IRRIGATING ALFALFA FOR MAXIMUM PROFIT

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INTRODUCTION

Most growers irrigate for maximum yield assuming maximum yield equals maximum profit. However, high irrigation costs and/or low crop prices may mean maximum profits occur at less than maximum yields. The question is then, how much water should be applied for maximum profit given a set of prices and costs.

The economic criteria for maximum profit are well known. Maximum profit occurs when marginal revenue equals margin costs, or, the slope of the equation relating revenue to applied water equals the slope of the cost equation. This equation depends on the relationship between yield and amount of applied water and on the crop price. The cost function depends on factors such energy costs for irrigation, labor costs, harvesting costs, pest control costs, and capital costs.

Many alfalfa growers in northern California are considering converting to dryland farming because of the relatively high energy costs of pumping groundwater. This action, they believe, will increase their profits since irrigation costs will be eliminated. Not considered, however, is the relationship between irrigation, crop yield, and revenue. Under dry-land farming, no irrigation costs will occur, but yields will be reduced and thus so will revenue. Assessing the impact of converting to dry-land farming requires information on yield versus irrigation amount.

A crop production equation relates yield to amount of applied water. Such relationships have been developed for alfalfa yield versus evapotranspiration for different locations. Yet, these relationships are very diverse, resulting in little confidence that a relationship developed at one location can be applied elsewhere. This limits applying the economic criteria to those locations with known production functions.

Several years ago, a technique for developing crop production functions using a line source sprinkler was developed. Results from this method showed very high correlations between yield and ET. We modified this method for developing on-farm crop production functions for alfalfa in the mountain valleys of northern California. Our approach consisted of installing catch cans in locations where sprinkler overlap was minimal, thus providing a gradient of applied water over a given area. Small plots, centered around each catch can, were harvested for each cutting. We were then able to compare the plot yields with the water caught in the can for that plot, and thus, correlate yields with water applied. Currently, we have three years of data from one site and one year of data from seven other sites.

EXPERIMENTAL PROCEDURE

Transects of catch cans were placed normal to the sprinkler lateral where little overlap occurred. Can spacing was about five feet for all sites, whereas, spacing between transects ranged from about 20 to 30 feet. volume of water caught was measured for each irrigation. A plot, centered around each catch can, was harvested for each cutting. Plot size was about 3-4 feet wide and about 5 feet long.

Data on harvesting, capital costs and pump performance were collected. Uniformity of application was determined on several of the systems for adjusting the experimental crop production functions for nonuniform applications. ET data from a CIMIS weather station was used to estimate maximum ET.

RESULTS

Figures 1-3 show results from sites M, I, and K in Fall River Valley. The first irrigation at site M shows little correlation between applied water and yield, indicating adequate stored soil moisture from the winter and spring, and that irrigation contributed little to the yield. For the second cutting, however, a linear relationship between yield and applied water occurred for applications less than about 4-5 inches. For larger applications, yield did not change with applied water. Maximum yield was about 1.9 tons per acre. The third and fourth cuttings showed no yield for applications less than about 1.5-2 inches. Thereafter, yield increased linearly with applied water up to about 6 inches, the maximum application of this irrigation system. Equations for these cuttings are in Table 1.

Data from Site I (Figure 2) show behavior similar to that of Site M, however, data from Site K show a much different behavior (Figure 3). For the first cutting, no relationship was found between yield and applied water, whereas, for the second and third cuttings, a linear relationship was found. However, these relationships showed a much smaller yield response than at the other sites. The equations, in Table 1, show a yield of about one-third to one-half of that of sites M and I for a given depth of water. Reasons for this behavior are unknown, but this poor yield response might be caused by nutrient problems.

We hypothesize that the relationships for the last two cuttings of site M and the last cutting of site I describe evapotranspiration versus yield. After the second cutting at both sites, little or no stored soil moisture appears to have remained, and thus, the water used by the crop was from irrigation only. Evidence for this is the negative value of b of these cuttings, which was somewhat similar for each site. Also, a relationship of ET versus yield for the Twin Falls, Idaho area, was similar to our relationships.

Sites W1, W2, and W3 (not shown) showed similar behavior as sites M and I although positive values of b occurred for the last cuttings. At Site L, yield responded poorly to applied water for all cuttings (only two cuttings), however, the average yields were about 0.85 and 1.43 tons per acre for the respective cuttings. At site MI, the sprinkler lateral was inadvertently positioned within experiment area, and as a result, desired behavior did not occur.

For most of the cuttings, maximum yield was not obtained, since the irrigation systems lacked the capacity to apply more water. However, for the economic analysis, we estimated the maximum yield using the calculated ET of a reference crop (grass) and the equations of the last cuttings. The reference crop ET was estimated from climatic data collected by a CIMIS weather station located in Fall River Valley. Also, since the second cutting of Site M showed a maximum yield of about 1.9 tons per acre, this data, coupled with the reference crop ET, was used to estimated a crop coefficient for water use between cuttings, which coefficient was 1.05.

The economic analysis for maximum profit requires that the experimental crop production function be adjusted to obtain the field-wide crop production function. The experimental functions, in Table 1, were assumed to be linear response and plateau models, in which yield responds linearly to applied water starting at a threshold value, and beyond some critical value of applied water, yield remains constant. Justification for this model is found in the experimental production functions for the fourth cutting of site W1 (Scott Valley) in 1984, the third cutting of site W1 in 1985, and the second cutting of site M (Fall River Valley) in 1986. These cuttings showed a constant yield for amounts of applied water in excess of the critical value, even where the maximum applied water was about twice that of the critical value. The experimental production equations were used to develop field-wide equations for uniformities of about 60%, 80%, and 90% (Christiansen CU). These relationships are shown in Figure 4 for Site M.

A profit equation was developed using the adjusted crop production equation, a crop price, and a cost equation. For the irrigation systems used in the study areas, the cost of irrigation depends on the unit price of electricity, the capacity and the total head developed by the pump, the pumping plant efficiency, and the amount applied.

The optimum amount of water for maximum profit for each cutting is shown for Site M in Table 2. Data used for this estimate are:

Crop price = $70/ton,
2 Energy cost $0.075/kwhr,
3 Pumping plant efficiency = 55%
4 Pumping plant head = 192 feet.

These numbers were obtained from pump test data for a particular field and from general cost and price data for the Fall River Valley area. From Table 2, we see that the optimum amount of water increased with time during a growing season. No water is needed for the first cutting, which reflects adequate stored soil moisture from the winter and spring. However, as this moisture is depleted, more irrigation water is required for the optimum amount. We also see that as the uniformity of application decreases, the optimum amount increases from 19 inches for a CU = 89% to nearly 30 inches for a CU = 59%. Interestingly, the yield remained at about six tons per acre for all three levels of uniformity. Profit, however, decreased because irrigation costs increased with decreasing uniformity. This analysis does not include fixed costs, which if included would reduce the profit but would not affect the optimum depth of applied water.

Figure 5, the relationships of yield versus applied water for all eight sites, shows significant variability among these locations. The question is, however, what effect does this variation have on the optimum amount of water needed for maximum profit. Table 3, which shows this optimum amount for five sites, reveals an interesting behavior. For a given uniformity of application, the optimum seasonal amount only varies slightly among these locations, ranging from 16.5 inches for Site W1 to 21.0 inches for Site K for CU = 77%. Thus, the optimum amount of water for maximum profit appears somewhat insensitive to the variability in the crop production equations. However, Table 3 also shows that yields ranged from 2.6 tons per acre for site K to 7.00 tons per acre for Site W2, and that variability in maximum profit reflects variability in the crop yields. The coefficient of variability was about 0.1 for the optimum depth and about 0.34 for the yield at this depth. Thus, although the optimum amount of water is relatively insensitive to variability in the crop production equations, yields and profits are highly sensitive.

Variability of the crop production equation with time must also be considered. Three years of data at Site W1, shown in Figure 6, shows a decreasing yield with time for the first cutting. For the remaining cuttings, the slope of the experimental crop production function decreases with time, thus yield response to applied water is less with time. This behavior is believed due to increasing age of the alfalfa.

SUMMARY

An economic evaluation of the benefits of irrigation using on-farm crop production equations shows no economic justification for converting to dry-land farming. For an application uniformity of 77 percent (Christiansens coefficient of uniformity), maximum profit occurs for a water application of about 21 inches. The analysis also shows the optimum amount to be insensitive to variability in the crop production equations, however, yield and, subsequently, profit are highly sensitive. Yield response to applied water decreased over a three-year period at one site.

Table 1. Regression coefficients for all eight sites (1986) where yield (tons/acre) = m x depth (inches) + b.

Site	Cutting	m	b	R^2
M	First	0.00424	1.34	~0
	Second	0.361	0.016	0.94
	Third	0.278	-0.356	0.84
	Fourth	0.206	-0.299	0.87
I	First	0.036	1.44	~0
	Second	0.287	0.247	0.74
	Third	0.348	-0.543	0.66
K	First	0.00925	0.75	~0
	Second	0.094	0.0265	0.82
	Third	0.105	-0.103	0.80
MI	First	0.121	1.12	0.25
	Second	0.0926	0.404	0.09
	Third	0.214	0.282	0.47
WI	First	-0.0729	1.13	0.25
	Second	0.212	0.305	0.83
	Third	0.211	0.0728	0.43
W2	Second	0.131	0.996	0.55
	Third	0.232	0.635	0.51
	Fourth	0.128	0.738	0.50
W3	Second	0.122	2.07	0.52
	Third	0.190	0.60	0.72
L	First	0.0495	0.85	0.09
	Second	0.0207	1.43	0.02

Table 2. Seasonal applied water and yield for optimum profit, Site M, 1986.

Cutting	Applied Water (inches)	Yield (tons/acre)	Profit ($/ton)
	CU = 89%		
1	0	1.35	94
2	6.5	1.91	119
3	13.5	2.77	164
Total	**19.0**	**6.03**	**379**
	CU =		
1	0	1.35	94
2	7.4	1.87	114
3	15.2	2.71	156
Total	**22.6**	**5.93**	**365**
	CU =		
1	0	1.35	94
2	9.4	1.89	111
3	20.1	2.76	149
Total	**29.5**	**6.00**	**355**

Table 3. Summary of five sites.

Site	Optimum Depth (inches)	Yield (Tons/Acre)	Profit ($/Ton)
	CU = 89%		
W1	16.5	4.5	276
W2	16.6	7.0	455
M	19.0	6.0	377
K	21.0	2.6	136
I	19.3	6.2	392
Average	**18.5**		
	CU = 77%		
W1	19.3	4.4	266
W2	18.3	7.0	447
M	22.6	5.9	365
K	21.9	2.5	128
I	21.8	6.1	378
Average	**20.8**		
	CU = 59%		
W1	24.5	4.4	256
W2	24.2	7.0	437
M	29.5	6.0	354
K	22.7	2.3	114
I	28.5	6.2	369
Average	**25.9**		

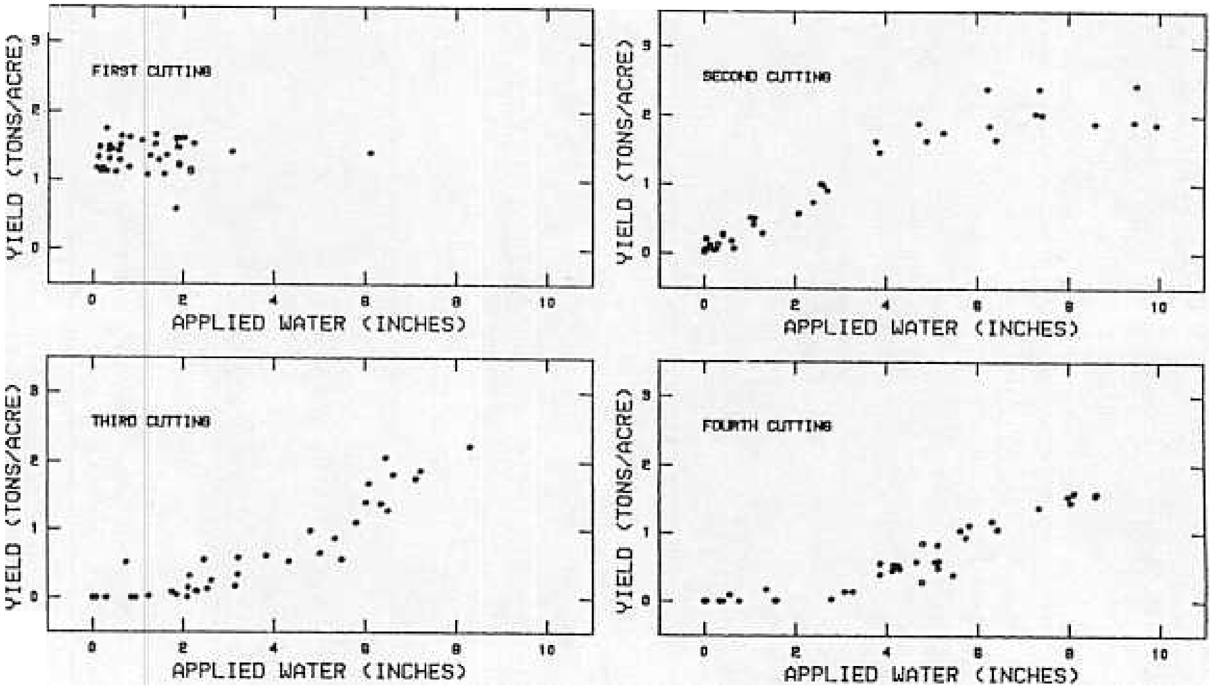

Figure 1. Yield versus applied water, Site M, 1986.

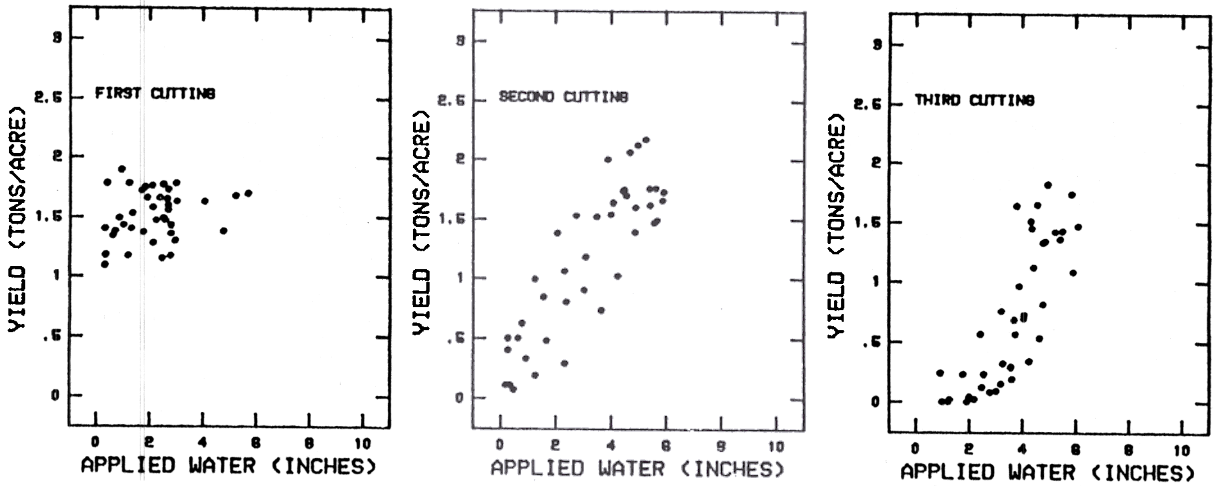

Figure 2. Yield versus applied water, Site I, 1986.

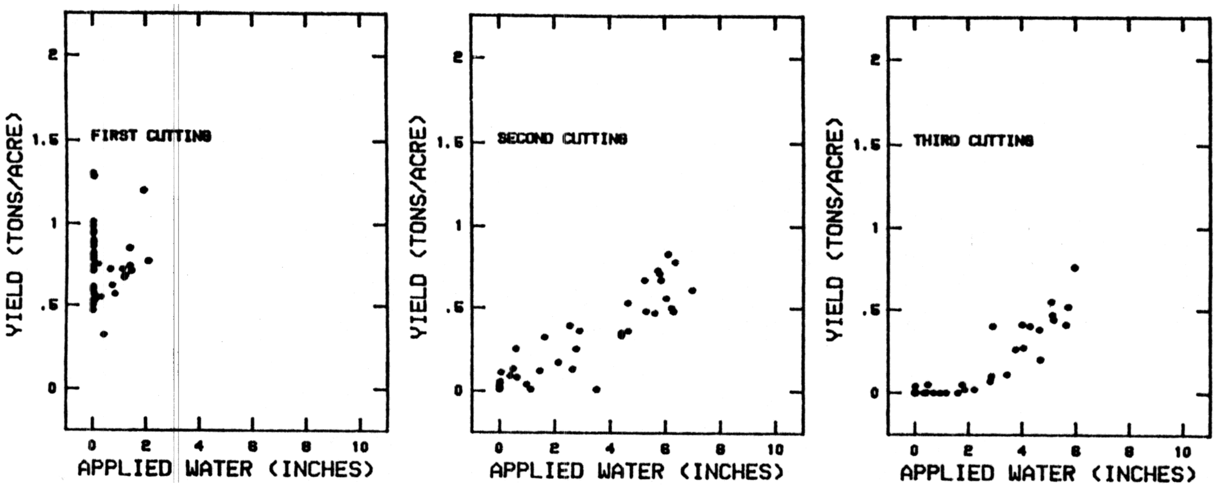

Figure 3. Yield versus applied water, Site K, 1986.

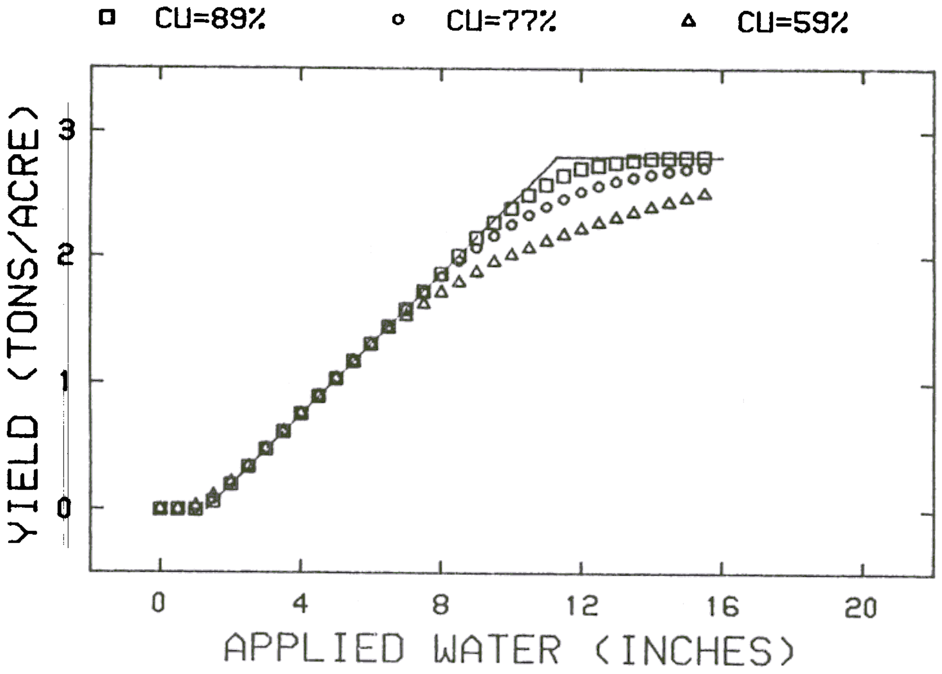

Figure 4. Experimental crop production equation (solid line) and adjusted equations.

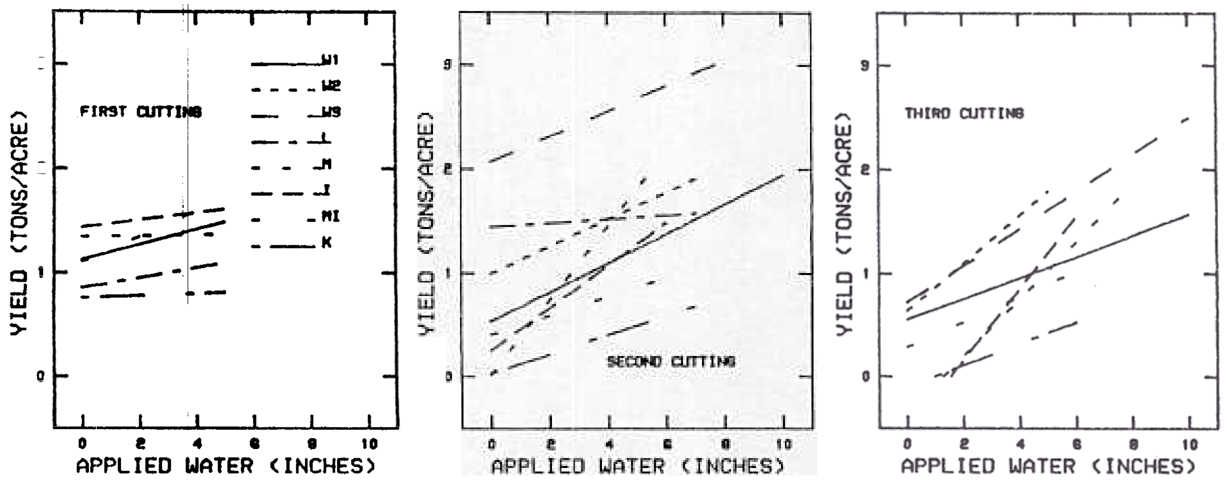

Figure 5. Variability of yield versus applied water, 1986.

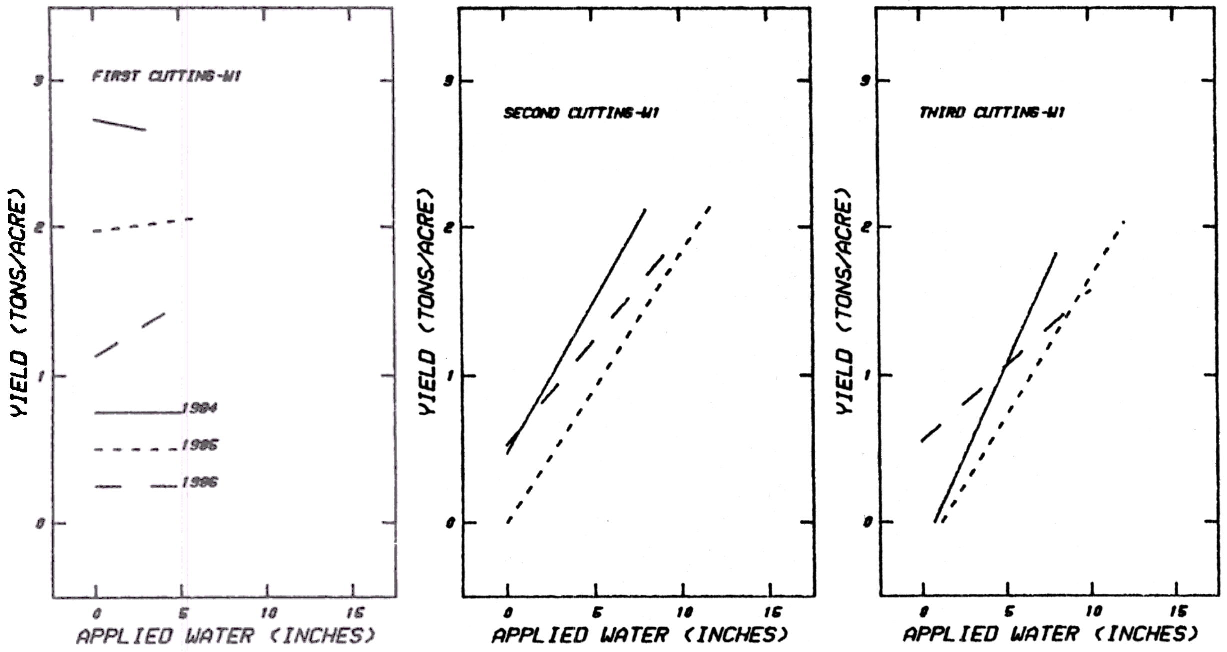

Figure 6. Variability of yield versus applied water with time.