SCHEDULING IRRIGATIONS BASED ON EVAPORATION MEASUREMENTS

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Maintenance of an adequate soil water supply to the crop at all times is the basis of good irrigation practices. In accomplishing this, there are some unavoidable losses resulting from the method of water application such as conveyance losses, percolation below the root zone, and run-off. It is essential that these losses are kept to a minimum under good water and energy conservation practices. This in turn requires that the irrigator must be able to determine as accurately as possible when to irrigate and how much water to apply. Knowledge of crop water use or evapotranspiration (ET) rates, soil water storage capacity and rooting depths, and the magnitude of the application losses will enable the farmer to schedule irrigations for maximum yields. In the case of alfalfa, where the harvestable yield is the total aboveground dry matter produced, water stress should not be allowed to occur throughout the growing season since vegetative growth is the plant process most sensitive to a water deficiency (Hsiao et al., 1976). Alfalfa yields would then be negatively affected even by a mild water stress.

Local conditions determine soil water storage capacity and application losses while climatic conditions play the major role in determining ET or consumptive use rates. Evaporation of water from soil or crop surfaces requires a great deal of energy (around 550 calories/gram). For a given yield, the total incoming energy available for evaporation represents an upper limit for the rate of ET from that field. The main source of energy is, of course, solar radiation, but energy in the form of heat may also be transferred by winds from hotter to cooler areas which will affect ET.

Since weather conditions largely determine the ET rates, many methods have been developed to estimate ET based on meteorological parameters. One of the most commonly used is based on measurements of evaporation from a standard, free-water surface. Many water use studies have shown that, for a given location, there is a correlation between crop ET and evaporation from free water. The standard water surface commonly used in these studies is the U.S. Weather Bureau Class A evaporation pan located in an irrigated pasture environment.

The ratio between ET and pan evaporation, Epan, is called crop coefficient, Kp. Kp varies with crop growth stages, but is assumed to be independent of location. Thus, if a set of crop coefficients is experimentally determined for one location, it could then be used to estimate ET for any other location where only Epan data may be available.

In essence, the crop ET can be obtained from the relation

$$ET = Kp \times Epan$$

Needed are the pan evaporation data, and the appropriate Kp for a given crop and time of growing season. In the case of alfalfa, the crop coefficient will depend on the amount of leaf area and plant height, both related to the time after harvest.

The Jensen-Haise equation is another method which may be used to estimate alfalfa ET Solar radiation and temperature data are required in order to compute the ET from a full grown alfalfa canopy prior to cutting.

Effect of Cutting on Alfalfa Crop Coefficient, Kp.

As stated above, Kp is a function of crop growth stage. In alfalfa it is at the maximum during the last two weeks prior to harvest and at the minimum inmediately after cutting. Figure 1 presents the relationship between Kp, time of growing season, and growth stage for an alfalfa crop (Dorenboos and Pruitt, 1977). Alfalfa ET is as low as 40% of the pan evaporation immediately after cutting as leaf area and crop height are at a minimum. It then increases rapidly within two weeks to approach a peak Kp of 0.9 (90% of Epan) before the following cutting. Growth rate and irrigation frequency will affect the rate of change of Kp (Figure 1). Careful analysis of the experimental data available indicates that when these oscillations are averaged out the value of mean Kp is relatively constant throughout the growing season, representing around 85% of the peak Kp.

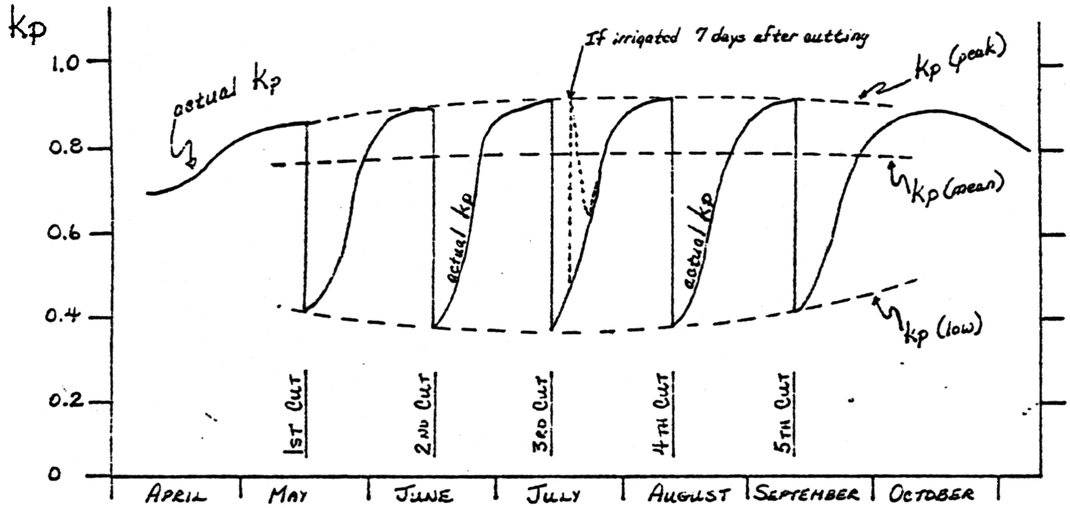

FIGURE Crop Coefficient Values For Alfalfa Grown in Dry Climate With Cuttings Every Four Weeks. Based on One Heavy Irrigation Between Cuttings. Adapted from Dorenboos and Pruitt (1977).

Taking the effect of cutting into account, a Kp mean value of 0.76 is presently recommended to compute alfalfa ET based on pan evaporation data. Similarly, the calculated ET by the Jensen-Haise formula multiplied by 0.85 should yield mean alfalfa ET since this formula calculates peak ET for full-grown alfalfa prior to cutting.

Estimating Alfalfa ET

Past estimates of alfalfa ET did not take into account the effect of cutting, resulting in overestimates of seasonal ET. Table 1 presents calculated average monthly ET values for several different areas of the State. These values are based on a detailed study conducted this year by the Interagency Agricultural Information Task Force summarizing the available data from studies by the State Department of Water Resources, the University of California and the USDA-ARS.

TABLE Normal Alfalfa *Evapotranspiration For Several Locations in California

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
	(ET, inches/month)												(inches)
Sacramento Valley	1.2	1.8	3.1	4.3	5.8	7.1	7.7	6.6	5.2	3.5	1.7	1.0	49.0
San Joaquin Valley	1.0	1.4	3.2	4.6	6.3	7.3	7.6	6.4	4.8	3.2	.4	0.7	47.9
Central Coast Interior Valleys	1.7	2.2	3.3	4.3	5.5	6.1	6.6	5.9	4.7	3.7	2.4	1.6	48.0
Central Coastal Plains 1/	1.8	2.3	3.1	3.8	4.5	4.8	5.2	4.6	3.8	3.3	2.3	1.6	41.
Northeastern Mountain Valleys 2/	0.6	1.0	2.1	3.6	4.9	5.7	7.7	6.8	4.8	2.9	1.0	0.5	41.6

* Estimated ET (Consumptive Use) based on past rates of measured water use.
1/ Coastal areas of San Mateo, Santa Cruz, Monterey, San Luis Obispo and Santa Barbara Counties.
2/ Mountain Valleys of Shasta, Lassen, Modoc and Siskiyou Counties.

The information in Table 1 may be used for water allocation studies and planning purposes; but for actual scheduling, it would be preferable to calculate ET estimates using current meteorological data since a "normal" year seldom occurs. The State Department of Water Resources has a network of meteorological stations where pan evaporation is measured at frequent intervals during the growing season. The Epan and crop ET data are available and being published weekly in several newspapers in the Central Valley. Also, the U.S. Bureau of Reclamation published ET data calculated by the Jensen-Haise method in several locations throughout the Valley.

Figure 2 presents a summary of the ET data for the summer of 1977 in four locations; Red Bluff, Davis, Bakersfield, and Sacramento. The first three have been computed by using pan evaporation data and the crop coefficient (Kp= 0.76). The data for Sacramento was calculated from the U.S. Bureau of Reclamation estimates based on the Jensen-Haise formula.

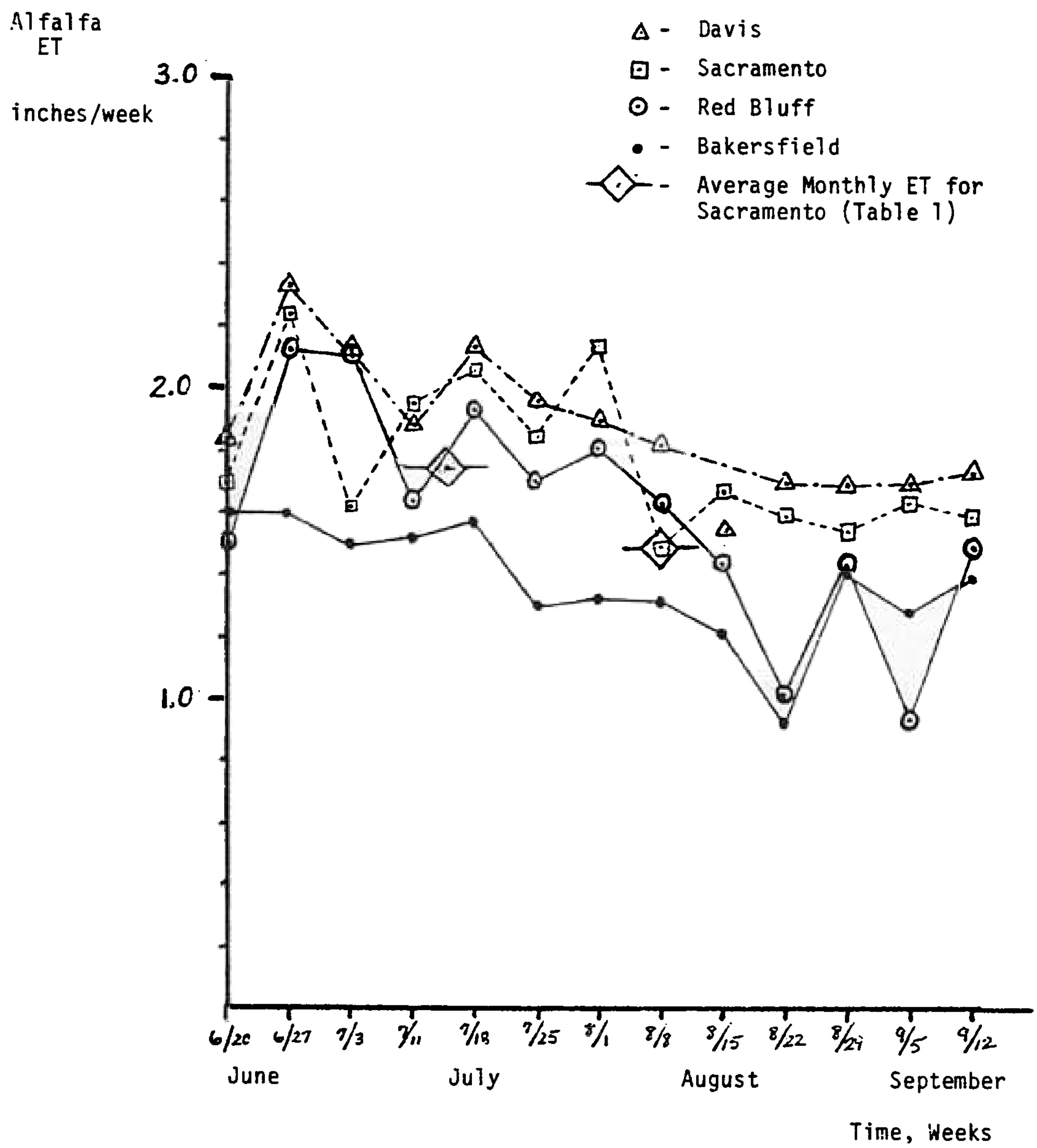

Figure 2. Calculated Alfalfa ET For Different Locations of The Central Valley During Summer of 1977.

Surprisingly enough, the calculated alfalfa ET for Bakersfield appears to have been less this summer than that of all three other locations. A preliminary analysis of weather data indicates that winds lower than normal may have been the reason for this difference (Norm McGillivray, DWR, personal communication). On the other hand, there seems to be little difference between Red Bluff and Daivs, confirming earlier observations of similar monthly ET rates throughout the Central Valley. There was also good agreement between the calculated ET for Davis based on pan evaporation measurements and the alfalfa ET calculated for Sacramento by multiplying the Jensen-Haise estimates by 0.85. Some discrepancies between the two methods were observed earlier in the season, with the calculations based on the Jensen-Haise equation being lower than those based on Epan data. Lysimeter measurements in Davis of wheat ET would indicate that, under the weather conditions of spring 1977 in the Sacramento Valley, the Jensen-Haise equation underestimated alfalfa ET.

In summary, weekly alfalfa ET data is currently available in many locations throughout the State and may be used in conjunction with knowledge of the available soil water storage capacity to schedule irrigations for maximum alfalfa growth and yield with high efficiency of irrigation.

REFERENCES

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