IMPLICATIONS OF DEFICIT IRRIGATION MANAGEMENT OF ALFALFA

Steve Orloff, Dan Putnam, Blaine Hanson, and Harry Carlson[1]

ABSTRACT

Water transfers from agriculture have largely occurred through fallowing of agricultural land. However, this type of transfer has negative consequences economically, socially, and environmentally. A partial solution to water shortages in drought years could be voluntary transfers of a portion of irrigation water used in alfalfa production in drought years in exchange for compensation. Large-scale field trials were established in the Intermountain Region and Sacramento Valley in 2003 through 2005 to evaluate the effects of early-season irrigation cut-off (deficit irrigation) on yield, forage quality, stand persistence and economics. The effect of deficit irrigation varied considerably between sites. Larger yield declines were typical in the Sacramento Valley sites. The water savings also varied greatly between sites but averaged 16.3 and 8.8 inches for the two treatments, respectively in the Intermountain area. No effect on stand or yield the following year was observed. These results suggest that early curtailment of alfalfa irrigation to conserve water is agronomically feasible. Assessing how much water is actually saved and assigning a value to the water are complex tasks that are regionally specific.

Key Words: alfalfa, irrigation, drought, water conservation, water transfers, economics

INTRODUCTION

Water is considered by many to be the most precious and heavily scrutinized natural resource, particularly in the arid West. Because of its high water use, alfalfa is often in the crosshairs of regulators and environmentalists searching for new sources to satisfy the increasing urban demand and for environmental mitigation efforts. It is undeniable that alfalfa production requires large amounts of water. More irrigation water is applied to alfalfa than to any other crop in California—19.5 percent of all the irrigation water used in California goes toward alfalfa

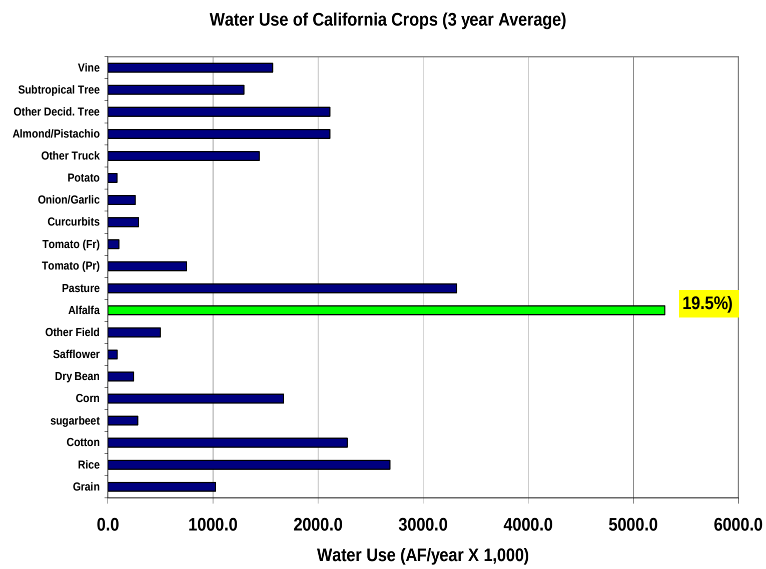

Figure 1. Comparative water used by different California crops (Source: California Department of Water Resources)

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[1] S. Orloff, UCCE Farm Advisor, Siskiyou County, 1655 S. Main St., Yreka, CA 96097; D. Putnam, Alfalfa and Forage Specialist, Plant Sciences Department, University of California, Davis, CA 95616; B. Hanson, Irrigation Specialist, Department of Land Air and Water Resources, University of California, Davis, CA 95616; and H. Carlson, Farm Advisor and Intermountain REC Superintendent, 2816 Havlina Road, Tulelake, CA; Email: sborloff@ucdavis.edu; dhputnam@ucdavis.edu; brhanson@ucdavis.edu; hlcarlson@ucdavis.edu **In**: Proceedings, California Alfalfa and Forage Symposium, 12-14 December, 2005, Visalia, CA, UC Cooperative Extension, Agronomy Research and Extension Center, Plant Sciences Department, University of California, Davis 95616. (See http://alfalfa.ucdavis.edu for this and other proceedings.)

production (Figure 1). However, this does not imply that alfalfa is a “water waster”. Alfalfa’s high water use is attributable to its long growing season and the number of acres in the state, typically around a million acres. Compared with other agricultural commodities, alfalfa is actually a fairly efficient water user (Loomis 1991).

There are few win:win opportunities when dealing with contentious issues like water allocation. Simply stated, the demand is oftentimes greater than the supply—especially in drought years—and the entities involved to do not want to forfeit a portion of their allotment, especially when their livelihood depends on adequate supplies. Alfalfa’s high water use, however, may provide some opportunities to free up some water, if methods of deficit irrigation are agronomically acceptable, and orderly voluntary transfer mechanisms can be developed. If a production system were developed that reduces the amount of water applied to alfalfa, it could result in a considerable water savings, while maintaining forage production systems.

Short-Term Voluntary Water Transfers. Water transfers from agriculture are discussed by water agencies as the primary option for dealing with water shortages in drought years. Complete fallowing of agricultural land is generally considered the only course of action. However, fallowing of large acreages can have devastating and enduring consequences on the farm economy of an area and can negatively affect the well being of an entire community. Furthermore, fallowed fields are more susceptible to wind erosion and weed encroachment and are poor wildlife habitat compared with alfalfa fields.

An alternative to complete fallowing is deficit or partial irrigation. Alfalfa is particularly well suited to this approach. As a species, *Medicago sativa* evolved in regions with seasonal rains and seasonal droughts, and alfalfa has genetic and morphological features that make it able to adapt to these conditions. Although forage yield is reduced by moisture stress, alfalfa plants survive by entering a “drought-induced dormancy” and recover once water is available. The concept then is to provide a mechanism so that interested alfalfa growers could voluntarily

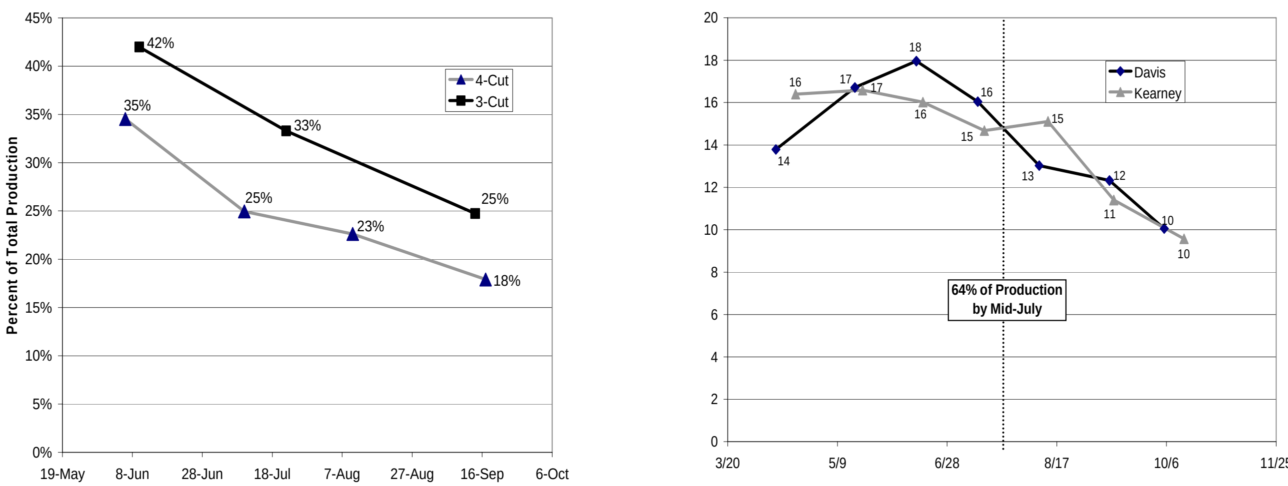

Figure 2. Seasonal yield patterns (proportion of total production per cutting) for the intermountain (left) and Central Valley (right) locations. These data are from UC variety trials in both locations averaged over several years and varieties.

transfer a portion of their irrigation water (in summer and fall) for alternative uses, environmental or urban, in drought years and receive compensation.

Advantages to the Temporary Deficit Approach. There are several advantages to this approach. Spring and early summer cuttings are often higher in yield and forage quality than late summer or fall cuttings. Yield per cutting normally trails off in fall as temperature and daylength decline. Therefore, a high percentage of the total seasonal production occurs before midsummer (see Figure 2). A likely deficit irrigation scenario would be to adequately irrigate alfalfa in the spring until June or July, and then cease irrigation to conserve water. This approach allows for harvest of the first cutting(s) in the spring and early summer, which typically represent a significant portion of the annual production.

Seasonal water use is highest in midsummer and lower in spring and fall (Figure 3). As a result of this yield and water use pattern, the water use efficiency or the amount of crop per unit of water is greatest in spring (Figure 3). The goal is to maximize water use efficiency—or obtain "more crop per drop". This is accomplished by irrigating in spring when water use efficiency is significantly higher. This approach also takes advantage of the moisture stored in the soil from winter and spring rains. Therefore, the return per unit of applied water is far greater in spring.

While this practice is logical in theory, field research was needed to evaluate the economic and agronomic viability of deficit irrigation of alfalfa for water conservation. How much yield is lost under different field conditions and management practices? How much water could be saved? Does the effect on yield carry over into the subsequent year once the field is fully irrigated? And, perhaps most importantly, is stand density deleteriously affected?

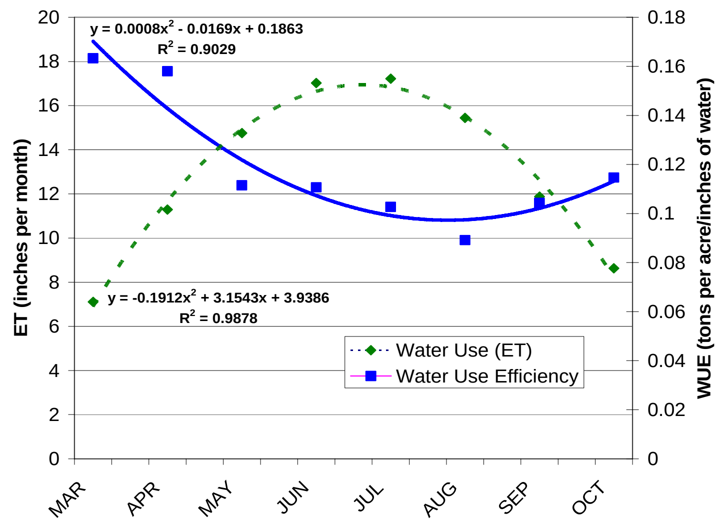

Figure 3. Changes in alfalfa water use (ET) and water use efficiency over the growing season.

ON-FARM FIELD STUDIES

Field trials were established in 2003-2005 in the Intermountain area (Klamath Basin and Scott Valley) and the Sacramento Valley of California to examine the impacts of deficit irrigation strategies. Two to three trials were conducted in producer fields in each region. These regions differ dramatically in climate, adapted varieties, and numbers of cuttings (3-4 for the Intermountain area, 6-7 for Sacramento Valley).

The **Intermountain** trials were conducted at locations with vastly different soil types representing some of the extremes in the intermountain area. The Klamath Basin sites were a fine sandy loam and a silt loam with high organic matter content. The Scott Valley sites are a

Settlemeyer Loam and a Stoner gravely sandy loam. All intermountain locations were sprinkler irrigated. Irrigation treatments were imposed by plugging three consecutive nozzles on the wheel-line irrigation systems for two 12-hour sets (minus down time for moving lines) so that each irrigation treatment was applied to a plot approximately 60 by 120 feet. Only the center area was evaluated to avoid areas where subbing (lateral movement of water) may have occurred or areas where irrigation water may have drifted onto the plots. There were three irrigation treatments:

1. normal full-season irrigation
2. no irrigation after first cutting
3. no irrigation after second cutting

The fields were cut three to four times depending on the location and the growers' management practices. Yield was determined for each cutting after the irrigation cut-off treatments were imposed. A predetermined area in the center of the plot was harvested with a flail-type forage harvester to estimate field yields. Samples were collected for dry matter determination and forage quality analysis. Forage quality, acid detergent fiber (ADF), crude protein (CP) and neutral detergent fiber (NDF), were determined using near infrared reflectance spectroscopy.

The 2005 deficit irrigation trial in Tulelake was conducted differently. The majority of the field was not irrigated after the first irrigation cut-off date. Relatively small areas, 20 by 50 feet, were irrigated with a 70-foot buffer between plots. A traveling irrigation boom on a hose reel was used instead of a wheel line irrigation system. This enabled us to put on more precise amounts of water very uniformly and by only irrigating small areas of the field, we minimized any concern about lateral movement of irrigation water into the plots via the perched water table.

After the irrigation treatments were imposed, each cutting was harvested with a flail-type forage harvester. Alfalfa stand density was assessed the following spring. First cutting the following spring was harvested to determine if there were any carry-over effects from the treatments.

The **Sacramento Valley** trials were conducted on two growers' fields in Yolo County, both clay loam soils susceptible to cracking. Both sites were flood irrigated and the irrigation treatments were applied to entire border strips. Treatments were:

1) normal full-season irrigation,
2) irrigation cut-off in mid summer (July)
3) irrigation cut-off in mid summer (July) with resumption of irrigation in fall.

The Sacramento Valley sites represented significantly different production methods than the Intermountain sites. These are very heavy soils. The cracking nature of these Yolo clay loam and Capay series clay loams are important hydraulically, since the cracks increase surface area for infiltration. The two sites were both 3-year old healthy stands of alfalfa when the irrigation treatments were imposed. The method of irrigation on these sites was check-flood irrigation. Treatments were imposed on individual checks approximately 50 x 1200 ft. Three replications were used per site. Yields were measured during the time of the deficit treatments using a cutter-bar type of experimental harvester. Samples were taken for dry matter percentage and to evaluate forage quality. At one site, monitoring equipment was installed to measure ET.

WATER SAVINGS-INTERMOUNTAIN

Water savings with the deficit irrigation treatments varied considerably between sites depending on the growers' irrigation practices (Table 1). Cutting irrigation off after 1st cutting (typically no irrigation after June 1st) resulted in a water savings of between 11 and 23 inches of water. When no irrigation was applied after 2nd cutting (usually equated to no irrigation after July 15) there was a water savings of between 6 and 18 inches. These amounts represent a considerable reduction in the total seasonal water application, as most alfalfa fields in the Intermountain area are only irrigated one or two times before first cutting.

Table 1. Water savings associated with deficit irrigation treatments at several experimental sites in the Intermountain Region (2003-2005).

	Water Savings (inches/acre)						
	2003	2003	2004	2004	2004	2005	2005
	Malin	Tulelake	Malin	Tulelake	Scott Valley	Tulelake	Scott Valley
Irrigation Termination	**Sandy loam**	**Silt loam**	**Sandy loam**	**Silt loam**	**loam**	**clay loam**	**sandy loam**
After 1st cutting	11.0	21.0	11.0	16.8	16.0	15.1	22.9
After 2nd cutting	5.5	16.8	5.5	8.4	6.4	6.2	13.1

YIELD IMPACTS OF DEFICIT TREATMENTS

Intermountain. Yield was reduced at all sites when irrigation was withdrawn after first or second cutting (Tables 2-8). Irrigation termination after 1st cutting reduced yield by 0.60 to 2.20 tons per acre (average yield reduction over 7 sites was 1.10 tons per acre). Ceasing irrigation in July after second cutting had less of an effect, reducing yield by 0.29 to 1.23 tons per acre (averaging 0.62 tons per acre).

For practical purposes the yield reduction is more than that indicated in these studies. It may not be justified for a producer to harvest a cutting that is less than half a ton per acre because the income from such a small yield may not cover costs. Therefore, the total yield in the deficit irrigated plots should not include the yield obtained from individual cuttings where the yield was less than approximately 0.5 tons. The last column in tables 2-8 shows the adjusted yield discounted for low yield cuttings assumed not to be worth harvesting. The adjusted figures show a yield penalty of 0.69 to 2.82 tons per acre when fields were not irrigated after 1st cutting. The yield decrease averaged 1.31 tons per acre. When fields were not irrigated after 2nd cutting, the adjusted yield decrease ranged from 0.31 to 1.42 tons per acre (average of 0.75 tons per acre).

The degree of yield reduction varied considerably between sites depending on several factors including depth to the water table, soil type, the age and productivity of the stand, the number of total cuttings, and the growers' irrigation practices. Klamath Basin locations had a relatively high perched water table (wet soil occurred at about 3 – 3.5 feet), whereas, the water table at the Scott Valley sites was inaccessible to the alfalfa roots. Therefore, deficit irrigation generally had a greater effect on yield at the Scott Valley sites than at the Klamath Basin sites (Malin and Tulelake). The yield reduction was also usually greater at sites with lighter textured soil, loam or sandy loam, than with the organic soils in Tulelake. In fact, the yield per cutting in deficit irrigated plots at the Tulelake sites with organic soil never fell below 0.5 tons per acre, the amount assumed to be necessary to warrant harvest. The yield reduction was greater at sites that were adequately irrigated. Even the fully irrigated treatments were under-irrigated at some sites so the full difference in yield may not have been realized at these locations.

Table 2. The effect of irrigation cut-off on subsequent alfalfa yield on a fine sandy loam soil in Malin, OR (Klamath Basin, 2003).

	Yield (tons/acre)				
Irrigation Treatment	**2nd Cut 7/22/03**	**3rd Cut 8/30/03**	**Total**	**Reduction**	**Practical* Reduction**
Normal full-season irrigation	1.03	0.67	1.70	–	–
No irrigation after 1st cutting	0.88	0.22	1.10	0.60	0.82
No irrigation after 2nd cutting	1.03	0.38	1.41	0.29	0.67
LSD 0.05	NS	0.18	0.34		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 3. The effect of irrigation cut-off on subsequent alfalfa yield on Capjac silt loam soil in Tulelake, CA (Klamath Basin, 2003).

	Yield (tons/acre)					
Irrigation Treatment	**2nd Cut 7/4/03**	**3rd Cut 8/5/03**	**4th Cut 9/11/03**	**Total**	**Reduction**	**Practical* Reduction**
Normal full-season	1.24	1.36	1.21	3.81	–	–
No irrigation after 1st	0.95	1.13	1.01	3.10	0.71	same
No irrigation after 2nd	1.22	1.20	0.86	3.28	0.53	same
LSD 0.05	NS	NS	0.33	0.66		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 4. The effect of irrigation cut-off on subsequent alfalfa yield on a fine sandy loam soil in Malin, OR (Klamath Basin, 2004).

	Yield (tons/acre)				
Irrigation Treatment	**2nd Cut 7/20/04**	**3rd Cut 8/30/04**	**Total**	**Reduction**	**Practical* Reduction**
Normal full-season	1.53	1.33	2.86	–	–
No irrigation after 1st	1.02	0.38	1.40	1.46	1.84
No irrigation after 2nd	1.41	0.71	2.12	0.74	0.74
LSD 0.05	0.45	0.40	0.34		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 5. The effect of irrigation cut-off on subsequent alfalfa yield on Capjac silt loam soil in Tulelake, CA (Klamath Basin, 2004).

	Yield (tons/acre)					
Irrigation Treatment	2nd Cut 6/29/04	3rd Cut 7/27/04	4th Cut 8/30/04	Total	Reduction	Practical* Reduction
Normal full-season	1.14	1.60	1.26	3.99	–	–
No irrigation after 1st	0.89	1.47	0.94	3.30	0.69	0.69
No irrigation after 2nd	1.20	1.48	0.82	3.50	0.49	0.49
LSD 0.05	NS	0.10	0.20	0.32		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 6. The effect of irrigation cut-off on subsequent alfalfa yield on a Settlemeyer loam soil in Etna, CA (Scott Valley 2004).

	Yield (tons/acre)				
Irrigation Treatment	2nd Cut 7/28/04	3rd Cut 9/6/04	Total	Reduction	Practical* Reduction
Normal full-season irrigation	1.73	1.06	2.80	–	–
No irrigation after 1st cutting	1.19	0.20	1.39	1.41	1.61
No irrigation after 2nd cutting	1.71	0.33	2.04	0.76	1.09
LSD 0.05	0.37	0.37	0.61		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 7. The effect of irrigation cut-off on subsequent alfalfa yield on a Tule Basin mucky silty clay loam soil in Tulelake, CA (Klamath Basin, 2005).

	Yield (tons/acre)					
Irrigation Treatment	2nd Cut 7/20/05	3rd Cut 8/23/05	4th Cut 10/12/05	Total	Reduction	Practical* Reduction
Normal full-season	2.28	1.55	0.82	4.65	–	–
No irrigation after 1st	2.00	1.40	0.59	4.00	0.65	0.65
No irrigation after 2nd	2.30	1.38	0.67	4.34	0.31	0.31
LSD 0.05	NS	0.13	NS	0.49		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 8. The effect of irrigation cut-off on subsequent alfalfa yield on a Stoner gravelly sandy loam soil in Ft. Jones, CA (Scott Valley 2005).

	Yield (tons/acre)					
Irrigation Treatment	2nd Cut 7/13/05	3rd Cut 8/18/05	4th Cut 9/30/05	Total	Reduction	Practical* Reduction
Normal full-season	2.56	1.33	1.03	4.92	–	–
No irrigation after 1st	2.10	0.48	0.14	2.72	2.20	2.82
No irrigation after 2nd	2.71	0.79	0.19	3.69	1.23	1.42
LSD 0.05	0.33	0.33	0.17	0.66		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Alfalfa stand density was assessed the following spring by visual ratings and counting the number of stems per unit area. Stems were counted to better assess the health of the stand. It is conceivable that an alfalfa crown could survive the effects of deficit irrigation but be weakened and produce fewer stems per crown. However, we found no difference in visual stand ratings or stem numbers between fully irrigated and deficit irrigated plots. First cutting yields the year following deficit irrigation were the same (data not shown) for all treatments indicating no residual effect from the deficit irrigation treatments.

Sacramento Valley. The Sacramento Valley Sites are a 6-7 cut system compared with a 3-4 cut system in the intermountain region. The summer dry-down treatments in these studies occurred in July, and yields were measured in July, August, and September/October, depending upon the year. Yields from the 2003-2005 studies are provided in Tables 9-14.

Yield losses due to the deficit irrigation treatments ranged between 0.23 tons/acre to 2.69 tons acre in the Sacramento Valley, depending upon treatment, sites, and years. In 2003, July dry-down treatments resulted in 1.5 to 2.5 tons/acre yield decline, but the practical yield impact was greater than this. A 'practical' yield impact takes into account the fact that very low yielding fields would not be harvested, since harvesting costs may exceed the value of the low yield. In 2005, summer dry down was not accomplished until August due to logistical constraints, and yield decline was less in this year due to generally low yields, and the fact that only two cuts were affected by the treatments. These fields at both sites were in the final year of production, and with the excessive heat in late summer, yields were low.

Alfalfa stand density was assessed the following spring in each year by visual ratings and stand counts. First cutting yields were measured in 2004 and 2005 to assess the effects of previous-year's irrigation treatments. Similar to the intermountain region, we found no significant differences at these two sites in stand decline or in relative next-season yield due to the irrigation treatments.

Table 9. The effect of irrigation cut-off on subsequent alfalfa yield on a Yolo clay loam soil in Woodland, CA (Site 1, Yolo County, 2003).

	Yield (tons/acre)					
Irrigation Treatment	**4th Cut** 7/13/05	**5th Cut** 8/18/05	**6th Cut** 9/30/05	**Total**	**Reduction**	**Practical* Reduction**
Normal full-season	1.56	1.35	0.58	3.49	-	-
July Dry Down	0.35	0.25	0.43	1.03	2.46	3.49
July Dry Down/Fall Rewater	0.28	0.16	0.96	1.40	2.09	2.53
LSD (P<0.05)	0.23	0.33	0.27	0.33		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 10. The effect of irrigation cut-off on subsequent alfalfa yield on a Yolo clay loam soil in Woodland, CA (Site 2, Yolo County, 2003).

	Yield (tons/acre)				
Irrigation Treatment	5th Cut 8/18/05	6th Cut 9/30/05	Total	Reduction	Practical* Reduction
Normal full-season	1.10	0.85	1.95	-	
July Dry Down	0.35	0.06	0.42	1.53	1.95
July Dry Down/Fall Rewater	0.40	0.61	1.02	0.93	1.34.
LSD (P<0.05)	0.22	0.24	0.33		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 11. The effect of irrigation cut-off on subsequent alfalfa yield on a Yolo clay loam soil in Woodland, CA (Site 1, Yolo County, 2004). The fall re-watering treatment was omitted this year.

	Yield (tons/acre)					
Irrigation Treatment	5th Cut 7/16/05	6th Cut 8/16/05	7th Cut 9/24/05	Total	Reduction	Practical* Reduction
Normal full-season	2.21	1.56	1.14	4.90		
July Dry Down	1.96	0.25	0.19	2.21	2.69	2.94
LSD (P<0.05)	0.32	0.30	0.18	0.55		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 12. The effect of irrigation cut-off on subsequent alfalfa yield on a Yolo clay loam soil in Woodland, CA (Site 2, Yolo County, 2004). The fall re-watering treatment was omitted this year.

	Yield (tons/acre)				
Irrigation Treatment	6th Cut 8/24/05	7th Cut 9/28/05	Total	Reduction	Practical* Reduction
Normal full-season	1.00	0.76	1.96		
July Dry Down	0.12	0.00	0.12	1.84	1.96
LSD (P<0.05)	0.08	0.08	0.10		

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings.

Table 13. The effect of irrigation cut-off on subsequent alfalfa yield on a Yolo clay loam soil in Woodland, CA (Site 1, Yolo County, 2005).

	Yield (tons/acre)			
Irrigation Treatment	6th Cut 8/23/05	7th Cut 10/6/05	Total	Reduction
Normal full-season	0.65	0.44	1.08	
Late July Dry Down	0.23	0.38	0.61	0.47
Late July Dry Down/Fall Rewater	0.32	0.52	0.85	0.23

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings. Since last cut of the re-water treatment was greater than controls in this year. Practical reduction in yield was not calculated in this case, since control yields were below the ½ ton practical limit. The growers in both cases harvested their last cut in spite of the low yields.

Table 14. The effect of irrigation cut-off on subsequent alfalfa yield on a Yolo clay loam soil in Woodland, CA (Site 2, Yolo County, 2005).

	Yield (tons/acre)			
Irrigation Treatment	**6th Cut** **8/23/05**	**7th Cut** **10/6/05**	**Total**	**Reduction**
Normal full-season	1.02	0.38	1.40	
Late July Dry Down	0.31	0	0.31	1.09
Late July Dry Down/Fall Rewater	0.26	0.42	0.69	0.71

*A yield of less than 0.5 tons per acre was considered not worth harvesting so the "Practical Reduction" excludes such low-yield cuttings. The last cut of the re-water treatment was equal to the controls in this year. Practical reduction in yield was not calculated in this case, since control yields were below the ½ ton practical limit. The growers in both cases harvested their last cut in spite of the low yields.

Implications of Yield Studies. Although yield penalties were present in almost all cases, these results suggest that early curtailment of alfalfa irrigation to conserve water is a feasible approach to deal with water shortages in drought years in both the Intermountain and Sacramento Valley sites. The grower is still able to harvest the more valuable and higher yielding spring cuttings and, while total alfalfa yield for the season would be reduced, a significant proportion of the annual production is still obtained. In addition, we did not observe a reduction in alfalfa stand density or a negative carryover effect on yield the following year in these studies. It must be noted, however, that in desert locations (Imperial Valley, Palo Verde Valley), stand losses are a significant risk of deficit irrigation, particularly when deficit irrigation occurs for several consecutive years.

The Intermountain area exhibited less yield impact and was more variable in the results due to the importance of high water tables at several of the sites. When irrigation cut-off started in July, the yield impact in the Sacramento region was greater.

WHAT IS THE ECONOMIC VALUE OF TEMPORARY TRANSFERS?

Determining an appropriate level of compensation for agricultural water is problematic. First, in many cases it is difficult to quantify how much water is truly saved by deficit irrigation. One viewpoint is that the water saved is equal to the total amount of water that would have been applied had the field been fully irrigated. However, this is not necessarily the case. Even after irrigation water is withdrawn, the alfalfa plant continues to transpire, utilizing residual soil moisture. Estimating the water conserved is especially complicated when the alfalfa roots are able to access a perched water table to satisfy at least a portion of its water needs, even when fully irrigated throughout the season.

Some believe it is incorrect to assume that the water not applied when deficit irrigating is the actual water saved. If a field is fallowed and void of vegetation, water loss nearly stops. However, a deficit irrigated alfalfa field may continue to transpire, although at a reduced rate, depending on the amount of residual soil moisture and amount of foliar growth. The water that continues to be transpired by the alfalfa plant even after irrigation ceases is water that in some cases could have become drain water and been recycled and used to irrigate another field. Or, it is water that may have eventually reached an aquifer that is pumped for irrigation or used for some other beneficial use. Therefore, some contend that the water saved through deficit irrigation should only be considered to be equal to the reduction in evapotranspiration.

IMPACT ON EVAPOTRANSPIRATION

After irrigation ceases, the alfalfa plant eventually becomes stressed, the stomates (holes in the leaves through which water evaporates) close and water use is reduced. How much evapotranspiration is reduced in deficit irrigated alfalfa is not well known and depends on several factors including soil moisture content, which is influenced by previous irrigation practices, soil type and the presence of a perched water table.

Research was conducted to assess how much evapotranspiration decreased in deficit-irrigated

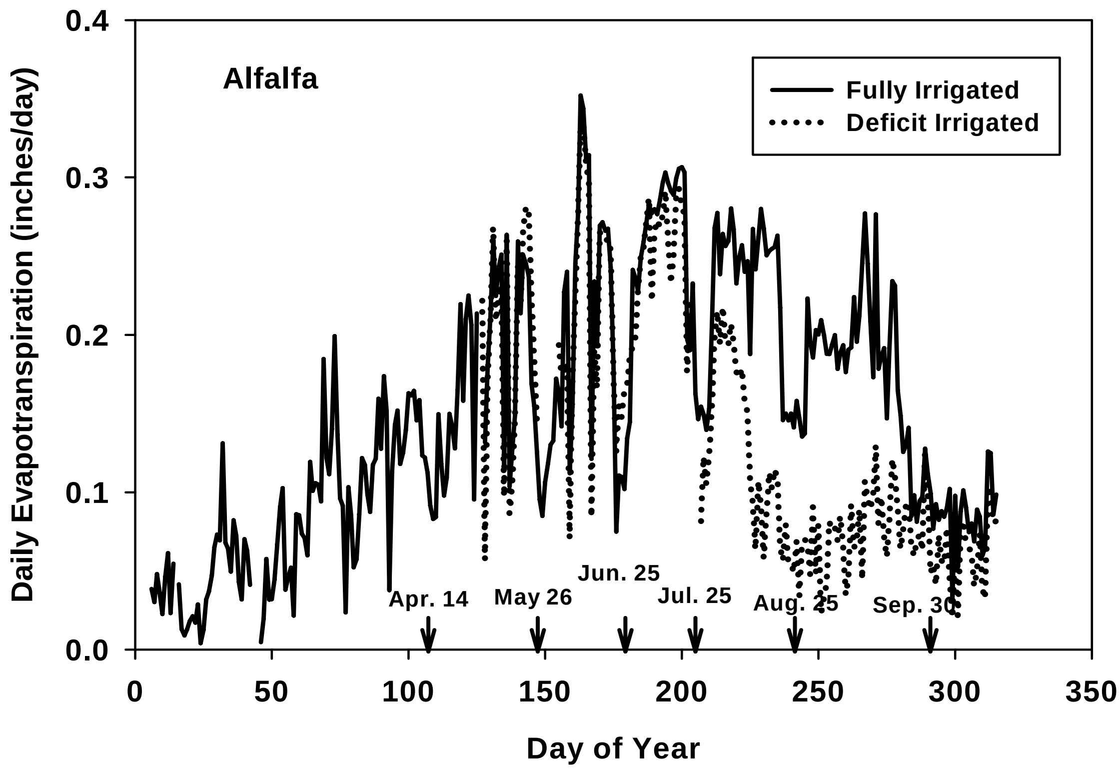

Figure 4. Alfalfa Evapotranspiration for fully irrigated and deficit irrigated alfalfa, Sacramento Valley, Site 1, 2005. The arrows and dates indicated harvest dates. Defict irrigation started July 25, 2005.

alfalfa compared with fully irrigated alfalfa. Alfalfa evapotranspiration (ETc) was determined for both fully irrigated and deficit irrigated conditions at the Sacramento Valley site 1 (Figure 1). The fully irrigated data showed increasing ETc with day of year (DOY) up to about DOY130 (Figure 4). Considerable variability occurred in the data due to the highly variable climate behavior during the first part of the year. However, just after a cutting, small values of ETc occurred and then ETc increased with time after cutting until the next cutting. This pattern is very obvious after DOY180, but is less obvious earlier in the year because of the day-to-day climate variability. Cumulative ETc as of November 12, 2005 was 46.1 inches.   This is very much in line with historical experience and other estimates of alfalfa ET which projects seasonal ET at about 48” for this region.

Deficit irrigation (no irrigation) started on July 25 in 2005. After the July 25 cutting, ETc of the deficit irrigated part of the field was less than that of the fully irrigated field and eventually decreased to values between 1 and 2 mm/day (1/25 to 1/12 inches/day). Cumulative ETc between July 25 and November 12 was 35.6 inches for the fully irrigated treatment and was 24.9 inches for the deficit-irrigated treatment. The difference in ETc during the deficit-irrigated period was 10.7 inches, according to this estimate.

CONSIDERATIONS WHEN CALCULATING WATER SAVINGS

Whether the amount of water saved should be considered the amount of water that is not applied or just the reduction in evapotranspiration depends to a large degree on the site and the hydrology and the fate of water applied in excess of crop ET. For example, the water saved might be considered equal to the water not applied at a location without a perched water table where any deep percolating water is not recycled and the soil moisture profile is filled at the end of each production season by winter rainfall. At some locations the groundwater aquifer is connected with a river system and deep percolating water that reaches the groundwater may exit the system during periods of high flow in the river and serve little beneficial use. At other locations, this water may contribute to stream flows for wildlife habitat or be captured and recycled to irrigate other fields or for other beneficial uses. At still other locations, deep percolating water may contribute to saline groundwater that is not usable. In situations where it is clear that water in excess of crop ET is re-used effectively, it may be more appropriate to consider the water saved to be just the reduction in alfalfa ET.

Another consideration is the source for the irrigation water. For example, if not irrigating in July and August when water is typically scarcer allows water to remain in lakes or reservoirs or be diverted into streams for environmental enhancement, then compensation for the full amount of water not applied may be appropriate. Deficit irrigation, as evaluated in this research, allows for irrigation in spring when alfalfa’s water use efficiency is higher and water is more plentiful and irrigation ceases in summer when water use efficiency is reduced and water supplies are oftentimes inadequate.

DETERMINING THE VALUE OF WATER

Assigning a value to the water conserved is not as easy a task as one might think for several reasons. From the grower’s perspective, at a minimum, the value of water should make up for production losses. However, assessing potential losses is a complex issue itself due to the differences in losses between fields. In the intermountain area, the water price needed to make up for the reduction in yield that occurred when irrigation ceased after first cutting varied considerably between sites depending both on the degree of the yield loss and the amount of water applied to achieve full yield (Figure 5). On average, a water value of $119 per acre foot was needed to cover the loss in alfalfa yield assuming an alfalfa hay price of $120 per ton. The value ranged from $49 to $240 per acre foot depending on the site. These values are calculated based on gross returns and are not discounted for the reduction in inputs that would occur if yield

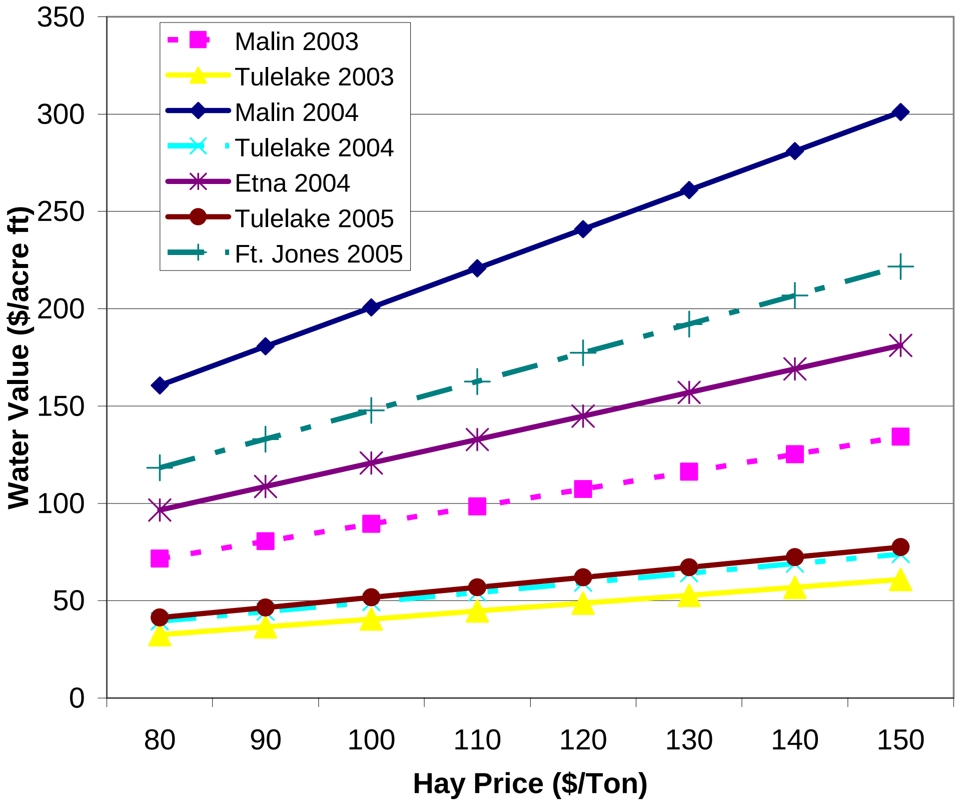

Figure 5. The water value necessary to compensate for alfalfa yield loss from ceasing irrigating after first cutting at several intermountain locations for a range of hay prices.

was reduced due to deficit irrigation (examples include lower harvest cost, less fertilizer required, perhaps reduced pesticide inputs, etc.).

At the Sacramento Valley site 1, where ET of the two treatments was measured in detail, the loss in yield during the period July 25 through November 12, 2005 was 1.08 tons/acre, with an estimated ET difference of 10.7” of water. At various hay prices, the value of this loss in hay ranged from 96.9/AF through over 200/AF (Table 15).

Should compensation merely be reparation for lost yield? It is likely that growers would expect more incentives depending upon the situation. The issues related to maintaining customer supply (risk of loosing dependable markets), and long-term risk of loosing stands must be considered. The risk of stand loss does exist even though we did not observe a permanent effect on productivity or stand in these trials. Variable alfalfa production on a farm from year to year could also be problematic for producers. Established growers strive to develop a customer base; an interruption in total supply from one year to the next could complicate maintaining that clientele base.

Table 15. Direct value of water saved calculated from value of hay, Sacramento Valley Site 1, 2005. Water savings estimates are based upon differences in ET measured in the control plots compared with the plot where irrigation ceased in late July . Note: This is a single site, single year, and negotiated price of water may depend upon a range of factors.

	Price of Alfalfa Hay					
	$80/ton	$100/ton	$120/ton	$140/ton	$160/ton	$180/ton
	Equivalent worth of water saved ($/AF)					
Late July Irrig. Cut-off	$96.90	$121.12	$145.35	$169.57	193.79	218.02

On the other hand, a payment for water transferred could benefit alfalfa growers because mid summer cuttings are often lower in yield and are typically the lowest in forage quality. Therefore, mid-summer cuttings are often more difficult to market and there is an abundance of mediocre quality mid-summer alfalfa hay often resulting in a poor price. A reduction in the supply of mid-summer alfalfa could improve price for all alfalfa hay producers. In the Sacramento Valley, growers could probably forgo the expense of insect control on deficit plots during late summer months. However, the implications of these techniques on pests in general have not been fully explored. For example, lack of flooding may increase rodent problems.

Other factors should be considered when establishing a value for the transferred water including the value of the water to the end user, whether it is urban uses or for environmental benefits. With the current interest across the state in water transfers from agriculture, economists are examining several different methodologies to establish a value for water. Whatever method is selected, growers should be confident that the value provides adequate compensation for their losses. Cooperation in transfer arrangements—like the one this research suggests may be possible—could benefit farmers in the long run by providing water for other uses in drought years while helping to obtain a more secure water supply for agriculture

CONCLUSIONS

Deficit irrigation of alfalfa shows promise as a strategy for dealing with water shortages. These data suggest that water transfers from alfalfa for other uses in drought years may be agronomically feasible. Under ideal conditions, this may be one of the few win:win scenarios when it comes to proposals to deal with water shortages in drought years. Water could be voluntarily transferred in critically dry years to satisfy urban requirements or for environmental needs, if the grower is adequately compensated for forgoing a portion of their production. Further work to understand the impact of deficit irrigation on yields and plant stands, and under different soil and hydrological conditions is needed, particularly to understand methods of controlling plant growth when high water tables occur. Methods to measure water savings and to assure orderly transfer protocols are required for this to be successful.