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Agricultural Water Conservation and Efficiency in California
- A Commentary -

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Introduction

This is a Commentary on some of the key points that are presented in "More with Less: Agricultural Water Conservation and Efficiency in California" by Cooley, Christian-Smith, and Gleick of the Pacific Institute, September 2008 (referred to as the "PacInst Paper" in the remainder of this discussion).

The authors of this Commentary have over 120 years combined of experience in agricultural and landscape irrigation. They have worked world-wide in design and installation of all types of irrigation systems (including automated drip systems from 1975 on), design and implementation of irrigation scheduling programs since 1977; design and implementation of water conservation programs at state, water district, and farm levels; teaching programs regarding water-related energy efficiency in both university and extension environments; and basic and applied research. Summary biographies are attached at the end of this discussion.

Executive Summary

The subject of water in California is complicated. There are numerous inter-connected issues related to energy consumption, public policy, water quality, sustainability, local and regional economics, food supply, in-stream flows, investment, water availability, inter-state compacts, urban growth, climate change, overlapping government agencies/regulations, and so on. For many questions there is a shortage of accurate and timely data that would allow conclusions regarding the current situation, let alone predict the consequences of taking certain actions.

Nevertheless, it is our opinion that certain points in the PacInst Paper directly draw incorrect conclusions, or infer incorrect conclusions based on significant errors in the underlying assumptions. The importance of finding solutions to California's water problems is so great that we would be remiss if we did not express our reservations. The main points from the PacInst Paper that we would like to address are:

- <u>First, many of the "new ideas" in the PacInst Paper appear to be "old ideas"</u>. The ideas about "more crop per drop", the importance of good on-farm irrigation efficiency, the need for better appropriate water measurement at various levels, and the minimization of art in water management are all ideas for which there has been extensive discussion, investment, and effort. Much remains to be done. But the ideas are not new as the PacInst Paper infers. As an example, the interested reader is referred at least as far back as "Agricultural Water Conservation in California, with Emphasis on the San Joaquin Valley" authored by David Davenport and Robert Hagen in October, 1982 (UC Davis LAWR Dept. paper 10010).

- The PacInst Paper defines four major water conservation strategies, implying the availability of major water savings, while downplaying or ignoring the Paper authors' own cautions such as "We note that a more detailed economic assessment is needed to capture the social, economic, and environmental benefits and costs of these improvements" (page 25). Without such an assessment, conclusions drawn by the authors of the Paper are difficult to support.

Davenport and Hagen (1982) also specifically discuss, among many other conservation methods, the four water management strategies used in the PacInst Paper. Davenport and Hagen specifically note the difference between soil surface evaporation (the "E" in "ET") and plant transpiration (the "T" in "ET"), as well as the institutional impediments to some potential solutions.

- Very specifically, the conclusions assume that on-farm water savings through "smart" irrigation scheduling (not including RDI), advanced irrigation management and efficient irrigation technology can be directly translated into equivalent basin-wide savings. Such an assumption is incorrect.

A few of the PacInst Paper's claims are overly broad and simplistic, especially:

1. That there are substantial volumes of water that could be easily conserved by agriculture in the San Joaquin Valley without reducing acreage.
2. That this conservation would have no or minimal effect on established economic, cultural and ecological environments.

We pose a reality check looking at the Tulare Lake and San Joaquin areas alone: If so much water is being wasted as implied by the estimates of potential savings in the PacInst Paper, **it would have to be going somewhere**. That somewhere could only be into the ground or out through rivers. But we know that **there is a huge groundwater overdraft** (perhaps 2 million acre-feet/yr) in the San Joaquin Valley, and that the San Joaquin River runs dry near Dos Palos in the summer.

We note that the PacInst Paper acknowledges the complexity involved in their proposals (again, we see the sentences such as "a more detailed economic assessment is needed to capture the social, economic, and environmental benefits of these improvements"), but it contains no significant discussion regarding these complexities.

We certainly believe that excellent on-farm irrigation design and management are important in numerous ways, including increasing the "crop per drop", optimizing fertilizer usage, minimizing deep percolation losses to localized salt sinks, at times reducing energy consumption, etc. But improving on-farm irrigation efficiency, by itself, will not result in anywhere close to the basin (also known as "transferable", "conservable") savings that are implied in the Paper. Realistic conservation claims are essential for achieving agreement on legitimate solutions to the very real problem we have of excess needs (demands) by all sectors with insufficient developed water.

The bottom line is we just do not have enough water to satisfy all demands. And we do not believe that on-farm conservation in the Sacramento and San Joaquin Valleys, as proposed by the authors of the PacInst Paper, is going to solve the problem.

To support our concerns, and further point out how often this mistake has been made, we note one of Davenport and Hagen's conclusions in the Executive Summary of their report from over 25 years ago:

> *11. It is erroneous to conclude that a particular irrigation system such as sprinkler or drip requires only a fraction of the water applied by systems such as flood or border-strip. (With good design and management, most irrigation systems have a similar potential for efficient water application.) Because of the recoverability and reusability of field runoff and deep percolation, it is even more erroneous to conclude that decreasing runoff and deep percolation will proportionately reduce the state's net water deficit. Therefore, statements suggesting a 10-50% potential savings in agricultural water conservation by improving irrigation application systems are a disservice to the people of California because water policy and action programs based on such statements will substantially underestimate the state's needs for future water supplies.*

We also advocate better knowledge of flows and volumes of water (surface and subsurface) at all times of the year at many different levels (basin, irrigation district, field) as appropriate. It only makes sense that we have transparency and good knowledge of the precious resource of water so that our water rights laws can be administered properly, and so that water resource planning and development can be conducted with enlightenment.

One might conclude that the PacInst Paper's purpose is to prompt discussions of California's water problems. But we note that the water conservation, institutional, financial, legal, and regulatory issues brought up in the Paper are not new. These topics have been discussed, studied, and researched in detail by groups such as BAYDOC, CALFED, AWMC, USDA ARS and NRCS, USBR Mid-Pacific's water conservation office, DWR's water conservation program since 1985, the UC and CSU systems' research and education programs over the past 40 years, and the private sector (including consultants and manufacturers). Huge investments have been made by irrigation districts and farmers in modernization, especially in the past 15 years.

As an example of the wealth of information available on the topic, we point out an easy-to-read update on California's water and reasonable estimates of "conservable" water (California's Water: An LAO Primer. October 2008. California Legislative Analyst's Office. www.lao.ca.gov). Figure 1 below is from that publication. Note that the agricultural water conservation estimate includes savings from Imperial Valley.

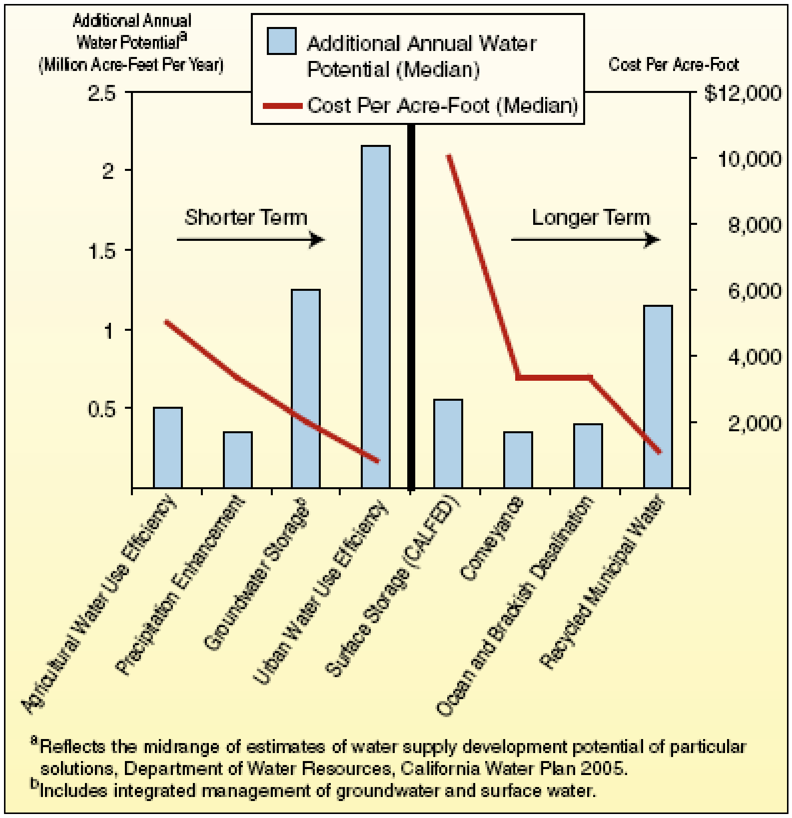

Figure 1. Estimate of amounts and costs of conservable water in California. Calif. Legislative Analyst's Office, Oct. 2008.

We recognize that the relationship between on-farm irrigation efficiency and true basin-level water conservation can be very confusing. Understanding this relationship is at the core of our Commentary. The interested reader is referred to http://www.itrc.org/papers/irrwaterbal.htm which is a discussion of basin-level and farm-level water balances.

The remainder of this Commentary will focus on technical issues associated with the four scenarios presented.

Our Analysis of the "Smart Irrigation Scheduling" Scenario

The PacInst Paper implies that some 3.45 MAF annually could be saved if farmers would only adapt "smart irrigation scheduling". (We are unsure what the qualifier "smart" implies. Irrigation scheduling as a formal practice was first developed in the early 1970's and formally introduced in California by the US Bureau of Reclamation and by commercial companies at about the same time in the early-mid 1970's. It has been and continues to be widely used in one form or another in California.) We interpreted the PacInst Paper's argument as follows:

1. The PacInst Paper uses Table 5 to support the statement at the bottom of page 27 "…California's farms still primarily rely on visual inspection or personal experience to determine when to irrigate." Table 5 is taken from a USDA Census of Agriculture listing the types of methods used by farmers to decide **when** to irrigate.

2. The PacInst Paper then proceeds to cite a study of 55 farmers performed in 1996-1997 and used in a 1997 DWR publication as to how use of CIMIS affected yields and water use. This study listed 8% increased yields and 13% reduced water use.

3. Finally, the PacInst Paper applies the 13% water use reduction across the entire baseline scenario (Table 3 in the PacInst Paper) to estimate the 3.45 MAF potential savings.

CIMIS refers to the "California Irrigation Management Information System", a program by the California Department of Water Resources that provides a "reference evapotranspiration" value on a daily basis through a system of statewide, standardized weather stations.

We note that irrigation scheduling as an Efficient Water Management Practice is the process of using one or more methods to help determine 1) when to irrigate and 2) how much water to apply at any one irrigation. We would argue that as far as water conservation is concerned, the latter is much more important. As an example, consider a drip irrigation system, generally considered a potentially high-efficiency irrigation method. Drip irrigation is a high-frequency irrigation system and at peak water use periods may be run every day. Thus, deciding when to irrigate with drip is not an issue. However, if a drip system is run twice as long as needed then it still is only 50% efficient. How much to apply during an irrigation is the important information. The PacInst Paper does not speak to methods employed by California farmers to determine how much to irrigate, nor does it mention the widespread practices of under-irrigation with many crops in California.

Table 5 speaks to the percentage of farmers who use different methods of timing irrigations, which seems to imply that somewhere in the range of only 10-20% of farmers use a "smart" kind of irrigation scheduling. However, Eching, Frame, and Snyder have the following to say about the number of farmers influenced by the CIMIS system as of 2002 (http://www.cimis.water.ca.gov/cimis/resourceArticleOthersTechRole.jsp):

> *As of April 2002, the number of registered users is 4,700. The number of direct users is much likely higher because some people use others' IDs and passwords to access the CIMIS computer. Since the system is unable to detect when several people use one ID, the number of direct users cannot be determined precisely.*
>
> *Twenty six percent (1,220 users) of the registered CIMIS users identify themselves as farmers. While this represents the potential number of farmers who access data directly, other farmers receive services from agricultural consultants who make up 10 percent of the registered users. In addition to these consultants, a list of 50 consultants who offer irrigation scheduling services is available on the CIMIS website. In a recent survey of 10 consultants to find out the extent that they used CIMIS in their services, it was found that they used CIMIS data to provide services to 411 customers. By extrapolation, the number of farmers receiving CIMIS related irrigation advisory service is estimated to be over 15,000. Farmers fall into a*

> *broad category that includes a range of operations from large agricultural operations and corporate farms to specialty farmers who grow small, intensive truck crops.*

The 2003 USDA report used by the PacInst Paper indicates there are about 46,000 farms in California (see Table 1). Thus, DWR seems to imply that more in the range of 33% of all farmers are using some sort of irrigation scheduling that utilizes CIMIS (which is only one form of scientific irrigation scheduling).

However, more importantly, the PacInst Paper does not speak to how much acreage is influenced by irrigation scheduling. The 2003 USDA report used by the PacInst Paper (see Table 1) also indicates that 8% of irrigated farms in California are 500 acres or larger and irrigate 67% of irrigated acreage. Further, 17% of irrigated farms are 200 acres or larger and irrigate 82% of irrigated acreage. Thus, whether you accept Table 3's implication of 10-20% or DWR's estimate in the range of 33%, the important question (not answered) is: "How much acreage is controlled by 'Smart Irrigation Scheduling?'" The PacInst Paper either does not recognize this facet or chose not to bring it up.

The PacInst Paper then cites a 1996 study of 55 farmers, representing over 130,000 acres that were already under the influence of irrigation scheduling (using DWR's CIMIS at that time). We point out that this study was done some twelve years ago and that agriculture has continually improved water management practices since then. While we will not argue against the study's finding of 13% average water savings in 1996 (not having access to the study methodology), we wonder if that same level of savings would still be found today, just by adapting irrigation scheduling.

> Given all the improvements in irrigation management that have taken place since 1996, including shifts to more uniform irrigation system types, improvements in irrigation event management, installation of tailwater return systems for flood irrigation systems, and recent shortages of water, just to name four, it is unlikely that we can we still expect to save another 13% through irrigation scheduling alone.

Our conclusion is that the PacInst Paper's estimate for potential savings is achieved by:

a) assuming that the bulk of California farmers do not now use irrigation scheduling even though DWR in 2002 was implying that about 33% were using CIMIS,
b) ignoring the question of how much acreage is controlled
c) ignoring the possibility that many farmers have learned from previous use of CIMIS and now apply those concepts to their irrigation scheduling
d) ignoring the existence of other methods of irrigation scheduling
e) using a study done twelve years ago of 55 farmers that controlled over 130,000 acres at that time.
f) applying the 13% savings across their entire "Base Scenario" without any baseline reference, and ignoring current widespread under-irrigation in many areas and with many crops.

However, regardless of the points above, the most important aspect of the PacInst Paper's argument is that the savings noted in the 1996 study are for **on-farm** water savings. The fatal flaw of the PacInst Paper is that it ignores the whole concept of **basin-wide** efficiencies even though it implicitly agrees with the argument that basin-wide efficiency can be quite high relative to on-farm efficiency due to re-use of surface and sub-surface runoff (see pages 14-16). You simply cannot apply an estimate of on-farm water savings to an entire basin to estimate net transferable water conservation.

> The PacInst Paper does not elaborate on the implication of basin-wide versus on-farm efficiency as regards net transferable water, but prefers to concentrate on the effects of excessive withdrawals on salinity and water quality. We agree that an assessment focusing entirely on basin-wide irrigation efficiency does ignore the detrimental effects on water quality and environment that can occur due to the timing and volume of withdrawals. We do not argue against improved on-farm water management, but the costs and benefits must be realistically understood.

Table 1. Number of Irrigated Farms by Size of Farms – truncated (From USDA Census of Ag Farm and Irrigation System Survey 1998 and 2003)

		U.S. Total - 2003	U. S. Total – 1998	California 2003	California 1998
Total	Farms	220,163	223,932	46,841	40,121
	Land in farms (acres)	196,515,390	194,529,190	15,714,032	12,351,793
	Acres irrigated	52,583,431	54,249,965	8,471,936	8,139,834
1-49 Ac	Farms	116,256	111,492	29,663	25,157
	Land in farms (acres)	12,235,580	12,606,952	1,271,804	393,080
	Acres irrigated	1,658,408	1,668,968	444,360	334,958
50-99 Ac	Farms	22,288	21,554	5,048	3,208
	Land in farms (acres)	11,817,481	13,014,584	1,164,764	221,584
	Acres irrigated	1,551,154	1,509,026	343,640	193,795
100-199 Ac	Farms	24,657	28,584	4,117	3,466
	Land in farms (acres)	28,650,930	21,894,227	1,989,340	511,026
	Acres irrigated	3,454,895	3,938,695	568,017	458,786
200-499 Ac	Farms	28,032	31,110	4,200	3,176
	Land in farms (acres)	45,758,559	45,011,307	2,356,394	1,068,206
	Acres irrigated	8,922,430	9,907,309	1,391,042	770,622
500-999 Ac	Farms	16,771	18,611	2,107	1,908
	Land in farms (acres)	37,994,582	37,249,552	2,265,955	1,336,841
	Acres irrigated	11,827,596	12,899,705	1,519,642	1,176,646
1,100-1,999 Ac	Farms	8,446	(NA)	1,082	1,966
	Land in farms (acres)	28,038,465	(NA)	1,948,794	2,528,019
	Acres irrigated	11,402,171	(NA)	1,520,550	2,171,217
2,000+ Ac	Farms	3,713	(NA)	624	1,240
	Land in farms (acres)	32,019,793	(NA)	4,716,981	6,293,037
	Acres irrigated	13,766,777	(NA)	2,684,685	3,033,810

Our Analysis of the "Modest Crop Shifting" Scenario

The Modest Crop Shifting Scenario of the PacInst Paper suggests "shifting 25% of the irrigated field crop acreage to irrigated vegetable crop acreage." This assumes that slightly over 1,000,000 acres of Central Valley field crops could be converted to vegetables with a potential water savings of 1.225 MAF. The report's rationale for doing this is to save water since, in general, vegetable crops might use less water than do field crops. At the same time, the report hypothesizes that net revenues would increase due to the crop shifting.

We note that the last paragraph in the PacInst Paper analysis identifies various confounding factors such as "market value, local weather, crop subsidy programs, need to rotate crops, seniority of water rights…potential for stranded infrastructure". It concludes with the sentence, "Future assessments should evaluate how shifting crop types affects the **net** production value" (our emphasis). Let's be clear: "net production value" is the profit to the farmer. The PacInst Paper implies that up to 1.225 MAF can be saved but neglects to examine the impact on profit to a farmer.

We certainly would applaud a shift to lower water use, higher value crops with more profit if it would be as good as the PacInst Paper indicates. Certainly, it has already occurred to a certain degree. However, the PacInst Paper analysis does not consider, or at least does not explicitly discuss, a number of factors:

1. At best estimate, there are currently slightly over 1.3 million acres of vegetables grown in California (USDA NASS, 2006), if processing tomatoes are included in the vegetable crop acreage. The vegetable market is stable with no significant vegetable shortages at the current acreage level. The PacInst Paper recommends that the vegetable acreage in California be nearly doubled, increasing the vegetable acreage to over 2.4 million acres. There is no economic analysis done as part of the PacInst Paper to determine if doubling the California vegetable crop acreage is feasible, what the impact on prices would be, or where the market would come from for double the current California vegetable production.

> If the vegetable market were as lucrative as the PacInst Paper claims, existing produce growers should have already expanded their acreage.

2. Vegetable production is often constrained by its growing condition (climate, soil, salinity, etc.). Using the PacInst Paper's own figures, currently nearly half of the vegetables grown in the Central Valley are processing tomatoes, reflecting their ability to grow under a variety of conditions. Expansion of processing tomato acreage in the Central Valley is highly unlikely, as recent history has shown little growth in the processing tomato acreage. Contracts between tomato growers and processors have stabilized the acreage, matching production to demand. Without expansion of processing tomato acreage, assuming that there could be very significant expansion (hundreds of thousands of acres) of cool season vegetables in the Central Valley is simply not justified. The PacInst Paper cites no study or information which indicates that such expansion is feasible.

We note also that vegetable growing is a high-risk endeavor and might likely result in more impacts to water quality as growers err on the high side of both fertilizer and pesticide applications. Also, due to this high risk, most vegetable growers are in the market continually with the larger companies leasing ground in different areas throughout the state so as to be able to harvest at different times of the year. Thus you might well expect double cropping (as in the Salinas and Santa Maria Valleys, where some fields are even triple-cropped) where feasible in order to mitigate risk of market fluctuations. Thus, some of the water savings calculated by the PacInst Paper just would not occur.

Our Analysis of the "Advanced Irrigation Management" Scenario

The PacInst Paper predicts 1.2M ac-ft of water savings if growers would adopt advanced irrigation management techniques. These techniques, often referred to as Regulated Deficit Irrigation (RDI), entail intentionally under-irrigating the crop during growth periods when minimal yield impacts will occur. The Scenario assumes a 20% savings for almonds, pistachio, and citrus and a 39% savings for vines. The 20% water savings using RDI for almonds and pistachio is generally accepted when compared to full irrigation. However, when one examines actual applied water on almonds and pistachios and compares it to the irrigation water needed, it is very common to find that extensive under-irrigation already occurs. Granted, the timing of that under-irrigation could be improved to maximize physiological benefits. But the existing under-irrigation definitely reduces the potential savings to well below 20%.

> The 20% water savings on citrus is not widely accepted since RDI strategies have been studied successfully on only limited varieties of citrus. The 124,000 ac-ft of citrus water savings projected under the scenario is therefore not based on established research.

The Scenario assumes a 39% RDI water savings for the vines in the Valley. This savings, totaling over 600,000 ac-ft, is based on generally accepted winegrape RDI research. We do not know the exact magnitude of RDI practices by winegrape growers in the Central Valley, but we know that it is common. What has already been reduced cannot be double counted.

The vine acreage in the Valley is not all winegrapes, however. USDA-NASS (2006-07) data on grape acreage by California County indicates that only about 250,000 acres are winegrapes. The other grape acreage in the Central Valley has raisins and table grapes. It is not appropriate to use RDI information developed for winegrapes on raisins and table grapes. The 39% potential water savings on the actual 250,000 acres of winegrapes in the Valley would be 225,000 ac-ft (not accounting for existing RDI), not the over 620,000 ac-ft estimated under the PacInst Paper scenario.

But things are not so simple. Regulated deficit irrigation of crops requires very precise control over water applications. Microirrigation systems should in theory allow irrigation with this precision, but surface irrigation and most sprinkler irrigation systems are not capable of such precision. Thus, when the PacInst Paper projects the RDI water savings under this scenario, they are assuming that every almond, pistachio, citrus, and grape grower has a microirrigation system. Since this is currently far from the case, the scenario is assuming that not only will thousands of growers adopt RDI strategies, but they will also all switch to microirrigation, an expensive conversion process.

In summary, the Advanced Irrigation Management Scenario assumes a 1.2 MAF of water saving based on adoption of RDI strategies for almonds, pistachios, citrus, and winegrapes. Nearly 400,000 ac-ft of that water savings is inappropriate due to an error in applying RDI savings for winegrapes to raisins and table grapes. The accuracy of the 125,000 ac-ft of savings under citrus RDI is questionable due to limited RDI citrus research. The scenario assumes that every almond, pistachio, citrus, and winegrape grower will invest in a microirrigation system – a very expensive undertaking. Finally, the scenario assumes that full irrigation exists on the applicable acreage, which is not the case.

We do note that RDI reduces evapotranspiration, which does indeed result in truly conservable water. However, it does bring up questions of long-term salinity buildup because leaching of salts is eliminated or reduced. Eventually, that accumulated salinity in the soil must be washed out with extra water.

Our Analysis of the "Efficient Irrigation Technology" Scenario

Under this scenario, the PacInst Paper assumes that approximately 50% of the field crop acreage in the Valley will convert from flood irrigation to sprinkler irrigation. In addition, they assume about 30% of the vegetable crop acreage will be converted to drip irrigation. These conversions are projected to save 0.6 MAF of water. However, since no water savings calculations are provided with the Paper, it is impossible to determine which portion of the 0.6 MAF projected savings could be attributed to conversions.

The flood to sprinkler conversion on field crops would need to occur on alfalfa, pasture, cotton, or corn. Cotton acreage is now less than 300,000 acres (not the 886,000 acres used in the report), and sugar beet acreage in the Valley will disappear soon. Safflower is most often minimally irrigated and rice is not a candidate for sprinkler irrigation. Corn is problematic to sprinkler irrigate due to its height, which would require that center pivot or linear move systems be installed. While alfalfa and corn prices have been strong lately, the cost of conversion from flood to sprinkler irrigation is considerable and may not be justified by field crop growing economics.

While the assumption of conversion of vegetable crop acreage from flood to drip irrigation is potentially realistic, it is unclear upon what basis the PacInst Paper assumed a conversion of 50% of the Valley's field crop acreage from flood irrigation to sprinkler irrigation. There is no economic or agronomic basis for the field crop irrigation system conversion.

Additionally, on-farm water applications do not necessarily result in basin-level water conservation.

A Short Note on Energy Use for Irrigation

The PacInst Paper discusses the concept of "embedded energy" as it pertains to applied water. This is the concept that the energy needed to apply water to a field must necessarily include the energy needed to deliver the water to the field, as well as distribute it over the field. We understand and agree with the concept.

However, their example used a flood-irrigated field in the Coalinga area being converted to drip irrigation. They note 718 kiloWatt-hours needed to deliver and apply an acre-foot of water with the flood system (718 kWh/AF) and 918 kWh/AF for the drip system (which accounts for the additional pressure required to run a drip system). Their example further assumes a 25 acre-foot reduction in applied water from a base of 100 acre-feet applied with the flood system. Thus, their analysis concludes that both water and energy are "saved" by converting to drip irrigation, because:

Energy required for the flood system = 718 kWh/AF × 100 AF = 71,800 kWh

Energy required for the drip system = 918 kWh/AF × 75 AF = 68,850 kWh

However, assume that the on-farm efficiency of the flood system is 70% (which is actually considered somewhat low in this era of improved water management). Further assume that the drip irrigation system is 90% efficient. This implies only a 22.2 AF reduction in applied water. Now,

Energy required for the flood system = 718 kWh/AF × 100 AF = 71,800 kWh

Energy required for the drip system = 918 kWh/AF × 77.8 AF = 71,420 kWh

In this analysis, energy usage is basically the same. One could use various numbers and assumptions with this specific example to prove a point. It is noted that the PacInst Paper example used the Coalinga area fed by a branch of the California Aqueduct, which included a very high "embedded energy" of 718 kWh/AF to deliver the water to the field. The numbers are different in areas that receive non-pumped irrigation district water.

A detailed study for the California Energy Commission (California Agricultural Water Electrical Energy Requirements – Final Report; ITRC Report No. R-03-006, www.itrc.org/reports.htm) predicts that a doubling of drip irrigated acreage in California will result in an increase in about 2 million MWh/yr of electrical consumption when one considers multiple factors in all of the different agricultural regions in California.

This should also identify to the reader the importance of avoiding what are known as "re-directed impacts". There are many resource management problems in California, including air quality, water quality, water conservation, energy conservation, and an aging electric grid. Policy makers must strive to avoid developing and implementing solutions that solve a problem "here" only to create more of a problem "there".

> We make these points not to argue against drip irrigation as an excellent water management tool or the concept of embedded energy. We do so to point out again that one cannot make sweeping statements about water and energy conservation without discussing the confounding details.

Conclusion

We recognize there is insufficient water to meet all of the demands in California as they presently exist. We recognize and promote the importance of improved on-farm irrigation management for a variety of reasons that we presented earlier in this document.

We recognize and promote the modernization of irrigation districts and improved flow control and measurement. We strongly promote an accelerated shift "from art to science" in all phases of irrigation.

Difficult policy and legal decisions must be and will be made that will impact the environment, lifestyles, and economics of the multiple water stake holders. We encourage the use of technically correct information to shape future decisions.

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