

IRRIGATING ALFALFA WITH LIMITED WATER SUPPLIES

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ABSTRACT

The evapotranspiration (ET) of fully-irrigated alfalfa ranges from 31.9 inches in northern California to 65.2 inches in the low desert areas of southern California. During low water years, however, ET may be reduced by limited amounts of applied water. Strategies for coping with limited water supplies include reducing the irrigated acreage (Strategy 1), fully-irrigating the earlier harvest periods until the water supply is used up and then no irrigation thereafter (Strategy 2), and deficit irrigate the field for the entire season by reducing the water applications between harvests (Strategy 3). An evaluation showed slight differences in returns to land and management between the first two strategies. The third strategy could not be adequately evaluated because of the lack of both cost data and yield-ET relationships under deficit irrigation.

INTRODUCTION

Alfalfa is California's single largest agricultural water user due to the amount grown, typically about 1 million acres, and its long growing season. Seasonal alfalfa water applications generally range from 4,000,000 to 5,500,000 acre-feet.

The evapotranspiration (ET) of fully-irrigated alfalfa measured in commercial fields ranges from 31.9 inches in northern California to 65.2 inches in the low desert areas of southern California. Drought conditions can reduce ET to levels smaller than needed for maximum yield due to limited water supplies. Several strategies are available for alfalfa growers to cope with a reduced water supply, but the bottom line is that yields will be reduced compared to normal water supply conditions.

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PROCEDURES

During the past five years, alfalfa ET and yield were measured in California in commercial fields located in the Imperial Valley, southern part of the San Joaquin Valley, Sacramento Valley, and the Intermountain Area of northern California (Scott Valley, near Yreka, CA and Tulelake, south of Klamath Falls, OR). These data provided a basis for evaluating strategies for irrigating alfalfa with limited water supplies. ET was determined at these sites using eddy covariance and surface renewal energy balance methods. At each site, ET and yield was measured for fully-irrigated alfalfa and for alfalfa subjected to mid-summer deficit irrigation (no irrigation).

RESULTS

Evapotranspiration

Daily evapotranspiration of alfalfa was small, generally between 0.05 and 0.1 inches per day, at the start of the crop growing season, the time of which varied depending on climate characteristics, increased with time of year to maximum values between 0.3 and 0.4 inches per day in June/July, and then decreased to small values at the end of the crop season (Figure 1). For each harvest cycle, small ET values occurred just after harvest, and then increased rapidly to maximum values after the first irrigation between harvests. Seasonal evapotranspiration ranged from 31.9 inches (Scott Valley 2008) to 65.2 inches (Imperial Valley 2008) (Table 1).

Yield – ET Relationships

Cumulative yield of the fully-irrigated alfalfa increased linearly with cumulative ET during the crop season at all sites except for the Imperial Valley (Figure 2). The effect of heat stress on yield during the later part of summer is believed to have caused the Imperial Valley behavior.

Strategies for Irrigating Alfalfa with Limited Water Supplies

Strategies for coping with limited water supplies include:

Strategy 1. Reduce the irrigated acreage

- ◆ Fully irrigate the reduced acreage for the crop season to obtain maximum yield over the reduced acreage.
- ◆ The amount of acreage reduction depends on the amount of available irrigation water.
- ◆ No irrigation occurs on the remaining acreage, which will result in a yield loss.
- ◆ No field-wide yield reduction may occur for the first harvest provided sufficient soil moisture from winter/spring snowmelt or rainfall exists. This condition may frequently occur in the Intermountain Region and the Sacramento Valley even during conditions of drought, but may not occur in the alfalfa production areas of southern California.

◆ The critical irrigation is the first irrigation after harvest, which should occur as soon as possible.

Strategy 2. Fully irrigate earlier harvests; no irrigation for the remaining harvests.

- ◆ Fully irrigate the entire field starting with the first harvest period until the water supply is used up.
- ◆ No irrigation will occur for the rest of the crop season, resulting in a yield loss.
- ◆ The number of earlier harvests that can be fully irrigated depends on the amount of available irrigation water.
- ◆ This strategy will maintain the high yields of the early harvests and will result in no irrigation during the later part of the crop season during which yields and quality normally are smaller compared to the earlier harvests.
- ◆ The critical irrigation is the first irrigation after a harvest.

Strategy 3. Deficit irrigate the entire field during the crop season.

- ◆ Irrigate the entire field during the crop season with a reduced amount of irrigation water applied per harvest period.
- ◆ Approaches for reducing the irrigation water per harvest period include applying smaller water applications per irrigation, reducing the number of irrigations per harvest period, or a combination of both. Applying smaller water applications per irrigation is appropriate for sprinkle irrigation, but not for flood irrigation. Reducing the number of irrigations can be used by both sprinkle and flood irrigators.
- ◆ Yield loss will occur over the entire field, but the amount of yield loss will depend on the reduction in applied water and the relationship between alfalfa yield and ET under deficit irrigation.
- ◆ No yield reduction may occur for the first harvest provided sufficient soil moisture from snowmelt/rainfall exists, depending on location.

Which Strategy is the Best?

The best strategy is the one that provide the largest returns to land and management for the irrigator, which will depend on the revenue reduction due to reduced yield and the production costs of a particular strategy. Variable production costs include irrigation costs and harvest costs. Variable production costs per acre per harvest will be the same for Strategy 1 as for a fully irrigated field, but because part of the field will not be irrigated, the field-wide production costs will be smaller than those normally incurred. Variable production costs per acre per harvest of Strategy 2 will be the same as those of a fully-irrigated field for the harvests that are fully-irrigated, but no variable costs will occur during the no-irrigation period. Production costs may be reduced for Strategy 3 because of smaller yields per acre per harvest, but the entire field will be harvested. Irrigation and harvest costs per acre should be smaller than those of a fully-irrigated field, but no information exists on the actual costs of a deficit-irrigated field. It should be noted that fixed costs will not change due to a particular strategy. Also, fertilizer and pest control costs may not change since these costs generally occur early in the crop season.

The returns to land and management were evaluated for the first two strategies using the relationships in Figure 2 and alfalfa production cost data for commercial fields found at “[http://alfalfa.ucdavis.edu/+producing/index.aspx?cat=Economics and Marketing](http://alfalfa.ucdavis.edu/+producing/index.aspx?cat=Economics+and+Marketing)”, for Scott Valley, Sacramento Valley, and the southern San Joaquin Valley. The economic analysis was not conducted for the Imperial Valley site because the production costs were not in a format that was usable for this study. Crop prices of \$100 per ton and \$200 per ton were also used. Total costs included the production costs and cash overhead costs (taxes, insurance, etc.). Non-cash costs (depreciation) were not included (recommended by R. Howitt, chair of the Department of Agricultural Economics, University of California, Davis). Note that the Tulelake data were not used for this analysis because little yield differences occurred between deficit irrigated and fully irrigated alfalfa at that site because of crop water use of shallow ground water.

Little difference in returns to land and management were found between Strategies 1 and 2 (Figures 3, 4, 5, and 6). Differences were the largest for small amounts of ET and decreased as the ET increased. In some cases, strategy 1 was more profitable than strategy 2, while in other cases, the opposite occurred. Negative returns occurred for a crop price of \$100 per tons until the available water was sufficient to supply 69 to 79% of the ET for the Sacramento Valley and San Joaquin Valley (40% for Scott Valley). However, for the Sacramento Valley 2008, negative returns occurred regardless of the amount of available water. At \$200 per ton, positive returns occurred for water supplies that could meet at least 31 to 50% of the fully-irrigated ET for the Sacramento Valley, 16 to 25% for the San Joaquin Valley, and 14 to 28% for Scott Valley. Little difference in the minimum ET was found between strategies. However, considerable differences occurred between Sacramento Valley 2007 (31 to 39 %) and 2008 (48 to 50%) (same field for both years), reflecting the higher yield-ET relationship of 2007 compared to 2008 (fig. 2). Smaller differences occurred between the San Joaquin Valley 2007 (23 to 25%) and 2008 (16 to 24%), which had similar yield-ET behavior.

Numerous studies have shown that yield is linearly related to ET for deficit-irrigation conditions, but these relationships are site-specific. Thus, for Strategy 3, a 50% reduction in ET generally will decrease yield by 50%; however, uncertainty exists concerning the actual yield for a given amount of ET and in the effect of this yield on variable costs since the entire field must be irrigated and harvested. One consideration is that for small amounts of applied water per harvest, yield per acre per harvest under Strategy 3 may be uneconomical to harvest. A yield of 0.5 tons per acre generally is considered to be a threshold yield for determining if it is economical to harvest.

CONCLUSION

Strategies for irrigating alfalfa with limited water supplies include reducing the fully-irrigated acreage to reflect the reduced water supply (Strategy 1); fully-irrigating the earlier harvest periods as long as possible and then terminating irrigation for the remainder of the crop season (Strategy 2); and deficit irrigating the entire field for the crop season by applying less water between harvests (Strategy 3). Yield-ET data for fully-irrigated alfalfa developed at various locations in California were used to evaluate

the economics of the first two strategies. Economics of Strategy 3 could not be completely determined because of the lack of data on yield and costs under deficit irrigation conditions. The evaluation showed little differences in returns to land and management between the first two strategies. The minimum amount of available water needed for positive returns depends on crop price, seasonal yield/ET relationships, and production costs.

Based on these results, Strategy 2 is recommended for irrigating alfalfa with limited water supplies. One advantage of the Strategy 2 is that it better guarantees using all of allocated water by applying the water during the earlier part of the crop season. Strategy 1 runs the risk of losing water allocations due to additional water reductions later in the crop season. The effect of Strategy 2 on crop ET and yield is illustrated in Figure 7 for Sacramento Valley 2007, where sufficient water was available to supply about 50% of the fully-irrigated ET. No irrigations occurred after the end of June (day of year 180). The no irrigation period reduced ET and yield; however, yields of the following year appeared to recover, based on the yield of the first harvest of 2008.

Table 1. Measured and historical seasonal ET of the fully-irrigated alfalfa at various locations in California. The historical ET was obtained from publications of state and federal agencies in California, but little or no published research supporting the historical values appears to exist.

Site	Year	Measured seasonal ET (inches)	Historical seasonal ET (inches)
Imperial Valley	2007	57.4	76
	2008	65.2	
San Joaquin Valley	2007	56.6	49
	2008	59.8	
Sacramento Valley	2005	50.5	48
	2006	54.4	
	2007	55.0	
	2008	50.3	
Scott Valley (Etna)	2007	38.9	33
	2008	31.9	
	2009	35.9	
Scott Valley (Fort Jones)	2009	40.9	33
Shasta Valley	2009	40.7	33
Tulelake	2007	39.9	33
	2008	37.9	

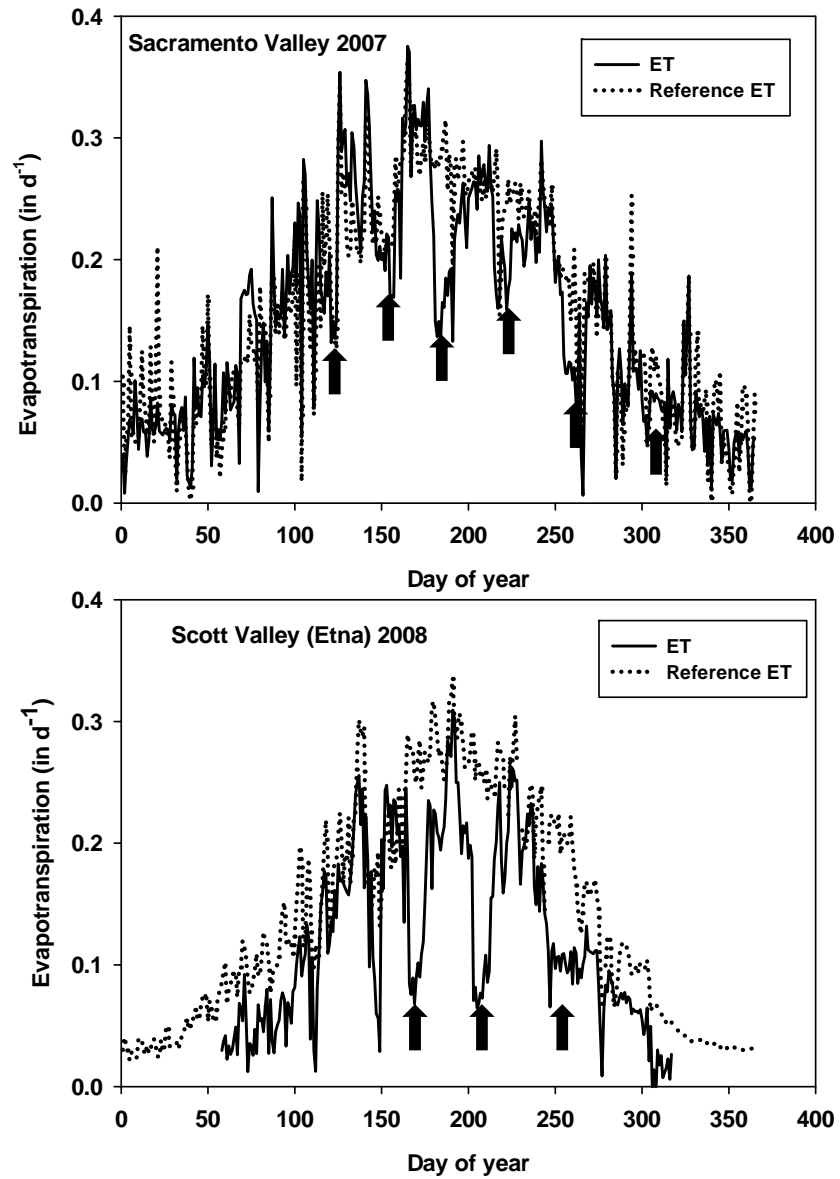


Figure 1. Evapotranspiration of alfalfa for the Sacramento Valley (2007) and Scott Valley (2008). The reference ET is that obtained from the California Irrigation Management Information System. The arrows show the harvest times.

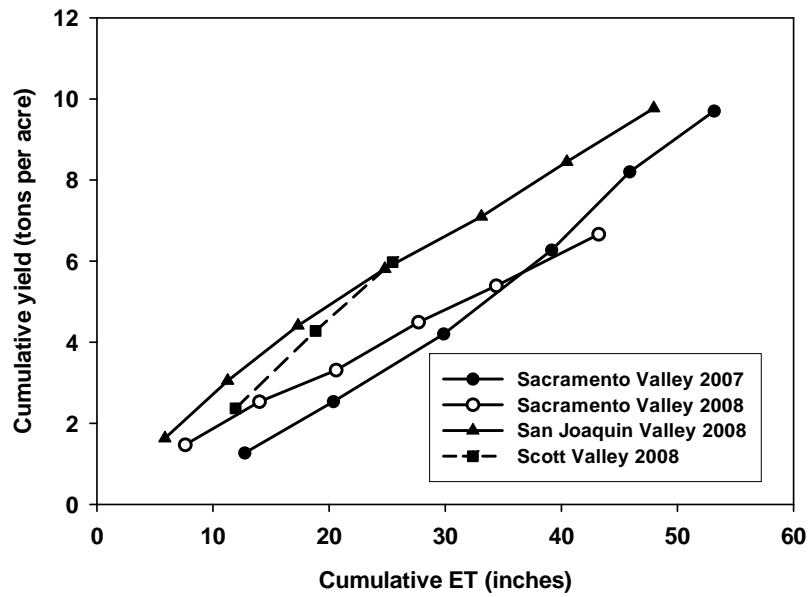


Figure 2. Relationships between cumulative evapotranspiration (ET) and cumulative yield for fully-irrigated alfalfa for three locations in California.

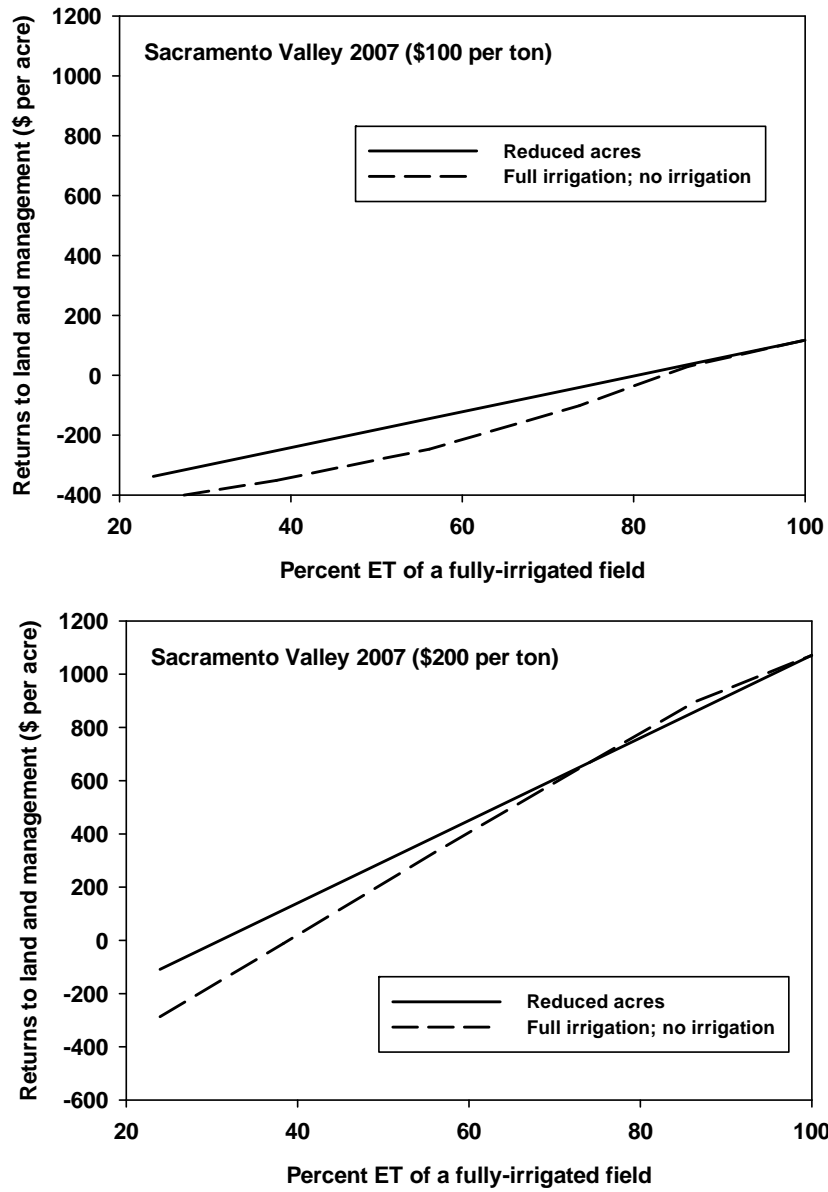


Figure 3. Effect of Strategies 1 and 2 and crop price on the returns to land and management for the Sacramento Valley 2007 site. Six harvests occurred at this site.

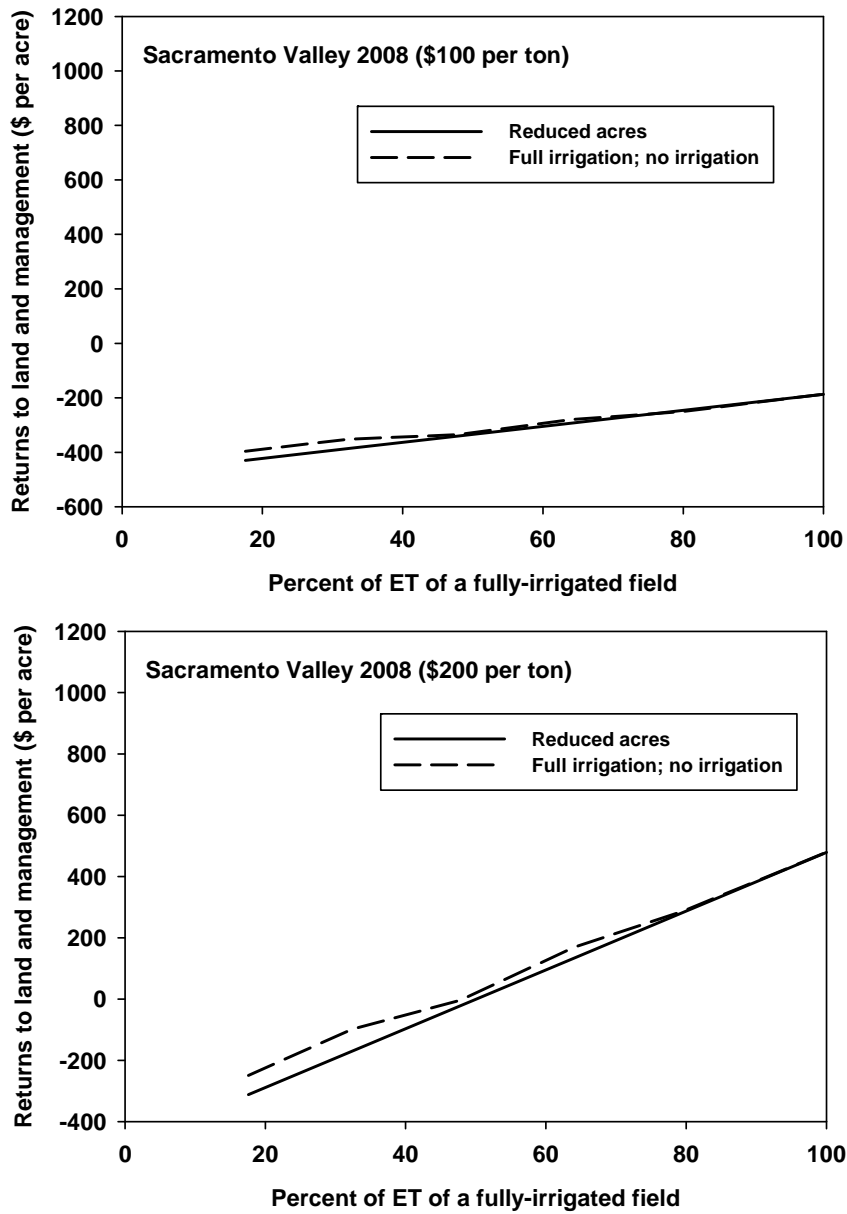


Figure 4. Effect of Strategies 1 and 2 and crop price on the returns to land and management for the Sacramento Valley 2008 site. Six harvests occurred at this site.

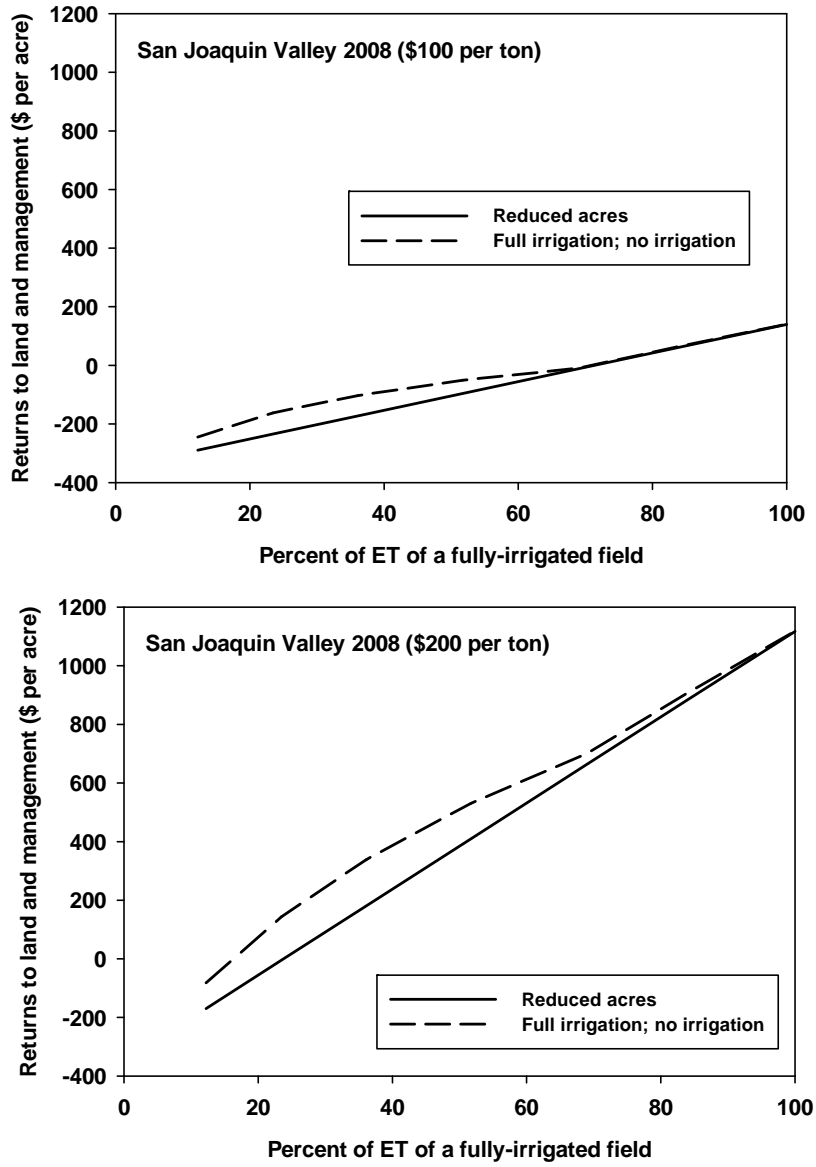


Figure 5. Effect of Strategies 1 and 2 and crop price on the returns to land and management for the San Joaquin Valley 2008 site. Seven harvests occurred at this site.

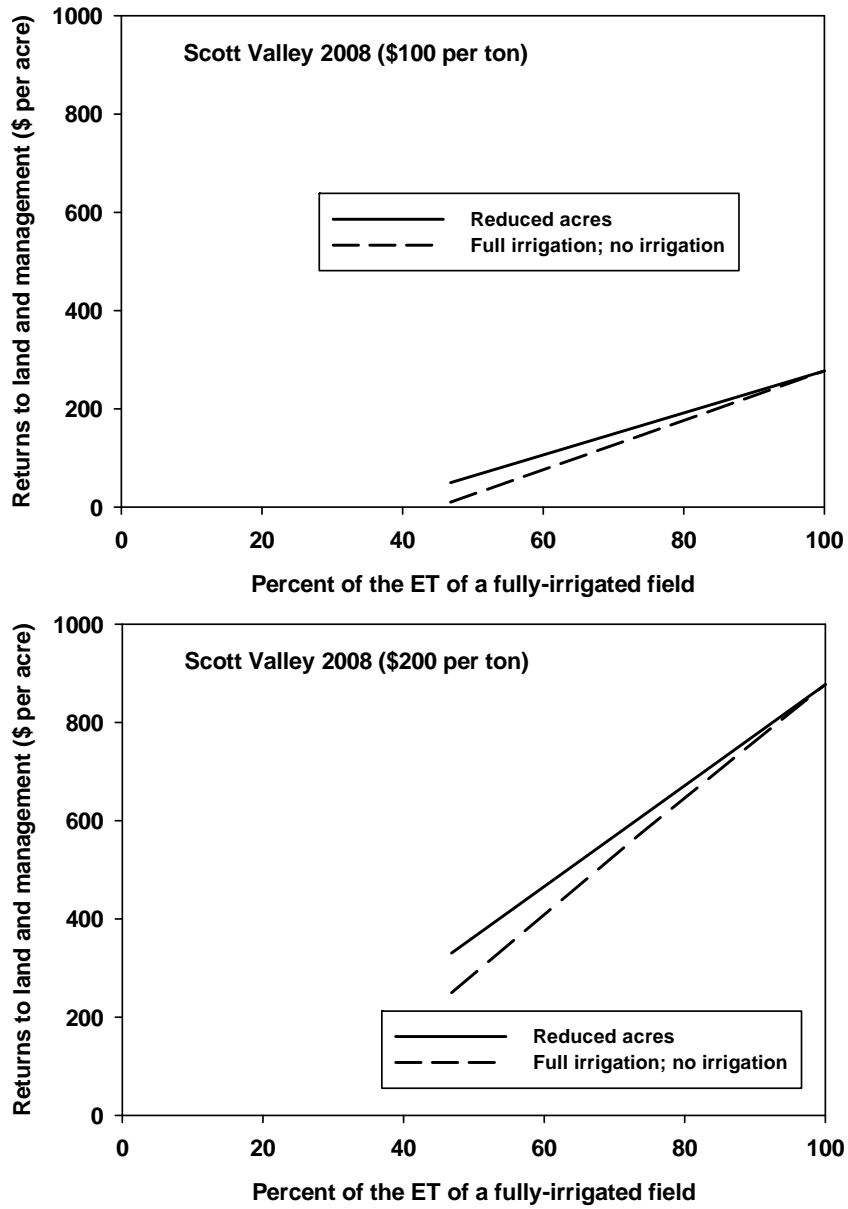


Figure 6. Effect of Strategies 1 and 2 and crop price on the returns to land and management for the Scott Valley 2008 site. Only three harvests occurred at this site.

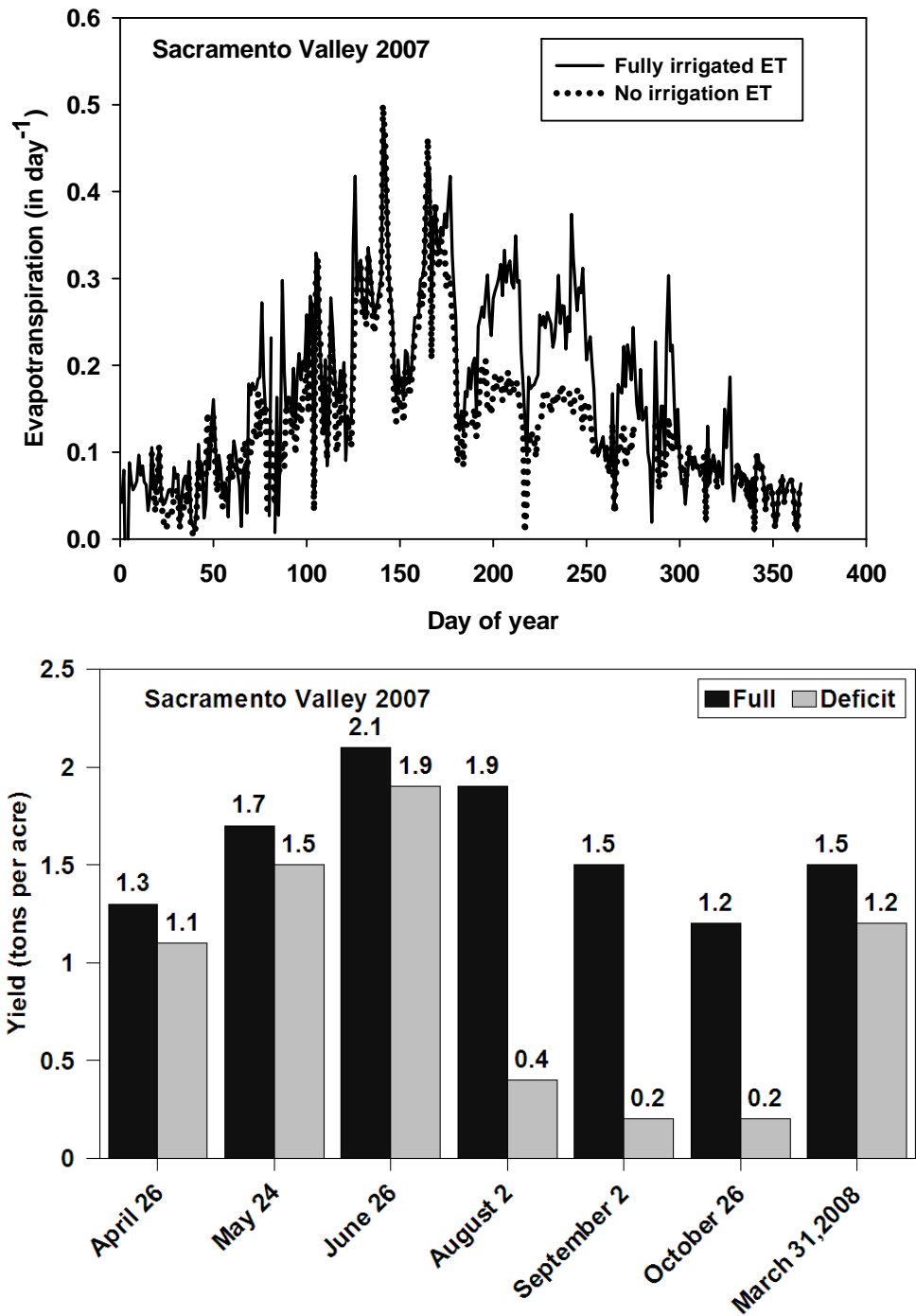


Figure 7. Effect of Strategy 2 on evapotranspiration and yield for the Sacramento Valley 2007 site. Full irrigations occurred for the first part of the crop season; no irrigations occurred after mid-June.