BASIC IRRIGATION SCHEDULING

Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

LEAFLET 21199

PRINTED JANUARY 1981

The Authors are E. Fereres, Irrigation Specialist, Cooperative Extension, Davis; D.W. Henderson, Professor of Water Science and Irrigationist in the Experiment Station, Davis; W.O. Pruitt, Lecturer in Water Science, Davis; W.F. Richardson, Farm Advisor, Cooperative Extension, Red Bluff; and R.S. Ayers, Soil and Water Specialist Emeritus, Davis.

Contributing authors are R.L. Branson, S.P. Carlson, R.M. Hagan, B.R. Hanson, J.L. Meyer, R.D. Meyer, G.S. Pettygrove, T.L. Pritchard, J. Quick, J.M. Rible, H. Schulbach, R.L. Snyder, W.E. Wildman of the Soil and Water Unit of Cooperative Extension, with the assistance of Ray Coppock, Communications Specialist, Cooperative Extension, Davis.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture, Jerome B. Siebert, Acting Director, Cooperative Extension, University of California.

5m–1/81–VL/LAM

BASIC IRRIGATION SCHEDULING

Farmers use numerous ways to schedule irrigations. This leaflet describes two technical procedures. The water budget procedure, which is based on supplying water needs or requirements of the crop, is the most complete. Use of devices which sense water in the soil is also described briefly.

WATER REQUIREMENTS

Water is lost from a cropped field in two ways: direct evaporation of water from the soil surface, and transpiration, which is loss of water vapor from plant leaves. This combination of evaporation from the soil and transpiration by the plant is called evapotranspiration (ET). It is the "crop water requirement"—the amount of water actually used by the growing crop.

However, delivering water to the farm and applying it to the land involves losses by runoff or percolation below the root zone. These losses can be minimized through good conservation practices, but they are difficult to eliminate and must be included to determine the "irrigation water requirement". In general:

Irrigation Requirement = ET − Effective Rainfall + Irrigation System Losses

In the northern and central parts of California, rainfall supplies an appreciable portion of the crop needs in normal years. Some rain may fall after the crop is planted, but most is stored in the soil from pre-season rains. Growers need to estimate the amount of rainfall stored at the beginning of the season, as it is too important to be ignored.

Figure 1 shows water received and potential losses at the farm level during and after irrigation. If losses are kept to a minimum, most of the applied water goes to meet the ET demand.

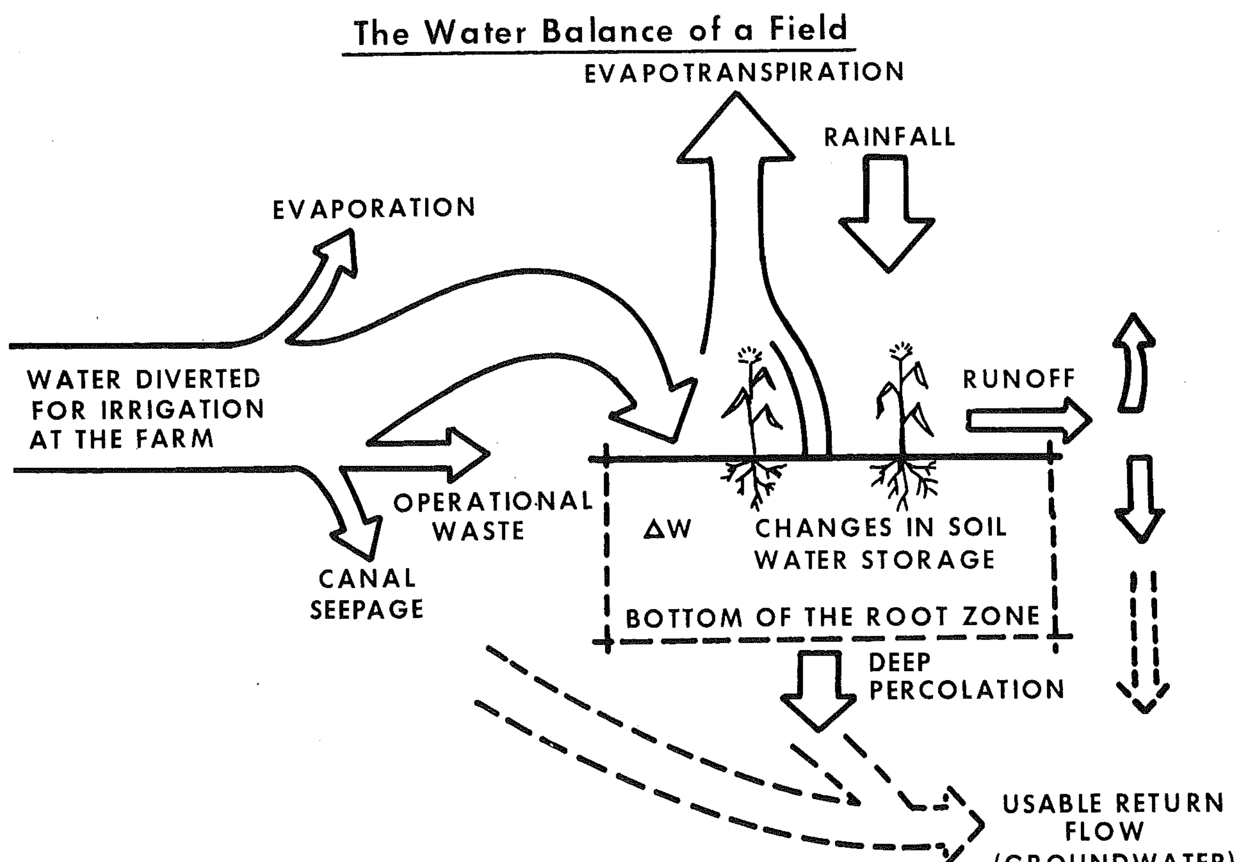


Fig. 1. Water balance of a field.

Besides ET and unavoidable losses in the system, there may be still another need for water. Irrigation waters contain salts which are concentrated in the soil as plants absorb water in the ET process. Where annual rainfall is insufficient to leach salts below the root zone, additional irrigation water is needed. This is the "leaching requirement", which then must be added to the irrigation water requirement. Frequently, the leaching water need be applied only once per year or less often.

Two questions must be answered in order to schedule an irrigation: When to irrigate?, and how much water to apply? A water-budget procedure can be used to answer both questions. Both rainfall and irrigation water are considered to be stored in the soil, so the root zone can be visualized as a reservoir for water to be used by the crop. If the capacity of that reservoir (the soil water available to the crop) and the ET are known, it is possible to determine the date of the next irrigation and the amount of water to be supplied. Thus, ET and soil-water storage are the basic information needed to use the water budget method for irrigation scheduling.

WHAT CONTROLS ET?

Evaporation requires energy. If field surfaces are effectively moist, as are leaves of well-watered plants and wet soils, the amount of water vaporizing and moving into the atmosphere is determined mostly by the energy available from solar radiation. Thus solar radiation level is the main climatic factor that determines the ET rate, although air temperature, humidity, and wind also affect it. ET rates are therefore higher in summer when daily radiation and temperatures are high. Exceptionally low relative humidity and high winds are likely to increase ET rates above normal. Particularly, hot dry winds during spring in the Central Valley may raise the ET rate 25 percent or more above normal, although such periods usally are brief.

The most significant crop factor affecting ET is undoubtedly the degree of ground cover. Many crops do not totally shade the ground, especially during their early stages of growth, and evaporation from the dry soil surface between the plants is very low. In such cases, the ET rate is essentially determined by the area of leaf surface that is intercepting sunlight, or, to put it another way, the percent of soil surface shaded by the crop. For this reason, ET for row crops in the early-growth stages and for many orchards and vineyards is considerably less than the maximum ET. As growth increases, ET reaches its maximum with nearly complete ground cover. ET measurements indicate that when the percent of ground shaded by the crop is above 70 to 80 percent, full ground cover and full ET rate can be assumed.

Evaporation from wet soil immediately after an irrigation is very close to full cover ET, but as the soil dries this water loss is drastically reduced. Thus, frequency of irrigation plays an important role in determining evaporation losses directly from the soil, especially when all the soil surface is wetted.

ESTIMATING ET

Because weather conditions largely determine ET, various methods based on meteorological factors have been developed to estimate ET rates. One of the most common measures evaporation from a standardized free-water surface, since there is good correlation between crop ET and evaporation from free water. The standard water surface commonly used is the U.S. Weather Bureau Class A evaporation pan located in an irrigated pasture.

The relationship between pan evaporation and crop ET under any particular set of circumstances is expressed as a number—the "crop coefficient" (Kp). This number varies with different crops, with planting dates, and with the stage of crop growth, but otherwise is the same in different locations. Thus, if a season-long set of crop coefficients (a "crop coefficient curve") is experimentally determined for one crop in a given location, it can be used there and in other areas to estimate the actual ET for that crop. All that is needed are pan evaporation readings for the period in question and the appropriate Kp values for a given crop and growth stage. Research over the last 20 years has developed crop coefficient curves suitable for many crops grown in California.

Pan evaporation data or weather information used in calculating ET are being gathered in various locations throughout California. Many local newspapers report either the pan evaporation data or the ET for one or more crops calculated from pan evaporation using the appropriate Kp values.

SOIL-WATER STORAGE

After an irrigation is applied, water tends to drain into deeper soil layers. Drainage is rapid at first but after one to several days—depending on soil type, layering, etc.—it decreases to a very small rate, so that for practical purposes it may be neglected. At this point, soil moisture in the root zone may be considered in storage; it can be depleted only by plant transpiration or evaporation from soil. This upper limit of water storage in the root zone is called "field capacity" (FC).

Similarly, a practical lower limit may be defined as the soil-water content below which severe crop water stress and permanent wilting develops. This lower limit has been defined as the "permanent wilting percentage" (PWP). While plants may remove some water below this level, such extraction has little or no significance in irrigated agriculture, although it may be crucial for plant survival.

The difference between FC and PWP is termed available water (AW). Table 1 presents the AW of various soil types. Once the AW value per foot of soil depth is known, the total depth of water available (and thus the capacity of the soil-water reservoir) can be obtained by multiplying the AW value per foot of soil by the root-zone depth. AW also may be estimated by applying a known limited amount of water to the soil when the profile water content is near PWP, and by observing the depth of wetted soil.

TABLE 1
AVAILABLE WATER FOR VARIOUS SOIL TYPES

	Available moisture	
Type of soil	**range in/ft**	**average in/ft**
Very coarse to coarse-textured sand	0.5 to 1.00	0.75
Moderately coarse-textured sandy loams and fine sandy loams	1.00 to 1.50	1.25
Medium texture—very fine sandy loams to silty clay loam	1.25 to 1.75	1.50
Fine and very fine texture—silty clay to clay	1.50 to 2.50	2.00
Peats and mucks	2.00 to 3.00	2.50

inches/foot inches/foot

ALLOWABLE DEPLETION

As the soil-water reservoir is depleted, there is no reduction in ET for a long time. However, ET starts to decrease before the PWP level is reached. This lower ET generally does not increase water-use efficiency because it is likely to reduce yield. For this reason, growers should irrigate before the root-zone water content reaches a level that restricts ET. This critical depletion level depends on several factors: plant factors (rooting density and developmental stage), soil factors (AW and soil depth), and atmospheric factors (current ET rate). Therefore, no single level can be recommended for all situations. For deep-rooted perennial crops on fine-textured soils under mild weather conditions, the depletion level may reach 80 percent or more of the available water without reducing ET. On the other hand, with low rooting densities and high evaporative demand, depletion levels of 40 to 50 percent may reduce the rate of crop growth. Judgment must be used to select an allowable depletion level between these two extremes.

THE WATER BUDGET

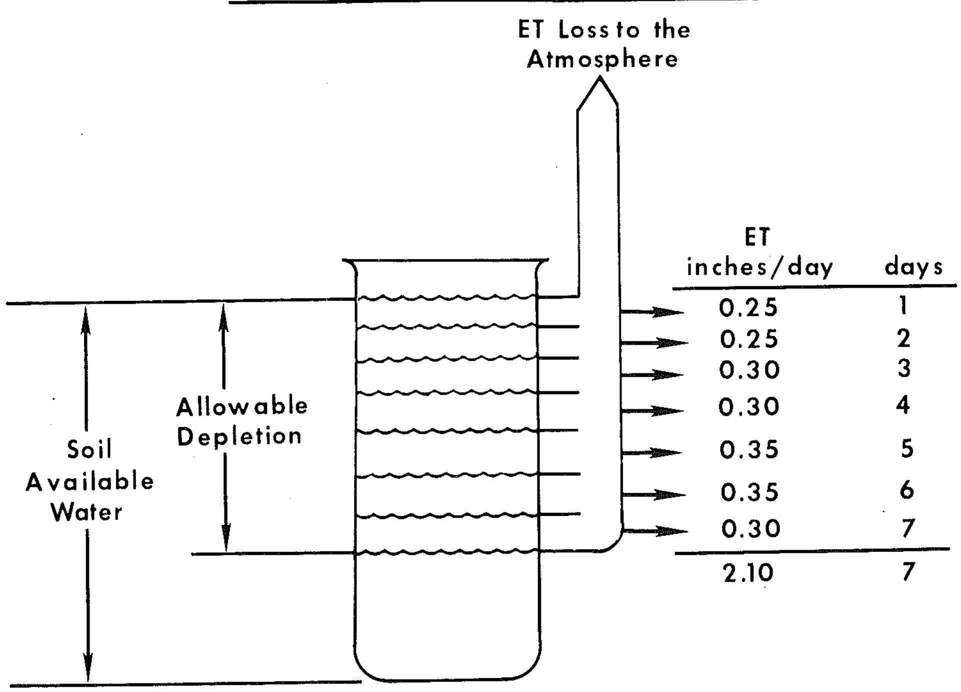
The water-budget procedure is similar to keeping a bank account balance. If the balance on a given date and the dates and amounts of withdrawals are known, the balance can be calculated at any time. Most importantly, the time when all funds would be withdrawn can be determined so that an overdraft is avoided.

The starting point often is after a thorough wetting of the soil by irrigation or winter rains which bring the soil reservoir to full capacity. If this is not the case, the initial balance must be determined by direct observation. Daily quantities of ET are then subtracted until the soil water has been reduced to the allowable depletion level. At that point an irrigation should be applied with a net amount equivalent to the accumulated ET losses since the last irrigation. The soil reservoir is thus recharged to full capacity, and the depletion cycle begins again. Figure 2 shows an example.

The capacity of the root-zone reservoir and AD levels can be estimated before the start of the season (although for annual crops they change as the season progresses). ET values for the actual depletion periods are now available from some newspapers and radio stations and will be more widely distributed in the future. If current ET rates are not available, long-term averages can be used without serious error especially in midsummer when weather does not vary much from year to year.

In some areas of California, complete irrigation-scheduling services based on the water budget are available by contract. These frequently are part of a package which includes fertilizer and pest management recommendations.

The Water Budget Method of Irrigation



IRRIGATE 1. When?--------After 7 days
2. How much?-- Apply 2.10 inches of water + losses (Efficiency consideration)

Fig. 2. Water-budget method of irrigation.

IRRIGATION MANAGEMENT PROGRAMS

Research over many years has established the ET requirements of several crops in California as well as the water retention properties of the principal soils. To make this information available for practical use, crop ET data for a normal year have been combined with data on soil water-storage capacity to design irrigation scheduling programs that apply under average or normal year conditions. An example is presented in Figure 3, which shows cumulative ET at any time after planting on a graph. The vertical distance between two adjacent horizontal lines represents the allowable depletion level for each depletion cycle. The date of irrigation is determined by drawing the horizontal line to intersect the ET curve, and then a vertical line to the date line at the base of the graph.

The normal-year irrigation management program provides an excellent base for irrigation scheduling by simply updating the ET curve periodically with values from the current year and changing the irrigation dates accordingly. Once the appropriate irrigation management program has been designed for a given soil-crop combination, it can then be used as a rational basis for irrigation scheduling with only periodic checks. In California, these checks should be made more frequently at the start and end of the irrigation season when unpredictable weather conditions may cause large year-to-year variations in ET rates.

The irrigation management programs are valuable planning aids to predict requirements for water, labor and other essential inputs. They are also helpful in planning the date of last irrigation so that expected winter rainfall can be stored within the root-zone of next year's crop. And while they are based on the crop's being fully supplied with water, they are helpful in adjusting cropping patterns, planting dates, and other drought year strategies in years when the pre-season prediction is for less-than-normal water supplies.

USE OF SOIL-MOISTURE INDICATORS FOR IRRIGATION SCHEDULING

Devices for monitoring soil moisture have been available for over 20 years. Among them, tensiometers are perhaps the instruments most commonly used in timing irrigations. Gypsum blocks are also being used on a limited basis. These devices register the status of water in the soil, generally in terms of soil-water tension, at the depth in the soil at which the device is placed.

For the same reasons that allowable depletion cannot be designated as a given fraction of available soil water for varied conditions, no single soil-water tension level can be recommended as indicating the need for irrigation. The level also varies with depth of placement of the sensing device.

U.C. Cooperative Extension Leaflet 2264, "Questions and Answers About Tensiometers," provides information on the use of tensiometers for irrigation scheduling. Tensiometers or any other soil-moisture monitoring device are most effectively used in combination with ET data by reading the device to determine when to irrigate and the ET data to calculate the volume of water lost since the last irrigation (hence, the volume to be replaced).

IRRIGATION WATER MANAGEMENT

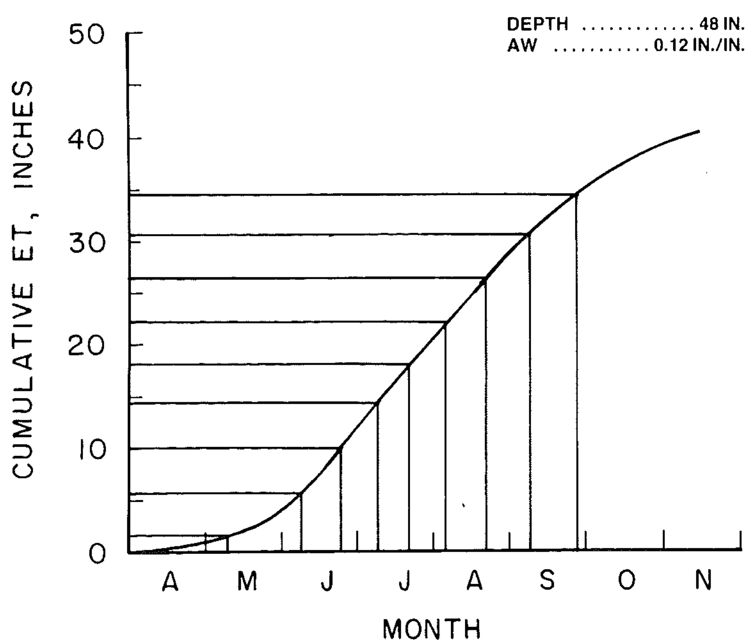
Good on-farm water management practices include not only precise irrigation scheduling, but also knowing the volume of water at each irrigation to each field. If the field size in the example of Figure 3 is 80 acres and the irrigation system efficiency is 70 percent (30 percent of water applied is lost), the gross depth of water to be applied during most of the season is $\frac{3.2}{0.7} = 4.6$ inches, and the volume of water required is $4.6 \times 80 = 368$ acre-inches.

If the field is irrigated with a stream of 3 cubic feet per second (1350 gallons per minute) which supplies 3 acre-inches each hour, 123 hours of irrigation (5 days) are required.

U.C. Cooperative Extension Leaflet 2956, "Measuring Irrigation Water," explains how to select and use devices for simple and accurate measurement of farm irrigation stream flows. In some cases you may get such information from your ditchtender or from pump performance tests conducted by your electric company.

Irrigation water is lost by runoff or by percolation below the root zone. Runoff can be minimized by careful irrigation, by using an irrigation method which does not permit runoff, or by installing a system to collect potential runoff and return it to the irrigation system. U.C. Cooperative Extension Leaflet 21063, "Tailwater Recovery Systems," provides information on the design and cost of such systems. Percolation losses are less obvious and stem mainly from the system's failure to apply water uniformly in different parts of the field. Nonuniform irrigation requires that excess water be applied in some areas so that others will get enough. Consult your Farm Advisor or Soil Conservation Service Office for assistance in evaluating the adequacy and efficiency of your irrigation system.

Scheduling irrigation according to the crop-water requirements, when combined with efficient methods of water application, should result not only in water and energy conservation but also in increased farm profits.



Crop	Sugar Beets
Planting	April 1
Harvest	Nov. 15
Location	Sacramento Valley
Root Zone Depth	4 feet
Available Water	1.5 in./ft.

Normal Year Irrigation Date	Amount of Water to Apply (in.)
May 8	1.4
June 6	3.6
June 22	4.2
July 6	4.2
July 20	4.2
Aug. 4	4.2
Aug. 20	4.2
Sept. 6	4.2
Sept. 26	4.2

ET deficit at harvest: 4.6 in.

Fig. 3. Irrigation management program for a given crop, soil and location.