, 2014. "Contribution of University of California Cooperative Extension to Drip Irrigation." *ARE Update* 18(2):5-8. University of California Giannini Foundation of Agricultural Economics.

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For additional information, the authors recommend:

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