Federal and state governments subsidize improvements in on-farm irrigation efficiency to conserve water. Some programs allocate irrigators a portion of the “conserved” water. Does improved irrigation efficiency lead to actual water conservation, or just the illusion of conservation? Will these programs, under the guise of water conservation, advance irrigated agriculture’s use of water at the expense of other beneficial uses?

Agriculture accounts for nearly 90 percent of the water consumed in the West. During critical months, overappropriated rivers may be dewatered completely in fulfilling senior irrigation water rights. Consequently, public attention has focused on conserving water in agriculture by increasing on-farm irrigation efficiency. California and Oregon already have passed agricultural water conservation legislation, and other western states appear ready to follow. The federal government also jumped on the bandwagon. Congress recently passed the Yakima River Basin Water Enhancement Project Act (Yakima Project Act) authorizing the expenditure of federal funds to improve irrigation efficiency on the Bureau of Reclamation’s (BuRec) Yakima Project in Washington State. Furthermore, the BuRec is embarking on its new mission as a water-conservation agency by promulgating guidelines for evaluating water conservation plans required of federal water contractees by the Reclamation Reform Act of 1982.

Public debate over agricultural water conservation focuses on the use of water savings. Irrigators want water savings to make their water rights more secure during drought periods or on otherwise overappropriated rivers (i.e., to “firm up” existing agricultural water supplies), rather than supply new out-of-stream or instream uses. Nonirrigators, such as tribes and environmentalists interested in fish and wildlife preservation, do not support public subsidies for water conservation primarily used to firm up irrigation water rights. They view the use of conserved water on additional acreage in BuRec water projects as illegal “water spreading,” the unauthorized use of federally developed water on lands not approved by the BuRec.

We contend that public debate about on-farm water conservation policy must include an assessment of whether water actually is saved by increasing on-farm irrigation efficiency. Senator Bill Bradley evidently agrees. He intends to reopen the debate on the Yakima Project Act because it conceivably could lead to “more irrigation in the basin, and thus even less water in the river” [Congressional Record 140(145):S14731 (7 October 1994)]. Here we will demonstrate how increased on-farm irrigation efficiency may create the illusion of water conservation when, in reality, the consumptive use of water may increase. We also will show how water supplies may be increasingly stressed if irrigators are allowed to use illusory water savings to irrigate additional acreage (i.e., classic water spreading), or to firm up junior rights during droughts. At these times, conservation programs may backfire. Finally, we will critique two examples of existing legislative programs, and will make recommendations about how future legislation should be drafted to avoid the problems of illusory water conservation.

**Key concepts**

The relationship between improved on-farm irrigation efficiency and water conservation must be discussed within the context of the prior appropriation system which provides the foundation for western water law.

**Prior appropriation**

In general, a person gains a usufructuary (user’s) right to publicly owned water by diverting it to a beneficial use. The priority date, diversionary entitlement, point of diversion, and place and purpose of use delimit appropriative water rights. Diversionary entitlement forever limits diversions to the amount of water first diverted. Priority of the right reaches back to the date of first diversion and
use. The appropriator with the earliest priority is most senior and entitled to his or her full diversionary entitlement before fulfillment of the second earliest right (i.e., "first in time—first in right"). The appropriator with the latest priority receives whatever remains of the water supply after satisfaction of all senior rights. Finally, the right-holder must continuously put water to beneficial use. Water not put to beneficial use becomes available to someone else further down the priority line (i.e., "use it or lose it").

**On-farm irrigation efficiency**

Irrigation scientists calculate on-farm irrigation efficiency as the ratio of the water stored in the crop root zone for consumptive use to the total water diverted for irrigation. Nineteenth century irrigation technologies and management skills gave low irrigation efficiencies of 25 to 30 percent. A crop consumptive use requirement of 2 acre feet per acre (af/ac) required that farmers divert and deliver 8 af/ac to the field. The remaining 6 af/ac either returned to the river via surface or subsurface return flows, or was irretrievably lost, through evaporation or consumption by phreatophytes, for example.

**Improved on-farm irrigation efficiency and water conservation**

Farmers improve irrigation efficiency by more timely applications of water and increased uniformity across the field. Crops consume more water because it is readily available, and yields increase. Increased irrigation efficiency reduces water lost to surface or subsurface return flows. For example, converting gravity flow irrigation systems to sprinkler irrigation technology increases irrigation efficiency from the gravity system's 25 percent to 80 percent for sprinklers, and reduces the diversion needed to meet the 2 af/ac of consumptive use from 8 to 2.5 af/ac.

The million-dollar question for agricultural water conservation policy is whether the 5.5 af/ac in reduced diversion is "conserved" water that the farmer can spread over additional agricultural land without decreasing the supply for other beneficial uses. The argument in favor is that the farmer still owns a water right granting a diversionary entitlement of 8 af/ac. Moreover, the "beneficial use" and "use it or lose it" principles of prior appropriation imply that the farmer must find employment for the "saved" water, or risk losing some of his or her defined water right.

**A numerical example**

We use the streamflow diagrams of figure 1 to consider the water conservation question in a hypothetical river basin. Figures 1a and 1b show basic hydrologic changes when more efficient sprinklers replace traditional gravity-flow irrigation technology. An average-weather year provides 200 units of stream inflow to the basin during the irrigation season. Figures 1d and 1e illustrate these changes in a drought year with only 100 units of stream inflow, and show the detrimental effect on instream flows if irrigators use "conserved" water to firm up irrigation water rights. Finally, figures 1c and 1f depict the effects on instream flow if farmers retain 75 percent of the "conserved" water to spread over additional acres.
additional acreage in average-weather and drought years, respectively.

Figure 1a shows the status quo situation with two farms, A and B, and priority dates on water rights, in that order. Each farm irrigates with traditional gravity flow technology at a low 25 percent efficiency. Thus, each farm requires diversions of 80 units from the river for 20 units of consumptive use (the encircled quantities in the diagram). Half of the unused 60 units of water percolates to an underlying common aquifer (seepage), while the other half rejoins the stream via surface runoff. When the aquifer is in equilibrium, the stream is recharged below B’s point of diversion with a spring outflow equal to 60 units. Basin outflow for downstream uses equals 160 units.

Now suppose that each farm replaces gravity-flow with sprinkler technology (figure 1b). Irrigation efficiency increases from 25 to 80 percent. For simplicity, we hold crop consumptive water use constant at 20 units per farm, though it would normally increase by 5 percent or more. Since improved irrigation efficiency normally increases the ratio of seepage to surface runoff, we assume that seepage increases to 80 percent and surface runoff decreases to 20 percent of the unused water. Each farm can reduce its diversions from 80 units to 25 units to generate the 20 units of crop consumptive use, thereby apparently “saving” 55 units of water each (for a basin-wide total of 110 units). However, a comparison with the preadoption situation in figure 1a shows that basin outflow remains constant at 160 units. Although streamflows immediately below B’s return flows are at a higher level after the change, subsequent aquifer discharge to the stream decreases in a countervailing amount. Thus, increased irrigation efficiency has redistributed basin water between the stream and the aquifer, but has not produced additional water.

Finally, suppose that the law grants each farm 75 percent of its 55 units of illusory water savings (figure 1c). Thus, each farm receives increased appropriative rights to divert about 40 additional units of water. This translates into approximately 30 units of additional crop consumptive use for each farm that is presumably spread over new land. The required diversion for each farm now equals approximately 60 units of water. Basin outflow decreases by 60 units, the additional crop consumptive use.

Figures 1d, 1e, and 1f repeat the above analysis for a drought period. Figure 1d assumes the old technology, but now drought limits basin inflow to 100 units, the stream is overappropriated, and farm B receives less than its full water entitlement. The priority of water rights (A-B) now matters. Farm B receives 50 units (about 63 percent of its water right), and its consumptive use decreases to about 13 units. The stream is completely dewatered below B’s diversion, a common occurrence in overappropriated rivers throughout the West. After recharge by B’s surface return flows and aquifer discharges, basin outflow reaches 67 units.

Figure 1e illustrates the drought-year situation after each farm adopts sprinkler technology. Farm B uses water “saved” from A’s reduced diversion to firm up its water right, and its crops consume an additional 7 units of water. While farm B benefits from A’s “conservation,” users below the basin receive even less water than before farms A and B installed “water-saving” sprinkler systems.

Finally, figure 1f demonstrates the detrimental impact on instream flows if the law grants both farms up to 75 percent of their decreased diversions to spread over additional acreage during a drought. Instream flows are insufficient at B’s point of diversion for it to take a full 75 percent, or
about 19 units. Thus, B diverts the full 41 units remaining after the point of A's return flow, and the river is completely dewatered. Basin-wide crop consumptive use increases by 43 units, which is exactly the amount that basin outflows decrease. Contrary to what downstream users would hope, the ability to spread water savings over additional land during a drought decreases the water available downstream. Worse yet for fish and wildlife preservation, the policy increases the probability that a stretch of the river becomes dewatered.

**Discussion**

Clearly, the shift in irrigation technology can create an illusion of conservation, when in fact consumptive use increases. These results do not qualitatively change with refinements in our illustration, so long as the hydrologic system remains closed (that is, water continues to recycle between the river and on-farm irrigation through surface and/or subsurface return flows). In fact, making the illustration more realistic often makes the results more pessimistic. For example, crop consumptive use and evaporative losses increase with higher irrigation efficiencies and reduce the amount available for nonagricultural uses in the basin and downstream.

Increased on-farm irrigation efficiency in a closed hydrologic system at best redistributes water within the basin and, more likely, expands water consumption by crops and decreases the supply of water for other uses. If farmers use “water savings” to firm up junior water rights, they compound the detrimental effects of droughts and overapportioned rivers on instream flows.

In general, crops must consume less water in the present to actually leave more water for alternative or future uses. Historical consumptive use quantities can be decreased by irrigating fewer acres, growing crops that require less water, or providing less water than the crops need to achieve maximum yields (deficit irrigation). Each approach will decrease agricultural production or net farm income to some extent; true water conservation does not come without a cost. Water conservation legislation may either promote or harm water supplies for alternative uses. Legislation which defines “conservation” in terms of reduced consumptive uses promotes supplies for other uses. Legislation which defines “conservation” by reduced diversions can harm supplies for alternative uses.

**Enacted agricultural water conservation legislation**

We now examine agricultural water conservation programs in Oregon and California. The Oregon statute falls into the trap of illusory conservation, while the California statute carefully avoids this trap.

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**The Oregon statute**

The Oregon water statute [Or. Rev. Stat. §537.455 (Supp. 1994)] authorizes water rights holders to submit conservation proposals to the state Water Resources Commission. The statute defines conservation as “...the reduction of the amount of water diverted to satisfy an existing beneficial use achieved either by improving the technology or method for diverting, transporting, applying or recovering the water or by implementing other approved conservation measures [§537.455(1)].” After determining the quantity of conserved water, the statute allocates up to 75 percent of it to the applicant, and the remaining 25 percent to the state. The priority of the “conserved” water is “one minute after priority of the water right held by the person implementing the conservation measures” [§537.485].

The Oregon statute falls squarely into the trap of illusory water conservation from improvement in on-farm irrigation efficiency. It calculates “conserved” water as the difference between diversionary quantities before and after improvement in irrigation technology, as opposed to the difference between consumptive-use quantities. Moreover, it compounds the potential damage to downstream flows by granting irrigators up to 75 percent of this difference.

The Oregon statute also promotes improved water conveyance facilities (lining diversionary canals and surface return drains, for example). These improvements, however, may only redistribute water within the basin rather than increase downstream supplies. The original conveyance losses may percolate down to an underlying aquifer which later recharges the river through springs, and lining the canal reduces this recharge. On the other hand, canal lining may create more water in the basin if conveyance losses do not recharge the aquifer, as, for example happens with phreatophytes.
The California statute
The California “Agricultural Water Conservation and Management Act of 1992” [Cal. Water Code §10520 (West 1992)] authorizes public agencies to assist farmers both technically and financially with the installation and operation of on-farm conservation equipment. The farmer does not receive a portion of the “conserved” water. The statute avoids the problem of illusory water conservation by defining water conservation as “the reduction of the amount of water consumed or irretrievably lost in the process of satisfying beneficial uses which can be achieved either by improving the technology or the method for diverting, transporting, applying, reusing, salvaging, or recovering water, or by implementing other conservation methods” [§10521(a)]. The statute correctly recognizes that conservation occurs only when it decreases consumptive use in a closed hydrologic system, or when it recaptures water irretrievably lost in an open system. The statute also demonstrates awareness of downstream uses when it limits the desirability of water-conveyance improvements. For example, the statute authorizes public agencies to assist farmers in “[l]ining ditches and canals or providing pipelines in the supplier’s delivery system..., except where seepage is desirable for groundwater recharge or environmental purposes” [§10522(b)(2)].

Suggestions for drafting future agricultural water conservation legislation
Several states in the West stand ready to adopt agricultural water conservation laws to simultaneously firm up irrigation water rights on overappropriated rivers, and to increase instream flows for fish and wildlife. To avoid the undesirable side effects of illusory water conservation, the new legislation should use proper accounting procedures for water use. In some special cases where irretrievable water losses can be prevented, water conservation may be adequately defined by the difference in necessary diversions before and after conservation measures. However, in general, true on-farm water conservation occurs only when crops consume less water. Thus, water conservation generally should be assessed in terms of consumptive use quantities, and not original diversionary quantities. The California Agricultural Water Conservation and Management Act of 1992 provides a good model for other states to follow in properly accounting for conservation in both general and special circumstances.

States should exercise extreme caution in allowing farmers’ claims to water “saved” from improved irrigation efficiency. Allowing such claims can result in irrigated agriculture advancing its use of water to the detriment of other beneficial uses through the pretense of conservation.