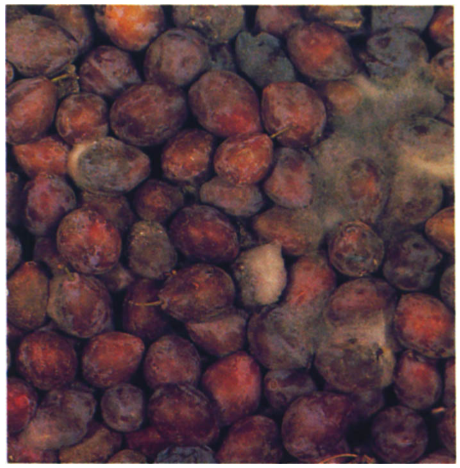
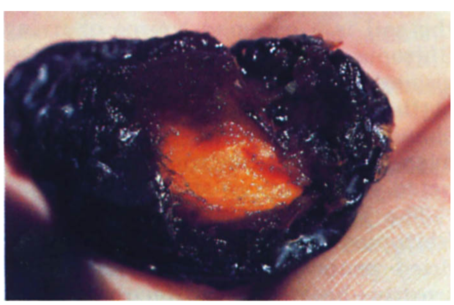


Rhizopus fungus infection spreads rapidly in fresh prunes stored in standard harvest bin.

Sulfur treatment to create golden color of prunes (right) kills *Rhizopus* fungus spores.



"Box rot" fungus infection of French prunes is characterized by macerated, wet, sticky areas on the fruit surface and a skin that slips with the slightest pressure.

storage at temperatures below 41°F to prevent rhizopus rot.

□ If cold storage is not available, fruits harvested in the morning should be held for drying after those harvested in the afternoon. Fruits harvested in the morning remain cooler longer and thus are less favorable for *Rhizopus* growth.

□ Protective chemical treatment of fresh prunes with compounds such as potassium sorbate has reduced decay rates under experimental conditions (not registered at this time).

□ In sun drying, if the golden color of prunes is desired fresh fruits may be exposed to burning sulfur or sulfur dioxide gas to kill fungal spores and make the prunes resistant to Rhizopus infections.

Peter L. Sholberg is graduate student, and Joseph M. Ogawa is Professor, Department of Plant Pathology, University of California, Davis. *This research was supported in part by the California Prune Advisory Board. The authors thank employees of Sun Diamond for their technical help in assessing deterioration and Mr. Clarence Paine for drying experimental fruit at the Fairfield dehydrator. The technical advice from Dr. T. Kosuge and technical assistance of Bill Manji, Elaine Bose, Steve Sibbett, Steve Koike, and Bob Hanowell are appreciated.*

Conserving water can have both beneficial and adverse effects

Since agriculture accounts for 85 percent of the state's applied water demands, much emphasis has been placed on agricultural water conservation. Farmers have practiced various forms of water conservation for years, particularly in areas where supplies are deficient and sometimes barely adequate to irrigate their planted acreage, but there is little incentive to conserve when water is plentiful and inexpensive. The complexities of the total water system suggest that reductions of water consumption by one user may have indirect or incidental effects on other uses and users. These effects may be costly or beneficial and, to the extent that they occur off the farm, growers have no direct incentive to account for them. The incidental effects of farm water conservation actions were the subject of a study suggested by the California Department of Water Resources (DWR).

Agricultural water conservation

In the November-December 1981 issue of *California Agriculture*, we briefly described concepts and techniques for conserving agricultural water and emphasized the distinction between the saving of water that is ultimately recoverable and the saving of water that is ultimately lost for use and is thus irrecoverable. Incidental effects of reducing recoverable losses (leakage, seepage, spillage, deep percolation, runoff) fall into a variety of categories, some of which occur on-farm and some off-farm. When irrecoverable evapotranspiration losses are reduced, on-farm crop yield may be curtailed; when irrecoverable flows to saline sinks are reduced, there can be off-farm incidental effects on instream values and on the saline water bodies that receive agricultural return flows.

Incidental effects

In a report to the DWR, we identified over 400 potential incidental effects of agricultural water conservation actions and divided them into 23 categories. Examples of these effects are given in

Incidental effects of agricultural water conservation

David C. Davenport □ Henry J. Vaux, Jr. □ Robert M. Hagan

the table; the report to DWR contains more detailed descriptions of the effects, along with pertinent literature references.

Identification of an incidental effect does not always show the magnitude of its importance, which depends partly on local conditions and partly on the extent of the water conservation action. For instance, the impact of "deficit irrigation" on crop yield will depend on the site, the crop, the severity and duration of moisture stress, and the timing of the stress relative to crop growth stage. Moreover, the effects of a single conservation action may be multiple and complex. For example, a reduction in applied irrigation water (due to a conservation action) may have both adverse incidental impacts, such as diminished crop yield, and beneficial impacts, such as a decrease in the energy needed to pump water or a smaller loss of nutrients because of reduced percolation.

Energy-related effects occur both on- and off-farm, depending on the specific conservation action and source of water. Energy impacts are most relevant on farms that obtain all, or most, of the irrigation supply from deep wells. Changing from gravity irrigation (flood or furrow) to a pressurized system (sprinkler or drip) may or may not save water, depending on the site, design, or management factors. On-farm water (and energy) may be conserved on-farm by land levelling and better management of existing gravity systems. However, where the energy required to deliver a unit of water to the farm is small, the use of pressurized systems that may be more water-efficient will increase total energy consumption both on-farm because of greater energy use and off-farm because of increased energy demands for the manufacture of that irrigation equipment. In contrast, when the energy required to deliver a unit of water to the farm is large, then the more water-efficient irrigation systems can reduce overall energy consumption.

In general, the most pertinent on-farm effects are those related to farm net returns. These include: (1) production input factors, such as energy, fertilizer, labor, management, and other production costs; and (2) production output factors (mainly crop responses to water quantity and quality, to pathogens, to pests, and the like), as well as the risks associated with conservation actions that affect the yield of marketable produce. Also important to farmers are water conservation actions that might have long-term effects on their farms' productivity, in the categories of soil and water quality, land utilization, groundwater depth, and drainage disposal.

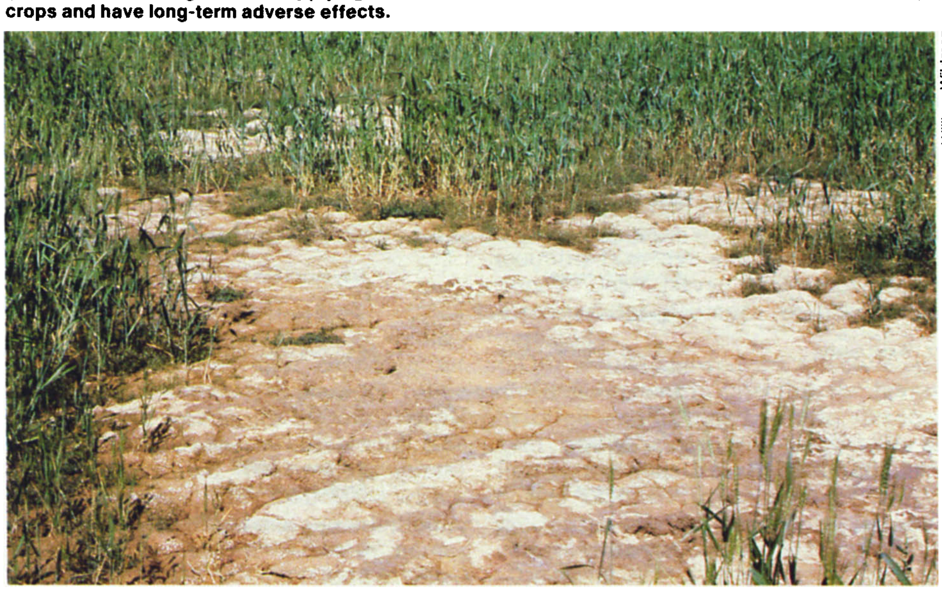
The most important off-farm effects of water conservation generally are in the categories dealing with the quality of air and water, including the hazards of toxic substances and impacts on various instream needs and wildlife.

To assess the extent to which agricultural water saving actions will be undertaken voluntarily, it is important to know whether the effects of those actions are "private" or "external." Private

David Goldhammer

William Wildman

Drip irrigation can conserve water, and also permits fertilization by injection through the drip system. Concrete lining of ditches (above right) prevents high seepage losses but may also reduce groundwater recharge. Below: Applying insufficient water to leach salts from the root zone can damage crops and have long-term adverse effects.



William Wildman

Examples of incidental effects of water conservation actions

Category	Water conservation action	Incidental effect	On-farm*	Off-farm*
1. Air quality	Less frequent irrigation	Increases dust in air from wind erosion	C	C
	Weed control	Reduces pollen-induced allergy problems	B	B
2. Crop response to water deficit or excess	Change to drip irrigation	May not increase or decrease yield if consumptive use was met	B/C	—
	Deficit irrigation	Increases risk of crop yield loss	C	—
	Preventing over-irrigation	Improves crop yield because of better root aeration	B	—
3. Crop response to water quality	Irrigation with brackish water	Decreases yield of sensitive crops and limits choice of crops	C	—
4. Drainage disposal	Improved irrigation application efficiency.	Decreases drainage volume needing disposal	B	B
5. Energy	Reduced farm water demand, e.g., by higher irrigation application efficiency	Reduces energy used for pumping from wells and for pressurized irrigation systems	B	—
	Use of sprinkler, drip, or other hardware systems	Energy is consumed in manufacture of hardware.	—	C
	Groundwater storage	Requires energy to recover water	C	—
6. Fertilizers and nutrients	Less runoff and deep percolation	Decreases leaching of nutrients from root zone; thus reducing fertilizer requirement	B	—
	Wastewater reuse	Provides free nutrients	B	—
7. Food and fiber production	Large evapotranspiration reduction	Reduces crop production, with possible effects on domestic and foreign markets	C	C
8. Groundwater depth	Reducing deep percolation by efficient irrigation or canal lining	Decreases groundwater recharge	C	C
		Causes smaller rise in high perched water tables	B	B
	Conserving to reduce groundwater pumping	Decreases land subsidence and saltwater intrusion	B	B
9. Hazards and risks	Deficit irrigation	Increases risk of crop yield reduction	C	—
	Financial incentives for water-saving investments	Reduce financial risk to farmer	B	—
10. Institutional	Savings that annually reduce farm water demand	Rights to saved water are lost under "use it or lose it" doctrine	C	—
		Reduces need for state-imposed regulations	B	B
	Open-market water transfers to make efficient use of water resources	Requires legislative time for revision of water rights laws	B/C	B/C
11. Instream needs	Conservation actions resulting in smaller farm water diversions	Leaves more water in streams for fish, recreation, navigation, other uses	—	B
	Reducing agricultural return flows to streams	May reduce stream quality degradation	—	B
12. Labor	Lining farm ditches	Reduces labor for ditch maintenance	B	—
	Well-managed automated irrigation systems	Reduce labor	B	—
13. Land utilization	Efficient drip and sprinkler systems	Permits irrigated agriculture on difficult and steep terrain	B	—
14. Management and planning	Improved irrigation application efficiency	Requires extra management effort	C	—
	Change to efficient sprinkler or drip system	Fertilizer and pesticides can be applied through system	B	—
15. Mosquito control	Reducing tailwater runoff	Reduces mosquito breeding habitat	B	B
16. Pathogens and pests of crops	Deficit irrigation	Increases crop susceptibility to pathogens	C	—
	Reducing cotton irrigation	Reduces lygus bug attack	B	—
	Wastewater reuse	Spreads plant pathogens	C	—
17. Production costs	Reducing farm water demand	May not maximize yield, but may maximize profit	B	—
	Drip irrigation	Reduces cost for fertilizer and herbicide	B	—
18. Soil — physical effects	Severe land levelling to improve irrigation efficiency	Good topsoil is lost	C	—
	Mulching	Reduces runoff and erosion	B	—
19. Soil salinity	Over-efficient irrigation that reduces leaching	Salt imbalance develops in root zone	C	—
	Wastewater reuse	May cause salt buildup	C	—
20. Toxic substances	Irrigation with M&I effluent	Risk of heavy metal and pathogen residues	C	C
21. Water quality	Reduced runoff and deep percolation	Reduces salt contribution to receiving surface and groundwaters	B	B
	Blending brackish with good-quality water	Degrades the good water	C	—
22. Weeds	Lining ditches	Decreases proliferation of weeds	B	B
	Less frequent irrigation	Decreases weeds	B	—
	Irrigation water reuse	Spreads weed seeds	C	—
23. Wildlife	Lining canals	Reduces wildlife habitat dependent on seepage	—	C
	Clearing phreatophytes	Destroys wildlife habitat	—	C

* B = beneficial. C = costly.

costs and benefits are those borne by an individual or firm that consequently has an incentive to account for them. Costs or benefits are said to be external when they are not fully reflected in the prices faced by the individual or firm. For example, a grower would have no incentive to account for the costs of water quality degradation downstream attributable to excessive tailwater runoff.

Most of the 23 categories of incidental effects identified had both private and external impacts. If the effects are solely private, and water is priced at its "true" or scarcity value (the value determined by the worth of water in its most profitable use), the level of water saving activity will be optimal for society. Conversely, the water user will not account for external impacts, and thus total water use will not be optimal for society.

Methods of estimating both private and external technological costs and benefits are fairly well developed both conceptually and theoretically. The economic impact of incidental water conservation effects that occur on the farm is relatively easily assessed because of data available on the economics of farming, but assessment of the significance and magnitude of external effects is more difficult because of the large requirement for economic and hydrologic information. Although several studies demonstrate that irrigation management practices may determine the salinity of receiving surface and groundwaters, there have been fewer studies of other external effects.

Most of the economically significant on-farm (and some off-farm) incidental costs and benefits of water conservation are accounted for by growers. However, they generally have only weak incentives to economize on water use when the water is both inexpensive and abundant. The artificial nature of many water prices makes it difficult to assess whether the external impacts of water conservation have values that are large enough, when compared with private values, to require further attention.

Recognition of some incidental effects (particularly savings in private costs such as energy) may give growers additional incentives to conserve water. However, water scarcity or relatively high water prices, or both, are the real motivating forces for conserving water in irrigated agriculture.

David C. Davenport is Associate Research Water Scientist, and Robert M. Hagan is Professor of Water Science and Extension Water Specialist, Department of Land, Air and Water Resources, University of California, Davis. Henry J. Vaux, Jr., is Associate Professor of Resource Economics, Department of Soil and Environmental Sciences, University of California, Riverside. *This study was funded by the California State Department of Water Resources.*

Parasitic nematode controls western poplar clearwing moth

Harry K. Kaya □ James E. Lindegren

Borers were reduced by one treatment

Larvae of the western poplar clearwing (WPC), usually found in trunks and branches of wild poplar and willow trees, have become pests of birch, poplar, and willow trees in nurseries, parks, and residential areas. Stressed trees, such as those that are newly planted or damaged, are preferred hosts. Most homeowners do not recognize the symptoms of attack by this insect and attribute the decline of the trees to other causes. Although infested trees may recover, they are usually deformed and slow growing and are more susceptible to additional WPC attacks.

The western poplar clearwing, *Paranthrene robiniae*, a moth native to western North America, is wasplike in appearance and size. It has a two-year life cycle. Adult moths deposit eggs singly in bark crevices and wounds. Larvae emerge from the eggs and bore into the trunk or branch, where they feed during two successive summer and fall seasons. Pupation occurs during the next spring, and adults are found from May into July. In southern California, adults have been found in November and from February through May.

The presence of actively feeding larvae can be detected by their sawdust-like frass near the gallery opening. Branches broken by the boring of the larvae and cast pupal cases left at gallery exit sites are also good indications of infestation. The larvae are difficult to control, because they are protected inside their galleries.

Parasitic nematode

The insect-parasitic "coding moth" nematode, *Neoaplectana carpocapsae*, has been effectively applied to other plant-boring insects (*California Agiculture*, January-February 1981 and November-December 1982). This nematode is mutualistically associated with a bacterium, *Xenorhabdus nematophilus*, which occurs in the infective nematode's gut. When the nematode invades the body of the host, it releases the bacterial cells, and the host dies from a bacterial infection 24 to 48 hours later. The nematode feeds on the bacterial cells and host tissues and develops to an adult, which reproduces sexually. Under the right moisture conditions, the nematodes leave the host and are capable of infecting new hosts. The life cycle of the nematode in the host, from infection to leaving the host, takes about seven to ten days.

The nematode-bacterial complex infects only insects and was recently exempted from registration by the U.S. Environmental Protection Agency and the California Department of Food and Agriculture. Other countries, in particular Australia and France, are using this nematode-bacterial complex against a number of tree-boring and soil-infesting insect species.

Application and results

We conducted a field test of *N. carpocapsae* (All strain) application against WPC larvae in 5- to 10-foot poplar and birch trees in residential areas in Davis. (Several homeowners donated severely infested trees for this research.) Fall and spring applications were all made with an atomizer containing an aqueous suspension of 35,000 infective nematodes per ml. Each gallery was treated with 70,000 nematodes (2 ml) or with 2 ml of water (control). Two weeks after application, the trees were cut and galleries examined for live and dead larvae and pupae. Dead larvae and pupae were dissected for presence or absence of nematodes.

Our results showed the effectiveness of the nematode in infecting the borers in birch and poplar trees. In October 1981, one *N. carpocapsae* application to five birch trees heavily infested with borers resulted in 88 percent (n=77) mortality. All 15 borers found in three control trees were alive. In March 1982, 90 percent of the borers (n=10) in one