

## Afternoon Session

HOW MUCH WATER CROPS ACTUALLY USE  
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In the State of California we are indeed fortunate that extensive studies have been conducted in the past on the water requirements of many crops in many locations within the state.

In the 1930's and '40's considerable effort went into the development of various methods of predicting evapotranspiration from climatological data. Most of these approaches were simple empirical ones where, for example, the water use by crops was correlated with the mean monthly temperature and the percentage of annual daylight hours occurring in the month being considered. The extensive work in the western United States where water use had been determined through soil-sampling techniques was invaluable in this work and the development of these procedures has been a very important factor in the planning phases of irrigation projects all over the world. During the late 1940's and in the 1950's, agriculturalists and engineers, along with some physicists, were seeing the need for more basic studies, involving the hour-by-hour changes in the energy balance of vegetative surfaces as well as the physics of the transfer processes taking place. It was in response to such developments that the then Department of Irrigation at the University of California at Davis installed in 1958-59 a large weighing lysimeter 20 feet in diameter and 3 feet deep. This tank of soil is resting on a 50-ton scale and is weighed to the nearest 2 pounds every 4 minutes. The sensitivity of the system is actually better than 1 pound which is equivalent to less than .001 of an inch of evapotranspiration or rainfall. Thus, it is capable of giving good accuracy for periods as short as 1/2 hour in length or, of course, very excellent accuracy over daily periods. A second large lysimeter, identical in size to the earlier one, was installed in 1962 for basic studies in micrometeorology under an Army grant. This unit, rather than being weighed on a scale, is actually a floating lysimeter, but with measurements of the depth of water in which the unit floats, a sensitivity fairly close to the weighing unit is realized. The floating lysimeter was used in collecting the evapotranspiration data for field beans which will be reported herein. All of the evapotranspiration data for grass reported for Davis came from the weighing lysimeter. Until the 1968 season, both lysimeters were in grass, and both were located near the middle of a 10- to 13-acre field of grass. For the bean study, an area of 1.5 acres which included the floating lysimeter was cropped to Sutter Pink beans. The sugar beet data reported in this paper came from a hydraulic pillow-type lysimeter which has only fair accuracy for daily totals. The accuracy over weekly periods or longer would be quite good, and thus periods of approximately this length only are reported. This lysimeter is somewhat less adequate in size, being 6 feet by 8 feet by 4 feet deep.

Seven years of monthly evapotranspiration data for well-irrigated, frequently-mowed grass are presented in figure 1. The bar diagram illustrates well the variation in demand for water which can be expected on a month-by-month basis under Central Valley conditions. Seasonally, the average monthly use varies from a low of around 1.0 inch in December and January to a high of 8.2 inches in July. During the midsummer months, the variation between monthly use with years is fairly minor, reflecting the normal small degree of variability in climatic conditions. The month of April showed the greatest variability with a range from a low of 2.7 inches in 1967 to a high of 6 inches in the previous year. On a fiscal year basis, the seasonal totals ranged from a low of 47.8 inches to a high of 58.1 inches, with a mean of 52.2 inches. The average yearly value was 52.63 inches for the 4-year ryegrass study and 51.86 inches for the alta fescue study. These evapotranspiration data were compared with evaporation data from Weather Bureau pans and no significant difference in the ratio of evapotranspiration to evaporation was found for the two crops except under very strong, dry wind conditions. During such periods, the ryegrass tended to suffer more from the high stress conditions.

Although the variation in monthly losses may be rather small for midsummer conditions in Central California, the variation for shorter periods is, of course, much greater. For example, in figure 2 where data for 5-day means of daily evapotranspiration are provided for the month of June, the highest loss was three times that for the lowest (.36 as compared to .12 inches per day). Although the low of 0.12 was, no doubt, due largely to a cloudy period, the variation even on clear days can be very great.

In figure 3, results for 3 years of the work at Davis are compared with data collected at Arvin near Bakersfield during the same 3 years. The Arvin data were obtained from two 6-foot diameter floating lysimeters. These comparisons plus other evapotranspiration data for pasture as well as extensive evaporation measurements in the Central Valley indicate only minor variation in potential evapotranspiration throughout the Central Valley of California should be expected.

In figure 4, evapotranspiration data presented previously in the Department of Water Resources Bul. 113-2 are reproduced. The lower curve, identified as central coast, is based on 2-1/2 years (1963-65) of pasture data obtained with floating tanks by the DWR at Guadalupe, very close to the ocean near Santa Maria. The coastal valley data were obtained by the DWR with weighing tanks in an improved pasture at Soledad, south of Salinas, during 1963-65. The data designated as Central Valley were obtained at Davis (1959-64), at Arvin (1961-64), and at Thornton (1963-64) in the Sacramento Delta using tanks and lysimeters.

The influence on evapotranspiration of the gradual modification of air mass conditions as the air moves in from the ocean is clearly evident in figure 4. For the midsummer months, the air mass warms up and becomes relatively drier as it moves inland producing an average 20 percent increase in evapotranspiration at Soledad but a 60-70 percent higher loss in the

much warmer and drier Central Valley. If we consider the totals for the April-October period shown in figure 4, the average increase was 18 percent and 50 percent respectively, for Coastal Valley and Central Valley situations. Part of the modification involved in coming in from the coast in summer months is the dispersal of fog which blanks out part of the incoming solar radiation at the coastal location.

The reversal in trends for the winter months is very interesting. During this time of the year the air temperature is modified in the opposite sense with inland areas experiencing colder conditions on the average than at the coast. The prevalence of fog in the Central Valley during some of the winter months is, no doubt, a factor in producing some 25 percent reduction in evapotranspiration as compared to the coast. Due to the mid-winter reversal in trends, the Central Valley figure of 52.5 inches for the yearly total is only 29 percent higher than for the coastal site.

So far we have looked at trends of evapotranspiration for grass and pasture situations where essentially full cover conditions persisted. Now let's look at some typical patterns of evapotranspiration for two annual crops. One of them, field beans, has a short growing season and before harvest the plants have lost their green cover and the leaves are senescent. In the other crop, sugar beets, maturity takes on a different meaning. At harvest time, the tops are still green and turgid and transpiration appears to be affected very little.

Rather than rely on the results of only one or two years of data, we have chosen to relate the losses by these two crops to the evapotranspiration of grass and then use the relationships found, along with 7 years of grass data, to arrive at a smooth curve prediction of evapotranspiration for both crops, including both an early and a late-planted crop of sugar beets.

In figure 5, ratios are shown of evapotranspiration for sugar beets to evapotranspiration for grass during various stages of growth for two crops of sugar beets. In drawing smooth curves, the high points for the 1965 crop were ignored. They are believed to be unreasonable due to several factors, but mainly because of the small size of the sugar beet plot that year plus the fact that it was surrounded on three sides by dry fallow or stubble fields.

Three significant factors revealed by the results are: (1) the very low water use rates in relation to grass during the first 6-8 weeks of the season, (2) a significantly higher (10-15 percent) use of water by sugar beets as compared to grass for two or more months after full cover developed, and (3) little, if any, reduction of evapotranspiration for sugar beets in relation to grass as harvest time approached.

In figure 6, the grass-pasture evapotranspiration curve presented in Bul. 113-2 (DWR, 1967) for Central Valley conditions is reproduced along with estimated evapotranspiration for sugar beets based on the smooth-curve relationships indicated in figure 5. Perhaps the most striking

feature in the results is the considerably lower total evapotranspiration for late-planted beets. By the time a late-planted crop reaches full-cover conditions, the high peak demand period of June-July is already past. These results indicate some 40 percent greater evapotranspiration for the early-planted beets as compared to the late-planted crop.

The low water use during early stages of growth for both crops is striking. Unless the young plants require very frequent irrigations or there are frequent rains to keep the soil surface moist, the evaporation losses from the soil are apparently very low. It is during such stages that irrigations, especially if heavy, can be highly inefficient.

In spite of greater water use by sugar beets than by grass during full-cover stages, the total use by grass during the respective sugar beet growing seasons exceeds that for beets in both cases, 15 percent for the early crop and 20 percent for the late crop.

It should be realized that the smooth curves in figure 6 for sugar beets are idealized. At the very early stages of plant growth, for example, at times when the soil surface was quite dry, actual evapotranspiration would be lower than that indicated. Conversely, for a day or so just following an irrigation evapotranspiration rates would be much higher than indicated, perhaps equal to or greater than that for grass. This is very well illustrated in figure 7 where daily ratios of evapotranspiration for field beans to evapotranspiration for grass are presented. In this 1968 study, very accurate data were available as both crops were grown in 20-foot diameter, highly-sensitive lysimeters. These daily data reveal much more clearly the effects of irrigations, degree of plant cover, and maturity on evapotranspiration, than was the case with the sugar beet data.

In the interest of brevity, only brief comments are made concerning figure 7. Significant factors revealed by the results are: (1) for periods when the soil surface was not wet, there was a very smooth transition (indicated by light dashed line) during the first 6 weeks from very low ratios of evapotranspiration for beets to evapotranspiration for grass up to the peak realized as full cover conditions were approached; (2) very great increases in this ratio for a day or two following each irrigation occurred except during full-cover conditions when little if any effects are discernible; (3) for periods of 30 percent and 60 percent cover, irrigations produced ratios, on the day following, of 1.17 and 1.35, respectively, with such large values probably due in part to release of much stored heat from the top layer of soil; (4) water use by beans reached equality with water use by grass when only 65-70 percent ground cover was being provided by the beans; (5) a significantly higher (10-15 percent) use of water by beans as compared to grass was realized for a 5-week period before maturity started setting in; and (6) the onset of maturity produced a dramatic and very systematic drop in ratio with time, with a low of 0.1 reached by harvest time. To arrive at smooth curve estimates of evapotranspiration for beans, the solid curve shown in figure 7 was drawn. It presumes that somewhat more uniformly spaced light irrigations would normally be applied.

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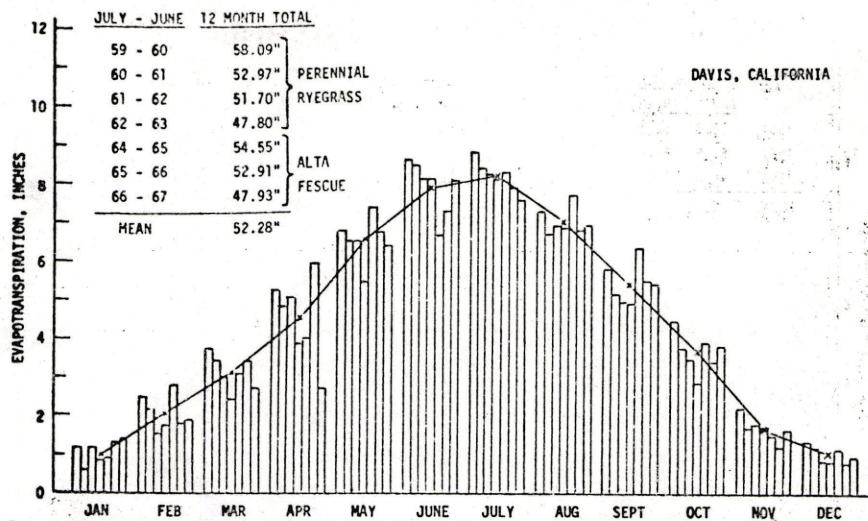


Figure 1. Monthly and yearly evapotranspiration for grass. Seven year record measured by the 20-foot diameter weighing lysimeter.

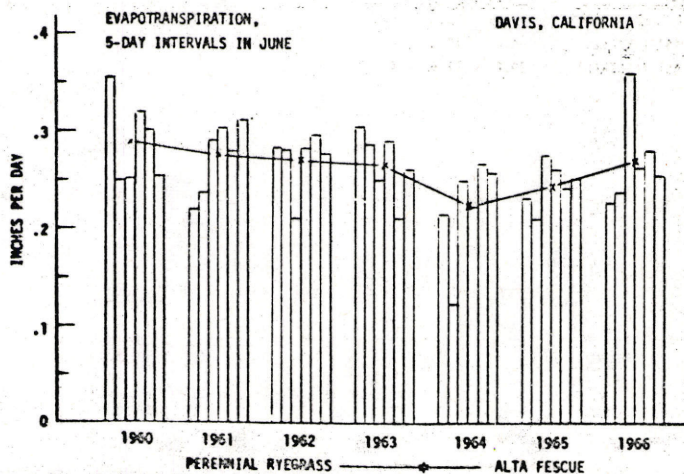
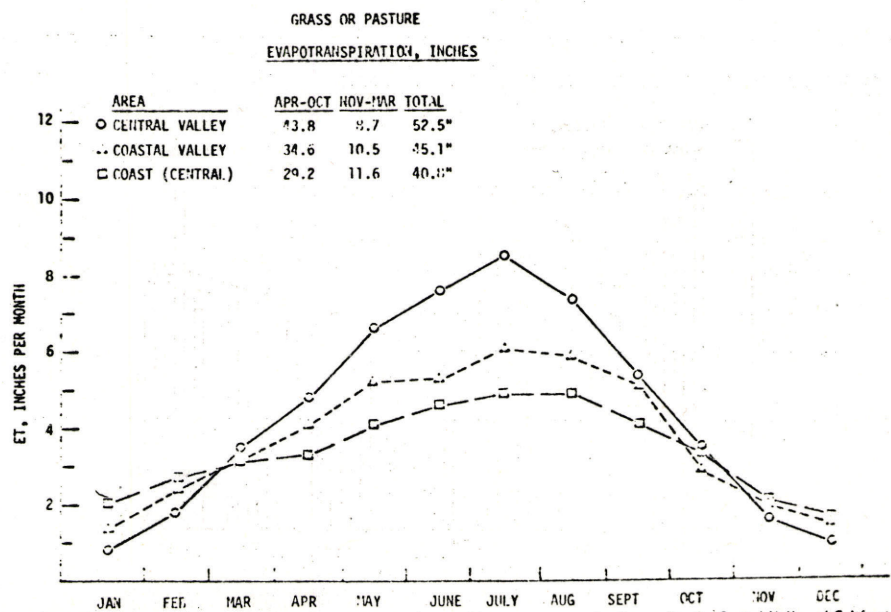
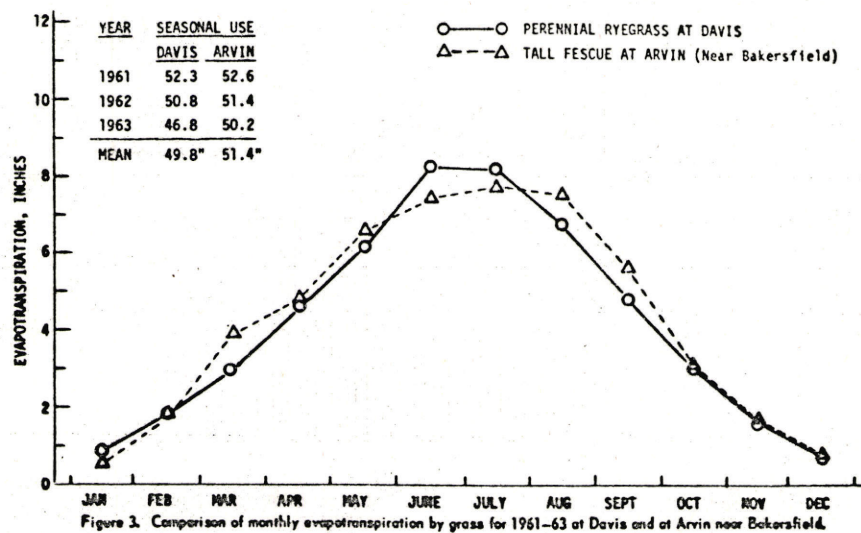


Figure 2. Mean daily evapotranspiration for grass during 5-day intervals in June for seven years.



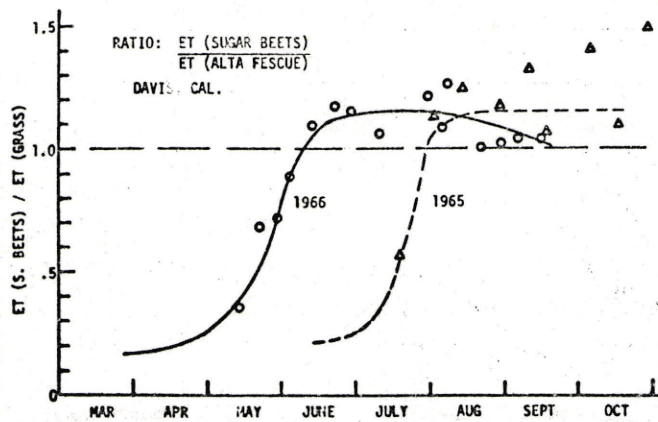


Figure 5. Ratios of evapotranspiration for sugar beets to evapotranspiration by alta fescue grass during weekly periods.

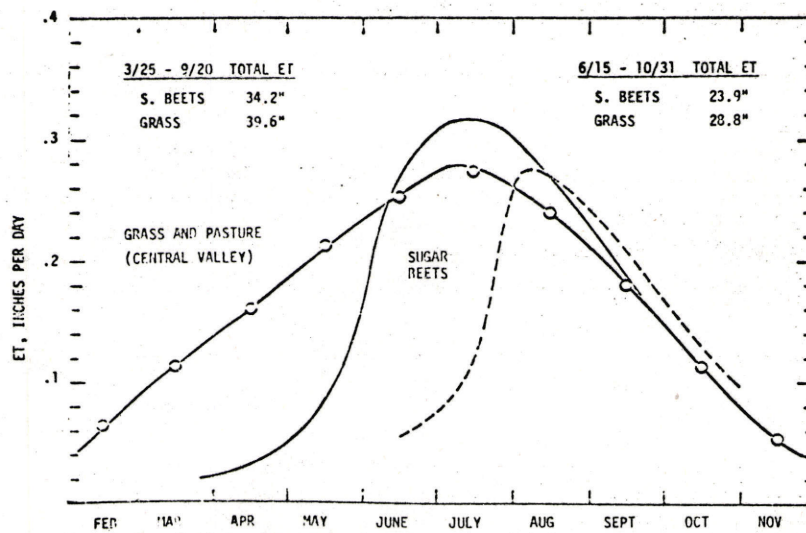


Figure 6. Generalized curves for evapotranspiration by sugar beets for both an early and a late-planted crop based on the grass-pasture curve.

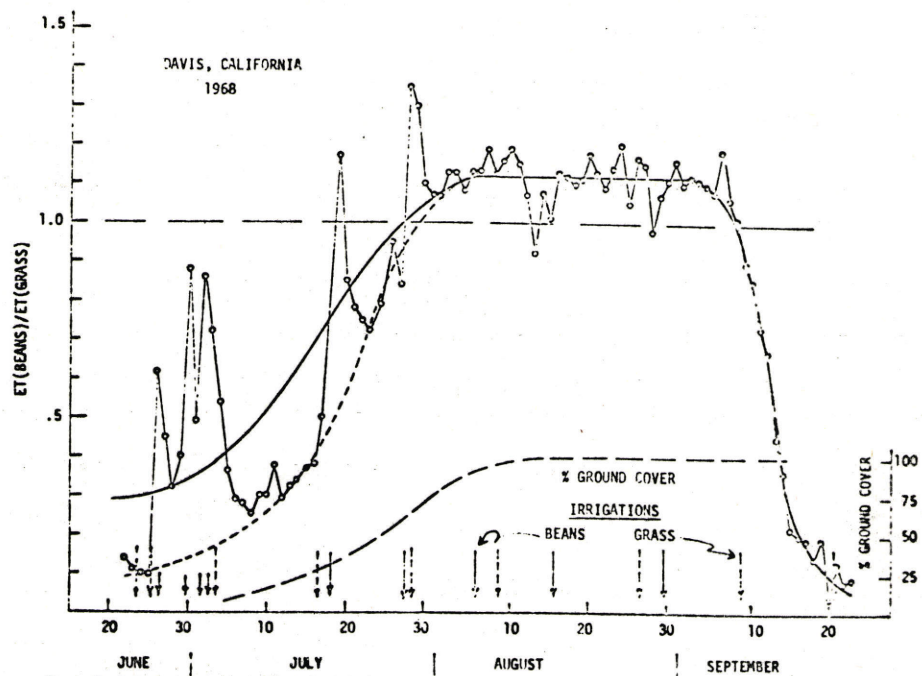


Figure 7. Ratios of evapotranspiration for field beans to alfalfa grass. Measurements were from 20-foot diameter lysimeters.

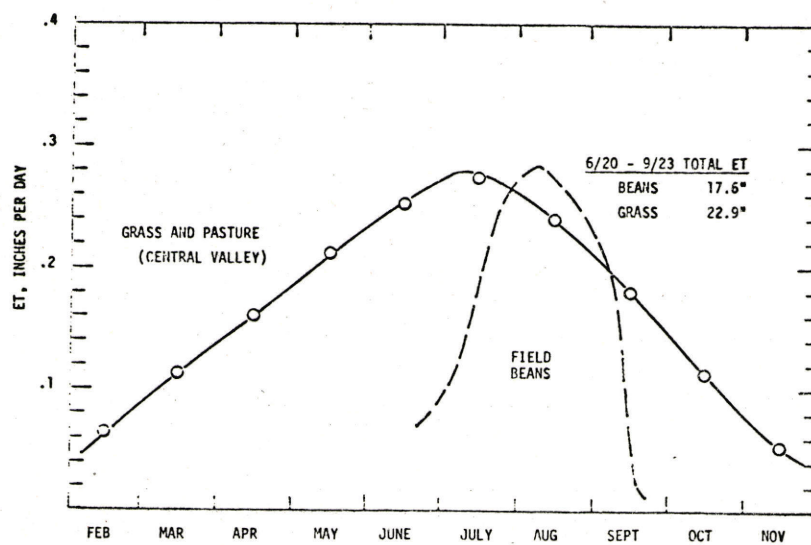


Figure 8. Generalized curve for evapotranspiration by field beans based on the grass-pasture curve.

In figure 8, the grass-pasture evapotranspiration curve presented in Bul. 113-2 (DWR, 1967) for Central Valley conditions is reproduced along with estimated evapotranspiration for beans based on the smooth curve relationships (heavy solid line) indicated in figure 7. The curve for bean evapotranspiration is very similar to that for the late season sugar beets during the first month or so. The major difference between the curves for the two crops is for the late season period when evapotranspiration for beans dropped off very sharply after five weeks of high water use; whereas maturity had no significant effect on evapotranspiration for the sugar beets. Of course, maturity has different meanings for these two crops, since the beets would stay alive on through the winter if not harvested in the fall.

The total of 17.6 inches for the beans compares with a total for grass-pasture during the same period of 22.9 inches. Because of the rapid drop in evapotranspiration with maturity of the bean plants as well as a shorter growing season, the total predicted water use is considerably lower than for beets.

#### SUMMARY

Seasonal and annual variations of evapotranspiration for a green vegetative cover (grass-pasture) were shown for Coastal, Coastal Valley and Central Valley conditions. Considering only the April through October period, the water use at the three locations above was 29.2, 34.6, and 43.8 inches, respectively, showing the marked effect of modification of air mass conditions with movement in from the coast. Highest water use during the November-March period, however, was at the coastal site.

Evapotranspiration data for two annual crops grown at Davis were presented to indicate some effects of time of planting, irrigation, and stage of growth and maturity on water use by such crops. More important effects noted were: (1) very low water use during early stages of growth, (2) a very significant increase in evapotranspiration for the first day or two following early irrigations, (3) significantly higher evapotranspiration rates for sugar beets and beans as compared to grass (10-15 percent) during full cover conditions, (4) a very rapid and smooth drop in evapotranspiration for beans during the last 2-1/2 weeks prior to harvest, and (5) total water use for a March planted crop of sugar beets may exceed by 40 percent the water use of a crop of beets planted in mid-June.