EFFECT OF WATER QUALITY AND FREQUENCY ON FARM

IN THE IMPERIAL

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Deteriorating water quality is a problem in many California agricultural areas. Effects of increased salts on crop yields, farm income, and future soil deterioration are of great concern to agriculturalists.

A study was undertaken to identify the effects of changing water quality and supply on farm net revenue and cropping patterns in the Imperial Valley. Substitutions of various soil types, water qualities, and irrigation frequencies were considered. The study uses *first-order* crop response approximations developed by Robinson at the Imperial Valley Field Station. He is presently conducting field experiments to refine a second-order approximation of the responses.

Previous research indicates that it is possible to offset the effects of applying a poor-quality irrigation water by increasing the amount or frequency of the water applied. However, the situation becomes more complicated when the different salt tolerances among crops and when soil drainage are also considered. Recognition of salt-tolerant crops and their levels of tolerance is essential. *Soil texture is directly* related to drainage. Generally, the sandier the texture, the better the internal drainage. The better-drained soils can utilize waters with higher salt contents than the more poorly-drained soils.

The experiment

Robinson selected six water qualities (900, 1,000, 1,100, 1,200, 1,300, and 1,400 ppm total dissolved salts), five irrigation frequencies, and four soils. The total amount of water applied during a year is the same with each irrigation routine (85 inches). The routines or frequencies are 16, 22, 29, 35, and sprinkler (35) irrigations per year. However, each routine has a different quantity of water delivered per irrigation; in other words, 5.25, 3.82, 2.90, 2.40, and 2.40 inches, respectively, were applied per irrigation. The soils considered in the study were those found in the Imperial Valley: Indio, Meloland, Holtville-Imperial Stratified, and Imperial Complex. The Indio group is coarse and well-drained; Meloland has a sandy surface and heavy subsoil; Holtville-Imperial Stratified has alternating sand and clay strata; and the Imperial Complex is predominantly clay.

To understand the general interacting processes in the soil-salt-water-plant system, it is helpful to simplify things by making various assumptions. The assumptions define one case among many possibilities. By carefully selecting the case, we can understand the general workings of the system. The basic assumption made in this study was a steady-state salt balance in each of the four soils. The steady state depends on the soil, water quantity, and quality combination selected. Salinity values were calculated for the possible combinations of water supply and quality. These were fitted into curves showing declining yields for each crop on each soil. Mean yields were obtained from the Imperial County Agricultural Commissioner's Reports (1965-1972). Final assumptions included no availability of fallow land, a 30 percent leaching fraction for water up to 1,100 ppm salt, and 40 percent leaching fraction for water in the 1,200 to 1,400 ppm range.

Analysis

The joint effects of water quantity and water quality imply that, to obtain the same crop responses for a given water quality, either a wetter moisture regime or a higher leaching fraction must be used. This relationship is described by a curve that indicates the necessary substitution between water quality and quantity to maintain a specified crop yield.

In order to analyze this substitution effect, a linear programming model was used to select the optimum cropping pattern and irrigation frequencies. The model maximized net farm revenue while water quantity and quality were varied. The composite farm model was set up to represent a large farm (2,125 acres) located in the area. The four soils that made up the farm were those in the Robinson study. Each soil was assigned a proportion of the total acreage according to the percentage that actually exists in the Imperial Valley.

Total water and peak water constraints were added to the model to represent peak total water and two monthly total

TABLE 1. WATER INPUT - CROP RESPONSE OF SUGAR BEETS ON IMPERIAL COMPLEX SOIL

Frequency of irrigation	Total dissolved salts (ppm)					
	900	1,000	1,100	1,200	1,300	1,400
	Yield (tons)					
16X	22	22	21 6	20.9	20.2	18.0
22X	22	22	22	21 8	21.0	20 5
29X	22	22	22	22	21.6	20.9
35X	22	22	22	22	22	21.6
Sprinklers	22	22	22	22	22	21.8

IRRIGATION INCOME

VALLEY

• J. H. SNYDER

water availabilities in the irrigation district. Totals were set at 11,570.83 acre-feet for the year and 38,250 acre-inches for the months of April and May.

Two marketing constraints were also needed to make the model representative of the area. Cotton and sugar beets were each allocated an acreage in accordance with that historically grown in the Valley.

Net farm revenue was defined as price times yield minus total production costs minus irrigation charges. The crops selected for analysis were barley, cantaloupe, cotton, lettuce, onions, sugar beets, sorghum, tomatoes, alfalfa, and wheat. Prices for these crops were based on a three-year average to smooth out the large price fluctuations of the last few years. Recognition of the price risk inherent in fresh vegetables is handled in the model by constraining the acreages of these crops by a maximum acreage allocation. The maximum represents the proportion of the total acreage of a crop in the Valley to the total land available in the linear programming model.

Production costs were generated from the Imperial County production guidelines (1974). Irrigation charges depended on the irrigation frequency chosen. These charges consisted of a water cost plus a labor cost per irrigation. An additional $35.00 per acre on the sprinkler irrigation cost represented the rental and labor.

Table 2 illustrates the optimal solutions to the model for six water quality levels.

TABLE 2. OPTIMAL CROPPING PATTERNS FOR CHANGING WATER QUALITIES

900 ppm salts

Crop	Acreage	Soil*	Irrigation frequency
Cantaloupe	45.25	1	16X
Cantaloupe	395.25	2	16X
Cotton	191.25	4	16X
Onions	10.0	1	16X
Sugar beets	265.62	4	16X
Tomatoes	10 0	3	35X
Wheat	30.35	3	16X
Wheat	2.13	4	22X
Alfalfa	962.65	3	16X
Lettuce-sorghum	212 5	1	16X

Net revenue – $332,854

1,000 ppm salts

Crop	Acreage	Soil*	Irrigation frequency
Cantaloupe	45 25	1	16X
Cantaloupe	385.25	2	16X
Cotton	191 25	4	16X
Onions	10.0	1	16X
Sugar beets	265 62	4	16X
Tomatoes	10 0	2	16X
Wheat	1,003.0	3	16X
Wheat	2 13	4	35X
Lettuce-sorghum	212.5	1	16X

Net revenue – $325,184

1,100 ppm salts

Crop	Acreage	Soil*	Irrigation frequency
Cantaloupe	45.25	1	16X
Cotton	191.25	4	16X
Onions	10.0	1	16X
Sugar beets	265 62	4	22X
Tomatoes	10.0	2	16X
Wheat	1,003.0	3	22X
Wheat	2 13	4	35X
Alfalfa	385.25	2	22X
Lettuce-sorghum	212.5	1	16X

Net revenue – $312,587

1,200 ppm salts

Crop	Acreage	Soil*	Irrigation frequency
Cantaloupe	257.75	1	16X
Cantaloupe	172.75	2	22X
Cotton	191 25	3	16X
Onions	10.0	1	16X
Sugar beets	265.62	4	22X
Tomatoes	10 0	2	22X
Wheat	811.75	3	35X
Wheat	193 38	4	35X
Lettuce-sorghum	212.5	2	35X/16X

Net revenue – $299,920

1,300 ppm salts

Crop	Acreage	Soil*	Irrigation frequency
Cantaloupe	45 25	1	16X
Cotton	191.25	3	16X
Onions	10 0	1	16X
Sugar beets	265.62	4	35X
Tomatoes	10.0	2	22X
Wheat	811.75	3	35X
Wheat	193 38	4	35X
Alfalfa	385.35	2	22X
Lettuce-sorghum	212.5	1	16X

Net revenue = $287,963

1,400 ppm salts

Crop	Acreage	Soil*	Irrigation frequency
Cantaloupe	267.75	1	16X
Cotton	191.25	4	22X
Onions	10.0	2	Sprinkler
Sugar beets	265.62	3	22X
Tomatoes	10 0	2	29X
Wheat	737 38	3	35X
Wheat	267.75	4	35X
Alfalfa	162.75	2	35X
Lettuce-sorghum	212 5	2	Sprinkler/16X

Net revenue = $278,470

*Soils are listed on a numerical basis. 1 = Indio, 2 = Meloland, 3 = Holtville-Imperial, 4 = Imperial Complex.

Results

Irrigation frequencies and soils are the primary factors in the allocation of different crop acreages. In general, as water quality declines, the number of irrigations increases. For example, at 900 ppm most 16X irrigations are selected, but from 1,100 ppm on, the other irrigation frequencies become more common until at 1,400 ppm only cantaloupe on the Indio soil is still using a 16X routine. This indicates that using a high irrigation frequency and maintaining a high soil moisture level would minimize the impact of reduced water quality.

The substitutions of the various production factors become evident from table 2. For example, cotton is grown on the Imperial Complex (clay soil) with 16X irrigation frequencies at 900, 1,000, and 1,100 ppm water. At 1,200 ppm the model shifts cotton to the Holtville-Imperial soil, a better drained soil than the Imperial Complex, substituting a soil type for water quality. Cotton stays on Holtville-Imperial until 1,400 ppm is reached; then it is shifted back to Imperial Complex, but the irrigation frequencies change from 16X to 22X. The irrigation routine or water management system is being substituted for a decrease in both soil quality and water quality. The same general conclusion can be made for sugar beets. This analysis supports the observation that better drained soils can handle low-quality water without drastically affecting crop yield.

An indication of a soil's economic value is its productivity when compared to other inputs that go into growing a crop. This study indicates that both Indio and Holtville-Imperial soils increase in relative value (or decrease less) as the water quality becomes poorer. The Indio soils show the least loss in productivity due to their ability to handle high-salt irrigation water.

Sprinkler irrigation, although commonly used on Imperial Valley farms, especially for germination purposes, did not enter into the optimum irrigation management results until extreme water-quality values were reached. This is partially explained by the higher costs in renting and moving sprinkler systems. Secondly, it is difficult to quantify some of the secondary benefits of sprinklers on replanting costs and crop quality.

The impact of reduced water quality on farm income is indicated by a 19.5 percent decrease in farm income from 900 ppm to 1,400 ppm water, an average 3.9 percent decrease in income for every 100 ppm increase of total dissolved salts in the irrigation water.

In summary, an economic model defining one of many possible combinations of characteristics of a composite farm firm was developed, representing resources available in the Imperial Valley. The model was used to project significant shifts in cropping patterns as the salt content of irrigation water increased within the framework of the defined system.

A substitution effect appears between water quality and the quantity of water applied through both higher leaching fractions and more frequent irrigations. At high irrigation-water salinity levels, lighter, better drained soils maintain their productivity and therefore their value in agriculture as compared to the heavy clay soils. Finally, decreased yields and higher water use per acre of crops planted are projected to have a negative effect on farm incomes in the Valley as salt content of the Colorado River increases.

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Irrigating for maximum

R. W. HAGEMANN

This experiment indicates that a high yield of alfalfa seed can be obtained in the Imperial Valley if water management and insects are properly controlled. Irrigations guided by tensiometer at the 50-centibar level during seed production gave the best yield in 2 years of testing. Irrigation control was obtained by using surface drip irrigation.

The three main requisites for good alfalfa seed production are irrigation, pollination, and insect control. The latter two can be accomplished with established management practices. The strength of the honey bee force required for pollination depends on factors such as plant population, time of year, and temperature. Insect control can be accomplished with available, proven insecticides. Insecticides that repel honey bees should be avoided.

Irrigation is the major alfalfa seed production problem in the Imperial Valley. Compared with alfalfa plants in other seed-producing areas, those in the Valley have a very shallow root system, normally 18 inches in depth or less, and the evapotranspiration rate is high. Alfalfa seed production is much easier to manage when the plants are deep-rooted. Deep roots are able to pick up moisture from a greater soil storage volume, which can supply moisture to the plant at a constant slow rate throughout the seed production period.

Shallow-rooted alfalfa requires frequent irrigations. If too much water is applied, the plant remains vegetative. To stimulate flower production and pollination, mild plant stress must be created by restricting the soil water supply. If too