Effects of changes in the water year on irrigation in the San Joaquin Valley

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Changing starting date of water contract year to March 1 from January 1 could avoid 'use it or lose it' situations

Concern about the quality of agricultural drainage water has encouraged growers in the San Joaquin Valley to reduce subsurface drainage water flows. Strategies at the farm level include more efficient application of irrigation water through improved uniformity, reduced leaching fractions, and greater recycling. Changes in pre-irrigation rates and timing have also been suggested as ways to reduce deep percolation and tile flows.

At the institutional level, changes in the price of water and restructuring of water contract years have been suggested to encourage more efficient use of irrigation and drainage resources. One objective of these efforts is to allow growers greater flexibility in the timing of pre-irrigations.

This study examined the responsiveness of farm-level irrigations to rainfall in fall and winter. The purpose was to determine the policy value of changing the starting date of water contract years from January 1 to March 1. Rainfall and irrigation data from a water district on the west side of the San Joaquin Valley were examined by statistical techniques.

Background

Water delivery contracts in the San Joaquin Valley are generally based on a 12-month period. A water district agrees to purchase an amount of water from the U.S. Bureau of Reclamation or the California State Water Project. Growers in the district may then enter an agreement with the district for delivery of water throughout the year. There are two major types of contracts: flexible and fixed. The specific nature of the agreement affects the grower's incentives to apply or conserve water at various times of the year.

In the flexible contract, growers agree to purchase water from the district at a given price, but the total quantity of water to be delivered is not specified. Fixed agreements obligate the grower to pay for an agreed-upon quantity of water, even if the cropping season doesn't warrant application of that amount.

The model

A generalized least squares regression model of monthly water applications, crop acreages, and monthly rainfall is constructed to test for grower responsiveness to winter rainfall. Monthly irrigation quantities are regressed on current and lagged monthly rainfall and crop acreages in the following set of equations:

$$(1)\ X_{2m} = \beta_{1m} + \beta_{2m}RF_m + \beta_{3m}RF_{m-1} + \sum_{k=1}^{K} \beta_{3+k,m} X_{1k} + \beta_{3+K+1,m}TREND + \epsilon_m$$

for m = 1, . . . ,5 ; representing the months of October, November, December, January, and February.

where: X_{2m} is the amount of water applied in month m, X_{1k} is the acreage of crop k, RF_m is the amount of rainfall received in month m, TREND is a time trend variable, β_{jm} are parameters to be estimated (j=1, . . . ,3+K), and ϵ_m is a random error term.

Three additional relationships are included to describe water use in winter and summer months. The ratio of total crop revenue to water price is included in these equations:

$$(2)\ X_{2s} = \beta_{1s} + \beta_{2s}RF_w + \beta_{3s}RR + \sum_{k=1}^{K} \beta_{3+k,m} X_{1k} + \beta_{3+K+1,m}TREND + \epsilon_s$$

for s = 6,7,8 ; representing summer, winter, and total water applied.

where: RF_w is the total rainfall received from October through February, RR is the ratio of crop revenue to water price, and ϵ_s is a random error term.

Information provided by growers and individual equation results are used to set the water use coefficients to zero in months when irrigation is not practiced, and to ensure that monthly quantities and winter totals are consistent.

Growers operating under flexible water agreements face the true cost of incremental water use decisions throughout the year. Growers who have contracted to purchase a fixed amount of water, however, face a "use it or lose it" situation as the end of the water year approaches, since any unused water within their allocation has already been paid for and may not be carried over into the following contract year. Many of these growers accept delivery of the full water allocation and attempt to store it in the soil by applying it to fields in the fall or winter.

Pre-irrigation water is often applied to flush excess salts through the soil before spring planting. The practice of storing water in the soil profile increases the amount of water applied to fields during the pre-irrigation period. This is the same time of year during which most of the annual rainfall occurs. February has the highest monthly average rainfall, while the highest maximum rainfall normally occurs in January and March in northwestern Fresno County (table 1).

Deep percolation of water to the shallow water table increases when rain falls on fields that are already saturated with pre-irrigation water. This adds to the amount of subsurface drain water requiring treatment or disposal. Furthermore, the effectiveness of rainfall is diminished when it simply replaces water already in the soil profile. Policies designed to reduce the overlapping of rainfall and pre-irrigation applications would therefore improve the efficiency of water use and decrease subsurface flows.

The potential for reducing pre-irrigation applications by altering the water contract year depends on the extent to which water use responds to actual rainfall during the late fall and winter months. For example, if a January 1 water year were changed to March 1, would growers reduce water applications in November or December while waiting to observe actual rainfall in these months? Would they shift from applying pre-irrigations in November and December and apply this water in January and February? If this potential exists, then improved efficiency of water use and decreased subsurface flows may result.

We explored the potential for achieving these goals by examining monthly water delivery data for the Broadview Water District, where growers operate under a flexible water purchase agreement and pay only for the water they request from the district, throughout the year. The water year in this area begins on March 1, allowing flexibility in applying pre-irrigation water in the late fall and early winter. The Broadview data should therefore provide evidence as to whether or not growers respond to winter rainfall when they are not subject to institutional constraints.

Analysis

We examined the importance of rainfall received in winter using a set of relationships that described monthly irrigations as a function of rainfall and crop acreages (see insert). The goal was to determine the degree to which changes in monthly rainfall quantities accounted for variation in the observed monthly irrigations. This analysis provided "coefficients" useful in describing the expected change in irrigation water applied in some months in response to an additional acre-inch of rainfall received.

The amount of rainfall received in the previous month (lagged rainfall) was included in the relationship explaining a current month's irrigation, since there may have been a delay in actual responsiveness. For example, rainfall received in late January may have caused reductions in the amount of water applied in February.

Estimated coefficients describing the relationship between monthly rainfall and irrigation are presented in table 2. Most of these are statistically significant, as indicated by a t-Statistic with an absolute value greater than 2. Acreage planted to dry beans, wheat, sugarbeets, and cotton received an estimated 1.13 to 1.36 acre-feet of water between October and February. Barley and tomato acreage received the least, 0.36 and 0.44 acre-feet per acre, during those months. Estimates of total applied water were highest for sugarbeets, dry beans, and tomatoes.

The negative coefficients on rainfall show that low pre-irrigations are related statistically to high rainfall received in November through February. This indicates responsiveness, on a monthly basis, to rainfall during fall and winter. For example, the higher the rainfall in November and December, the lower the amount of water applied in December. January and February irrigations follow a similar pattern with respect to current and lagged monthly rainfall amounts.

The overall importance of monthly responsiveness to rainfall is determined by examining the total winter rainfall coefficient in the winter irrigation equation. This coefficient represents the change in acre-feet applied per inch of precipitation received in October through February. One inch of rainfall covering an acre is equivalent to 0.083 acre-foot. The average crop acreage in Broadview is 668 acres. One inch of rainfall on this acreage provides 55.7 acre-feet of water. The estimated winter rainfall coefficient of −33.29, therefore, indicates a "usefulness" of 60 percent. That is, for every 55.7 acre-feet of winter rainfall received, water applications are reduced by 33.29 acre-feet. The usefulness factor is expected to be less than 100 percent, since the frequency and intensity of winter storms, the amount of crop canopy, and other circumstances affect the true effectiveness of winter rainfall.

The time trend coefficient in the winter irrigation equation is positive and statistically significant. This indicates that the amount of water applied during winter months has increased, over time. This may reflect increases in the amount of leaching performed as salinity problems developed in the district.

Conclusion

Statistical analysis of winter water deliveries indicates significant responsiveness to winter rainfall by growers operating under a March 1 water contract year. This provides a reason for offering this schedule to other growers who currently have January 1 contracts. Both the total amount of water applied and the amount of deep percolation may be reduced by implementing this policy, since significant rainfall occurs between January and March in some years.

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TABLE 1. Monthly precipitation in northwestern Fresno County, 1960-85

Month	Average rainfall	Standard deviation	Minimum	Maximum
	inches			
October	0.40	0.36	0.00	1.33
November	1.25	1.05	0.00	4.05
December	1.35	0.78	0.07	2.89
January	1.32	1.21	0.06	4.36
February	1.51	1.24	0.08	3.51
March	1.45	1.23	0.00	4.57
April	0.76	0.80	0.00	3.43
May	0.19	0.30	0.00	1.15
June	0.02	0.05	0.00	0.23
July	0.01	0.03	0.00	0.15
August	0.02	0.07	0.00	0.33
September	0.23	0.52	0.00	2.39
Annual	8.51	2.81	4.93	14.23

SOURCE: Climatological Data Annual Summary, California, National Oceanic and Atmospheric Administration. U.S. Bureau of Reclamation, Mendota Dam, California.

TABLE 2. Generalized least squares estimates of monthly water use coefficients (Coef.), with across-model restrictions imposed

	Equation															
	October		November		December		January		February		Winter		Summer		Total	
Variable	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat	Coef.	t-Stat
Sugarbeets	.56	5.69							.59	4.66	1.15	7.66	5.15	17.86	6.30	21.20
Cotton	.12	2.66	.17	4.43	.18	4.33	.34	7.96	.32	5.28	1.13	14.39	1.76	11.11	2.89	22.22
Barley			.07	1.24	.10	1.66	.19	3.10			.36	4.21	1.00	5.14	1.36	6.89
Wheat	.20	2.20	.25	3.25			.24	2.67	.49	4.25	1.17	7.39	2.18	8.37	3.36	12.60
Melon							.18	2.53	.35	3.60	.53	4.27	1.43	5.48	1.96	8.86
Tomatoes							.11	2.68	.33	5.84	.44	6.12	3.39	12.65	3.82	27.91
Alfalfa seed	.21	4.97	.32	8.98	.15	3.65			.13	2.18	.80	11.23	2.35	17.06	3.14	23.48
Milo													2.61	5.25	2.61	5.30
Safflower													1.57	3.60	1.57	3.45
Dry beans					.47	4.21	.42	3.83	.47	2.96	1.36	7.10	2.81	8.35	4.17	12.17
Revenue ratio											.02	0.24	1.80	0.97	1.82	0.57
Sep rainfall	35.10	2.54														
Oct rainfall	−3.82	−0.25	−18.34	−1.27												
Nov rainfall			−12.72	−2.26	−20.89	−3.50										
Dec rainfall					−12.87	−1.74	−18.52	−2.43								
Jan rainfall							−25.88	−4.06	−11.85	−2.00						
Feb rainfall									−30.44	−5.94						
Winter rainfall											−33.29	−7.41	−3.47	−0.38	−36.75	−3.88
Time	2.15	1.60	0.07	0.06	2.54	1.89	4.33	3.06	−4.54	−2.42	5.31	2.15	−2.48	−0.61	2.84	0.65

NOTES: Crop coefficients are interpreted as acre-feet of water applied per acre. The weighted R-square for the system of equations is .74.