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THE USE OF CALCULATED ACTUAL AND POTENTIAL EVAPOTRANSPIRATION FOR ESTIMATING POTENTIAL PLANT GROWTH

RODNEY J. ARKLEY and RUDOLPH ULRICH

UNIVERSITY OF CALIFORNIA · BERKELEY, CALIFORNIA

Potential evaporation, ET_p, can readily be calculated from monthly mean temperatures by means of tables and nomograms now available in the literature. Actual evapotranspiration, ET_a, is calculated from ET_p by taking precipitation and the water-holding capacity of the soil into account. Either value can be calculated for the whole year (ET_p or ET_a) if frost-tolerant plants are under consideration; or for the frost-free period ($ET_p32°$ or $ET_a32°$) if frost-sensitive plants are under consideration.

All four values—ET_p, ET_a, $ET_p32°$, and $ET_a32°$—were calculated for 211 California stations and for 27 Nevada and Oregon stations near California. Plotting these values for 25 stations along a traverse through central California and western Nevada reveals great differences from coast to inland stations, and from low to high altitudes. Comparison of the values with natural vegetation and with crops in the different regions indicates that the values are useful as indexes of expected growth of cultivated crops, range, and forest. ET_p values are useful if moisture is not limiting, as in humid climates or where irrigation water is available; ET_a values are useful for predicting the suitability of a climate for dry-farmed crops, estimating the potential for increased growth obtainable by irrigation, and for more precise studies of the effects of climate on natural vegetation. The indexes, used together, can be helpful in crop selection and other soil-management decisions.

Isograms of the four ET values, based on all California stations and plotted on maps of the state, furnish much information about those climatic limitations on plant growth that involve moisture and temperature relations.

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THE USE OF CALCULATED ACTUAL AND POTENTIAL EVAPOTRANSPIRATION FOR ESTIMATING POTENTIAL PLANT GROWTH[1]

RODNEY J. ARKLEY and RUDOLPH ULRICH[2]

PLANT GROWTH depends on three major factors—soil, climate, and management—working together. Of the three, soil and management have been investigated more thoroughly, for a longer period of time, and are better understood than the climatic factor.

Recent methods of climatic analysis based on formulas developed by Thornthwaite (1948), Penman (1948), and Blaney-Criddle (1950) have greatly increased our understanding of climate as it influences plant growth. The work, however, has centered on the radiant energy or temperature components of climate as they influence evapotranspiration,[3] and potential rather than actual evapotranspiration has been emphasized. As few radiant-energy measurements are available, temperature has been used as a measure of radiant energy. For areas with temperature and moisture supply nearly in balance, as in the humid temperate eastern part of the United States, or where moisture shortages can be corrected by irrigation, estimates of potential evapotranspiration are especially useful.

Large areas of the United States and the world do not have a favorable balance of temperature and moisture, however, and an estimate of actual evapotranspiration in these places is more meaningful than potential evapotranspiration. Even in areas of favorable climate, it is important to have an estimate of actual evapotranspiration so as to better understand the temperature and moisture balances involved and to provide a basis for management decisions. Other research and applied uses in soils and with plants are also possible.

This paper presents a simplified method for calculating actual evapotranspiration (ET_a) and the water balance of soil, and indicates the application of the derived values to soil and land classification and soil use and man-

[1] Received for publication August 10, 1961.

[2] Mr. Arkley is Lecturer in Soils and Plant Nutrition and Specialist in the Experiment Station, Berkeley; Mr. Ulrich is Soil Scientist, Soil Conservation Service, Berkeley.

[3] "Evapotranspiration" is a term used to express the total water loss from the soil to the atmosphere and includes both direct evaporation from the soil and transpiration via the plant cover.

TABLE 1

THE WATER BALANCE FOR SACRAMENTO, CALIFORNIA*

Town: Sacramento WB/AP County: Sacramento State: California

Elev.: 17 feet Lat.: 38°31′ Long.: 121°31′

Years record: Precipitation 1921–50 years; Temperature: 1921–50 years; Frost: 1921–50 years; Frost-free season (32°): 1/24 to 12/11 = 321 days

Step Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1. Mean temperature, °F	44.3	49.7	53.9	58.2	64.0	70.3	74.6	73.2	70.3	62.7	53.1	45.8	60.0
2. i values	1.61	2.79	3.83	5.04	6.84	8.96	10.52	10.01	8.96	6.41	3.62	1.91	70.50
3. Weekly ET_p, inches	0.12	0.22	0.35	0.50	0.78	1.07	1.27	1.13	0.90	0.57	0.28	0.12	.....
Monthly ET_p, inches	0.53	0.88	1.55	2.14	3.45	4.58	5.62	5.00	3.86	2.53	1.20	0.53	31.87
4. Precipitation (P), inches	2.66	2.76	2.09	1.38	0.54	0.11	0.00	0.00	0.06	0.91	1.50	3.01	15.02
5. $P - ET_p$ (+), inches	2.13	1.88	0.54	....	....	....	....	....	....	....	0.30	2.48	7.33
(−), inches	....	....	....	0.76	2.91	4.47	5.62	5.00	3.80	1.62	....	....	24.18
6. ET_p32°F, inches	0.12	0.88	1.55	2.14	3.45	4.58	5.62	5.00	3.86	2.53	1.20	0.17	31.10
Available water holding capacity of soil (AWC) 2 inches													
7. Change in S ($\triangle$S), inches	0	0	0	−0.76	−1.24	0	0	0	0	0	0.30	1.70	.....
8. Storage (S), inches	2.0	2.0	2.0	1.24	0	0	0	0	0	0	0.30	2.0	.....
9. ET_a, inches	0.53	0.88	1.55	2.14	1.78	0.11	0.00	0.00	0.06	0.91	1.20	0.53	9.69
10. ET_a, 32°F, inches	0.12	0.88	1.55	2.14	1.78	0.11	0.00	0.00	0.06	0.91	1.20	0.17	8.92
Available water holding capacity of soil (AWC) 4 inches													
7. Change in S ($\triangle$S), inches	1.22	0	0	−0.76	−2.91	−0.33	0	0	0	0	0.30	2.48	.....
8. Storage (S), inches	4.0	4.0	4.0	3.24	0.33	0	0	0	0	0	0.30	2.78	.....
9. ET_a, inches	0.53	0.88	1.55	2.14	3.45	0.44	0.00	0.00	0.06	0.91	1.20	0.53	11.69
10. ET_a 32°F, inches	0.12	0.88	1.55	2.14	3.45	0.44	0.00	0.00	0.06	0.91	1.20	0.17	10.92
Available water holding capacity of soil (AWC) 6 inches													
7. Change in S ($\triangle$S), inches	2.13	1.09	0	−0.76	−2.91	−2.33	0	0	0	0	0.30	2.48	.....
8. Storage (S), inches	4.91	6.0	6.0	5.24	2.33	0	0	0	0	0	0.30	2.78	.....
9. ET_a, inches	0.53	0.88	1.55	2.14	3.45	2.44	0.00	0.00	0.06	0.91	1.20	0.53	13.69
10. ET_a 32°F, inches	0.12	0.88	1.55	2.14	3.45	2.44	0.00	0.00	0.06	0.91	1.20	0.17	12.92
Available water holding capacity of soil (AWC) 7.33 inches													
7. Change in S ($\triangle$S), inches	2.13	1.88	0.54	−0.76	−2.91	−3.66	0	0	0	0	0.30	2.48	.....
8. Storage (S), inches	4.91	6.79	7.33	6.57	3.66	0	0	0	0	0	0.30	2.78	.....
9. ET_a, inches	0.53	0.88	1.55	2.14	3.45	3.77	0.00	0.00	0.06	0.91	1.20	0.53	15.02
10. ET_a 32°F, inches	0.12	0.88	1.55	2.14	3.45	3.77	0.00	0.00	0.06	0.91	1.20	0.17	14.25

* SOURCE OF DATA: U.S. Weather Bureau. 1959. Climatic values are expressed to two decimals only to match Weather Bureau precipitation data but the second decimal is not considered significant.

agement. Actual evapotranspiration is used here in the same sense as by Thornthwaite (1948). It refers to a value derived from the water balance and the calculated potential evapotranspiration; thus it is also a calculated value and does not imply a real measurement. The principle involved in calculating actual evapotranspiration—that of evaluating the limitation on plant growth due to either temperature or moisture—can be used with any of the methods for calculating potential evapotranspiration. When the same reference standards are used, all the methods give similar results, according to recent studies by Smith (1959). Alternatively, the procedure may be based directly on soil-moisture or lysimeter measurements, and evapotranspiration for a particular soil can be measured directly, rather than calculated by means of formulas.

PROCEDURE FOR CALCULATING CLIMATIC VALUES AND THE WATER BALANCE

The calculations outlined below are basically the same as those described by Thornthwaite (1948). But the procedure is simplified by using tables of Heat Index and nomograms of potential evapotranspiration that are now available; and application to soil management and plant growth is facilitated by rearranging the order of the calculations of actual evapotranspiration.

Thornthwaite and Mather (1954) have introduced a correction for a reduction in rate of actual evapotranspiration as the soil nears the wilting point. In deriving annual or seasonal totals, this correction is of importance only when the sum of the negative monthly values of precipitation minus potential evapotranspiration is between 1.0 and 1.5 times as large as the maximum soil moisture storage. But for studies of individual months, the correction should be made as described by Thornthwaite and Mather or Palmer and Havens (1958).

The procedure outlined here assumes that runoff and deep percolation beyond the depth of rooting do not take place until the entire root zone has reached field capacity. This assumption is reasonable for well-drained soils on very gentle slopes and where the soil is sufficiently permeable to absorb the precipitation as it falls. Where water losses due to runoff are important they should be subtracted from the precipitation before calculating the water balance. Similarly, moisture that percolates beyond the depth of rooting should be excluded from the water available to plants. For soils receiving runoff or seepage water, this moisture should be added to the precipitation before calculating the water balance.

Table 1 shows the water balance for Sacramento, California, for soils having 2, 4, 6, and 7.33 inches available water-holding capacity based on average monthly climatic data for that station (7.33 inches is used because it is the maximum available for storage under average Sacramento climatic conditions). Figure 1 shows the water balance graphically for soils with 4 and 7.33 inches available water-holding capacity. Calculations can also be on an average weekly basis or for any specific year, month, or week. Pruitt (1958) suggested a simple timetable, recording cumulative depletion of soil moisture using daily estimates of evapotranspiration, but Pelton, King, and Tanner (1960) report that predictions of daily values based on mean temperature are

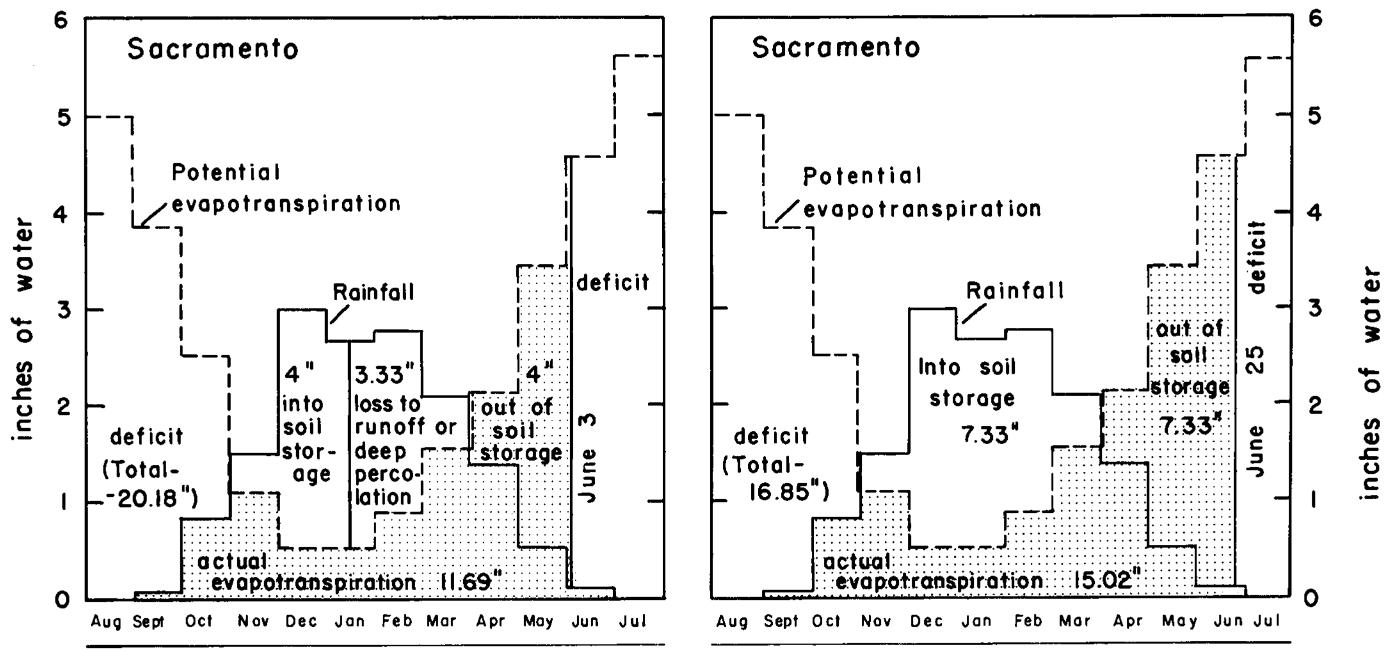


Fig. 1. Water balance for soils of 4 and 7.33 inches available water-holding capacity at Sacramento, California.

not feasible. The step-by-step procedure for calculating the various climatic values is given below.

Step 1. Enter mean monthly temperature in degrees Fahrenheit.

Step 2. Enter i values by months, for example, from Palmer and Havens (1958, Table 1). The sum of the i values is the Heat Index, I.

Step 3. Determine potential evapotranspiration (ET_p), for example, from the graphs of Palmer and Havens (1958), which gives weekly values quickly convertible to monthly values by the use of a table prepared for this purpose. Alternatively, the van Hylckama (1959) nomogram may be used to obtain monthly potential evapotranspiration.

Step 4. Enter mean monthly precipitation (P) in inches.

Step 5. Subtract potential evapotranspiration (ET_p) from precipitation (P) to obtain monthly positive or negative values.

Step 6. Determine the potential evapotranspiration for the frost-free season, ET_p 32°. These values are the same as the monthly potential evapotranspiration exclusive of the months or parts of months having temperatures below 32°F. Estimates for 28°, 24°, or other temperature extremes may be similarly made.

Step 7. Determine or estimate the total available water-holding capacity (AWC) of the soil in inches to the average depth of rooting of the dominant crops. If a number of soils with differing available water-holding capacities are to be considered, a series of AWC values, for example, 1, 2, 4, 6 inches, should be selected and appropriate computations made. Using the selected AWC, determine the change in soil moisture storage (ΔS) as follows: Beginning with the first positive value in step 5 in the fall or winter (or if there are no negative values in step 5, begin with the lowest positive value) enter the monthly positive values as ΔS until the sum equals the AWC. For the remaining consecutive months with positive values enter zero as ΔS; the soil remains at field capacity during this period and there is no change in soil moisture storage. Beginning with the first month with negative value, moisture is withdrawn from the soil; thus the negative values represent the negative change in soil moisture storage until the AWC is exhausted. In the remaining months with negative values, the soil remains essentially dry (at or near wilting percentage) so that the net change in soil moisture storage for these months is zero.

Note: This procedure assumes that soil moisture depletion proceeds at the maximum rate. This assumption is generally satisfactory for calculating annual or seasonal values of actual evapotranspiration.

Step 8. Enter the soil moisture storage (S) at the end of each month. If the sum of the negative values in step 5 is less than AWC, then there is a carry-over of soil moisture storage, which must be added to the beginning month (step 7), and succeeding months readjusted accordingly.

Step 9. Calculate actual evapotranspiration (ET_a) by comparing: (*a*) the monthly ET_p (step 3) with (*b*) the sum of the rainfall (step 4) and soil moisture storage (step 8) at the end of the previous month and enter whichever is the minimum. It is evident that moisture is not a limiting factor in months with positive values for step 5. The same is true for all but the last month in which ΔS (step 7) is negative. Therefore enter the value of ET_p

(step 3) as ET_a for the months in which moisture is not limiting. For the last month in which ΔS is negative, enter the sum of precipitation (step 4) plus the value of ΔS (step 7), disregarding the negative sign. For remaining months in which storage (S) is zero (step 7), enter the precipitation only.[4]

Step 10. Determine actual evapotranspiration for the frost-free season, ET_a 32°. These values are the same as monthly ET_a exclusive of the months or parts of months having temperatures below 32°F. Estimates for 28°, 24°, or other temperature extremes may similarly be made.

SIGNIFICANCE AND USE OF THE CALCULATED VALUES

Potential evapotranspiration (ET_p)

Potential evapotranspiration is the rate of water loss to the atmosphere from the soil with a large area of continuous cover of green grasslike plants with an optimum supply of moisture and ample plant nutrients. Potential evapotranspiration thus is an estimate of the maximum rate of water loss from the soil and plant cover to the atmosphere that can take place under a given set of climatic conditions. As plant growth and water use are directly related, potential evapotranspiration can be used to estimate the maximum potential plant growth to be expected where water and nutrients are in optimum supply. Data reported by workers such as Kiesselbach (1916) and Briggs and Shantz (1914) show that plant dry-matter production is proportional to the water transpired by a particular species of plant, other conditions being held constant. The factors affecting the relation when conditions are varied were analyzed by Arkley (1961), who found that relative humidity was the main factor affecting the proportionality. Thus in regions of similar relative humidity the annual potential evapotranspiration, ET_p, can be used for frost-tolerant perennial crops such as pasture, or the frost-free-season total, ET_p 32°, can be used for frost-sensitive crops such as corn or cotton.

Actual evapotranspiration (ET_a)

Moisture is a limiting factor in many areas where crops are grown under natural rainfall. As shown in Table 1, the actual evapotranspiration for each month is determined by comparing the potential evapotranspiration with the water available from precipitation and stored soil moisture. The actual evapotranspiration may thus be limited by either temperature or moisture. Temperature is usually the limiting factor during the winter months, but as the temperature rises to the summer maximum, moisture becomes increasingly limited. Table 1 shows that moisture supply becomes the limiting factor at Sacramento in the month of June and continues through the month of October for a soil having 4 inches of available-water-holding capacity. Thus actual evapotranspiration provides an estimate of the climatic limitation on crop growth where crops depend on natural rainfall and soil storage for their

[4] Where the sum of the negative values (step 5) exceeds both the AWC and the sum of the positive values, the annual ET_a can be obtained for any given AWC by the following formula:

$$ET_a \text{ (annual)} = P \text{ (annual)} + AWC - \text{(Sum of positive values)}$$

If the sum of the positive values is equal to or less than AWC, then the formula is simply ET_a (annual) = P (annual).

moisture supply. It can be calculated for a soil of any moisture-holding capacity and applied to any length of growing season. For instance, for frost-sensitive crops, ET_a 32° can be used.

For the purposes of soil and land classification and use in predicting plant growth and behavior, the pertinent climatic values are:

Soil management	*Climatic value to be used* For frost-tolerant crops	For frost-sensitive crops
Irrigated	Annual ET_p	ET_p 32°
Natural rainfall	Annual ET_a	ET_a 32°

In comparing one climate with another as they affect plant growth, it should be kept in mind that actual evapotranspiration depends in part upon

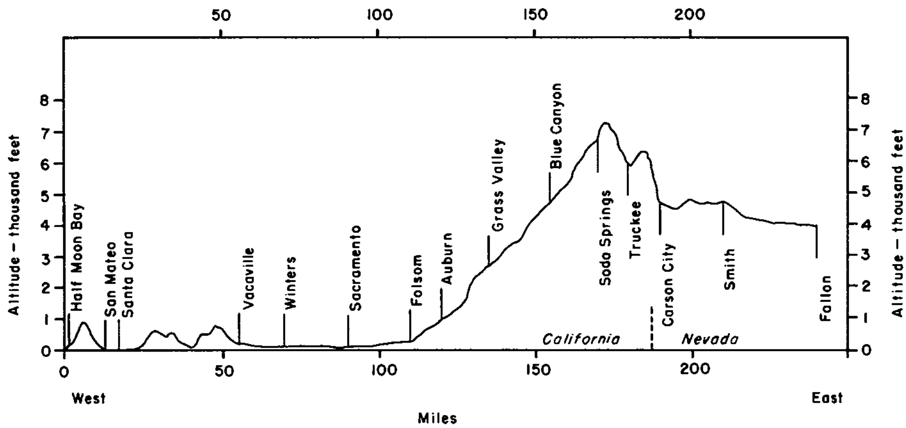


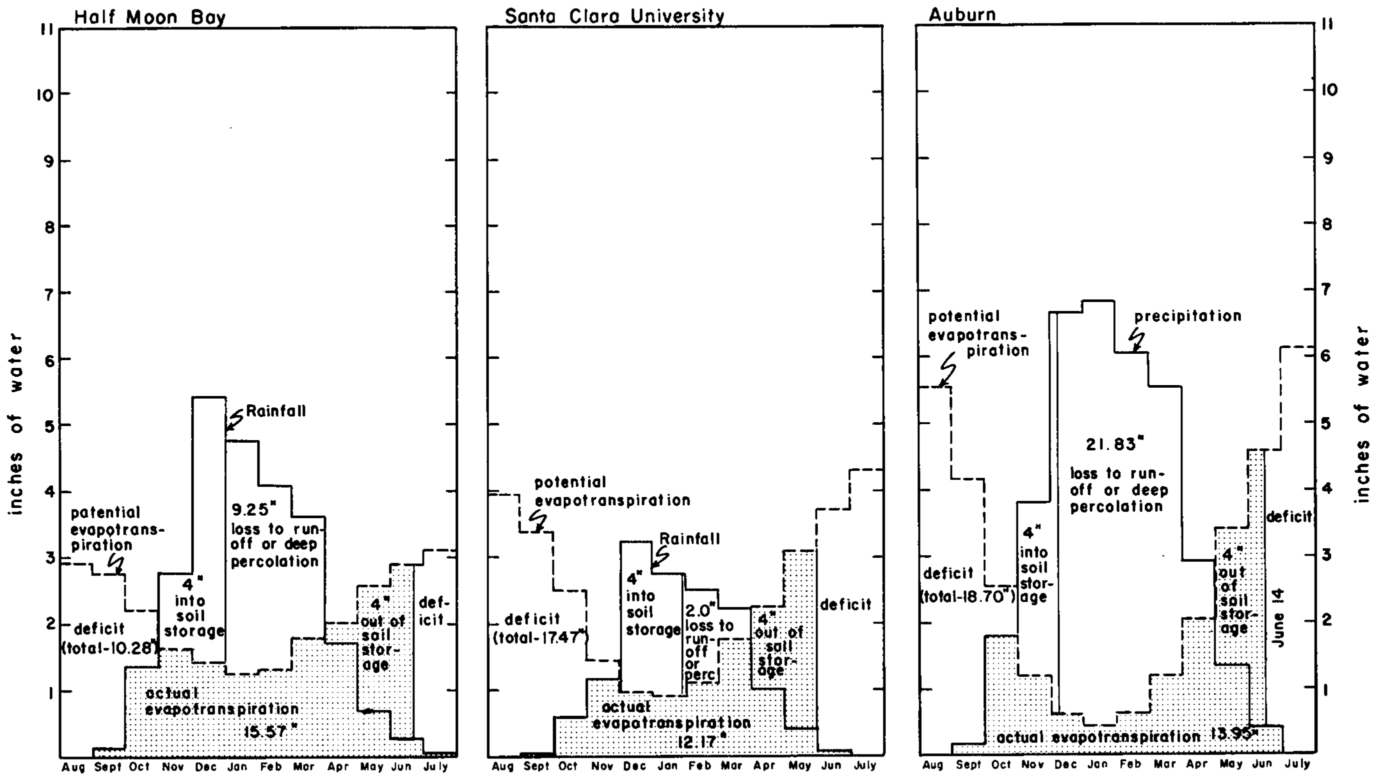
Fig. 2. Traverse through central California and Nevada, showing altitudes and distance from coast of representative stations.

the available water storage capacities (AWC) of the soils in question. Purely climatic comparisons can be based upon a soil of an assumed standard water-holding capacity such as 4 inches (10 cm). This was done by Thornthwaite (1948). For decisions about a specific soil, however, the water-storage capacity of the soil in question must be used. Thus provision is made for calculating actual evapotranspiration for various values of AWC in Table 1.

In arid regions where the precipitation available for storage (that is, the excess of precipitation over evapotranspiration during the moist season) is very low, even in years of above-normal rainfall, the amount of moisture available for storage in the soil is usually only 1 or 2 inches. Thus in arid areas, the moisture-storing ability of the soil is of little significance unless the soil is to be irrigated. This fact has implications in mapping and classifying soil in nonirrigated arid regions.

Water balance

The water balance (Thornthwaite and Mather, 1954, 1955) consists of the complete analysis of measured or calculated additions to or subtractions from available soil moisture on a yearly, monthly, weekly, or daily (Pruitt, 1958)


Half Moon Bay
Santa Clara University
Auburn
inches of water
potential evapotranspiration
Rainfall
precipitation
4" into soil storage
9.25" loss to run-off or deep percolation
2.0" loss to run-off or perc
21.83" loss to run-off or deep percolation
4" out of soil storage
deficit
deficit (total-10.28")
deficit (total-17.47")
deficit (total-18.70")
actual evapotranspiration 15.57"
actual evapotranspiration 12.17"
actual evapotranspiration 13.95"
June 14
Aug Sept Oct Nov Dec Jan Feb Mar Apr May Jun July

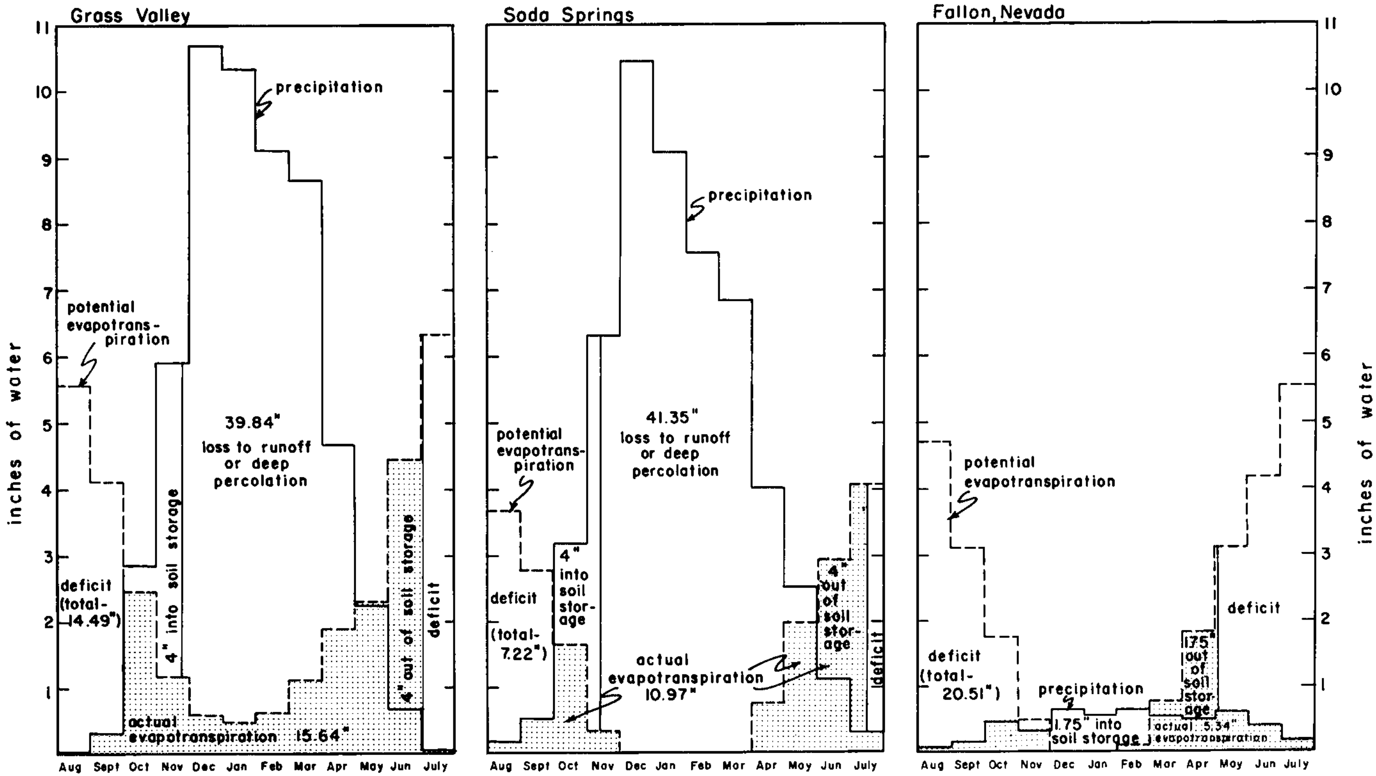


Fig. 3. The water balance for soils of 4 inches available water-holding capacity at six representative stations along the central California and Nevada traverse.

basis. The additions may be either natural or artificial as under irrigation, the amounts added being related to crop needs and available water-holding capacity. The water balance thus provides essential information for interpreting soil behavior. The difference between the potential and actual evapotranspiration indicates the maximum potential increase in plant growth to be expected from the change from dry-farmed to irrigated agriculture. For example, the difference between potential and actual evapotranspiration for soils with an available water-holding capacity of 4 inches is 23.1 inches at Carlsbad, New Mexico, but only 9.0 inches at Helena, Montana. This represents a tremendous difference in growth potential even though the mean annual precipitation at the two places is the same, about 13 inches. The difference between the two stations is even more marked for the frost-free season, 22.5 as compared with 5.6 inches.

STUDY TRAVERSE

To study the application of the water balance to land-capability classification, the water balance was calculated according to the procedure outlined above for a traverse extending from the Pacific Coast near San Francisco inland into western Nevada (Fig. 2). Subsequently, the conditions along the traverse were examined in the field by a group of soil scientists, a climatologist, and specialists in crops, range, and forestry. Within a few hundred miles, the mean annual precipitation varied greatly, being about 25 inches at Half Moon Bay, 15 inches at Sacramento in the Central Valley, 52 inches at Soda Springs in the Sierra Nevada, and 5 inches at Fallon, Nevada. At the same stations, the mean annual temperatures are 54°, 61°, 50°, and 51°F, respectively. Also included for comparison were colder stations north of the traverse, such as Alturas, California, with 13 inches precipitation and a mean annual temperature of 46°. Figure 3 shows the water balance for six stations along the traverse. The calculated evapotranspiration values are indicated in figures 4 and 5.The data for Sacramento shown in Figure 1 are a part of this traverse.

Annual potential evapotranspiration (ET_P), study traverse

Consider first the annual potential evapotranspiration in Figure 4. The values increase from the coast at Half Moon Bay to a maximum in the Central Valley, remain high in the foothills of the Sierra Nevada from Auburn to Grass Valley, drop abruptly in the mountains from Soda Springs to Boca, and rise again on the Nevada side of the mountains. The annual precipitation is less than annual potential evapotranspiration in much of this area so extra water must be supplied if the need is to be met. The maximum potential growth for frost-tolerant crops under irrigation is in the Central Valley, with lower values on the coast and in the desert, and minima at Boca in the mountains and Alturas in a cold valley on the eastern side of the mountains. A large number of crops such as fruits, nuts, vegetables, and forage crops are possible in the Central Valley under irrigation. Double-cropping with small grain in the winter and row crops in the summer is also possible. But at Alturas hay and small grain are about the only adapted crops.

Annual actual evapotranspiration (ET_a), study traverse

Consider next the calculated annual actual evapotranspiration for a soil of 4 inches AWC in Figure 4. The values along the traverse are all limited by moisture, as can be seen by comparing them with the corresponding annual potential evapotranspiration values. This is true in most of the western United States. Examining the annual actual evapotranspiration values, it is evident the best growth of grass without irrigation would be expected at Half Moon Bay ($ET_a = 15.2$ inches) on the coast and at Grass Valley ($ET_a = 15.4$

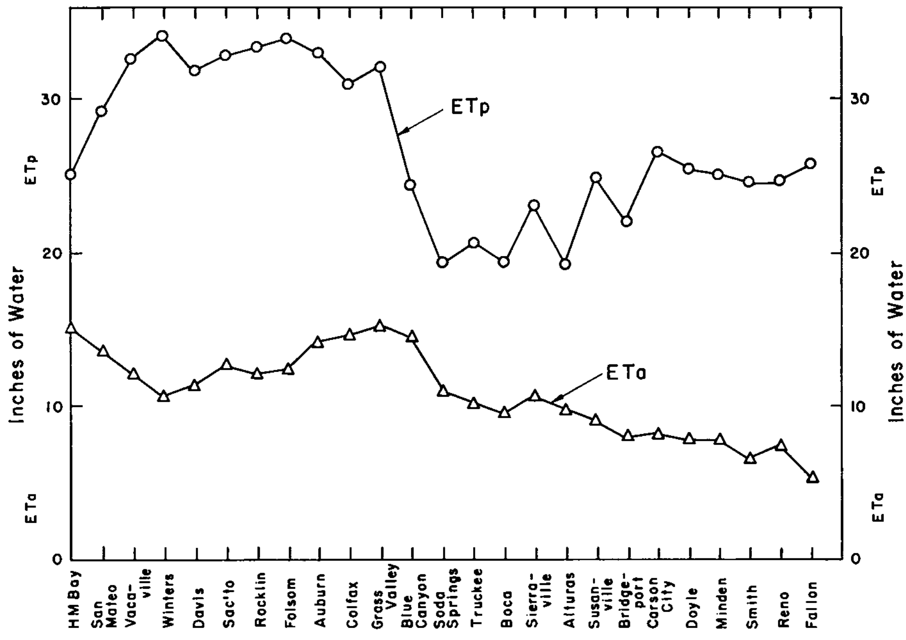


Fig. 4. ET_p and ET_a (for soils with an available water-holding capacity of 4 inches) at representative stations along the central California and Nevada traverse.

inches) in the more humid portion of the foothills of the Sierra Nevada. This is in accord with the facts: perennial grasses thrive along the coast and in the vicinity of Grass Valley, as the name implies; but only annual grasses that can use winter moisture do well at Winters without irrigation ($ET_a = 10.7$ inches). In the mountains and eastward into the desert, the growth potential is lower. At Fallon ($ET_a = 5.3$ inches), the vegetative cover is mainly widely spaced desert shrubs and a little grass in wet years.

Thus for unirrigated vegetation, the calculated annual actual evapotranspiration serves as an index for the expected growth of frost-tolerant plants. The implications for ecology, range, and forest management are evident. For dry-farmed crops, the soil is usually cultivated during the period between harvest and planting time, so little or no water is transpired and more can be stored in the soil for the growing season. The water balance must then be altered in accord with local studies of the efficiency of fallowing as a means of conserving soil moisture. Most studies indicate that the efficiency of fallowing varies from 10 to about 40 per cent, the other 60 to 90 per cent of the precipitation during the fallow period being lost by evaporation from the soil.

Another important point clearly evident in Figure 4 is the potential for increased plant growth obtainable by irrigation, mentioned earlier. This is shown by the difference between the annual ET_p and ET_a values at each station. Thus for frost-tolerant crops, very large increases can be expected under irrigation at Fallon and Winters, somewhat less at Half Moon Bay, and still less at Alturas, although even here the potential increase is about 100 per cent.

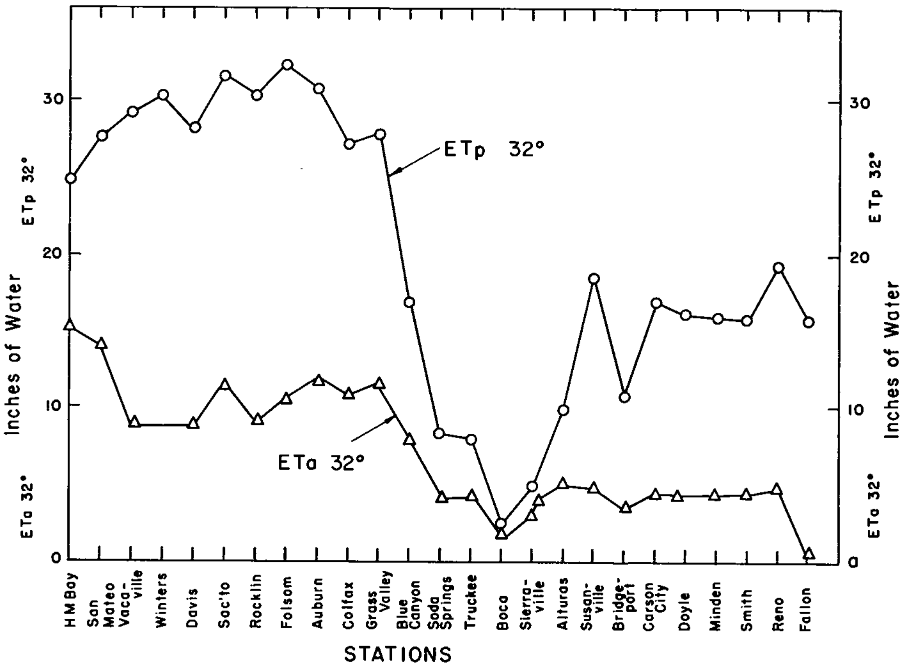


Fig. 5. $ET_p32°$ and $ET_a32°$ (for soils with an available water-holding capacity of 4 inches) at representative stations along the central California and Nevada traverse.

Potential evapotranspiration for the frost-free season (ET_p 32°), study traverse

Figure 5 shows that west of Grass Valley the ET_p 32° is almost as great as annual ET_p. This reflects the very long frost-free season. The maximum occurs near Folsom, where citrus is grown. The minimum occurs in the high mountains at Portola and Boca, where the frost-free period is about one month. In Nevada, ET_p 32° is about two thirds of the annual.

Working in the Intermountain West, Hutchings (1954*a–d*, 1955) has developed a tentative scale of values for ET_p 32° as given in Table 2. It is clear from Table 2 that the number of crop alternatives increases with increasing ET_p 32°.

To determine if the values given for cotton apply in Midwestern areas, it was found that the ET_p 32° for Alva, Woods County, Oklahoma, is 31.4 inches and well within the range for cotton. The soil-survey report for adjoining Alfalfa County, Oklahoma, shows that cotton is grown without irrigation. This being the case, the ET_a 32° should also fall within the range of ET_p 32° given for cotton. The ET_a 32° value of 25.0 inches at Alva puts this area near the lower limit of 24 inches evapotranspiration required for cotton. Cotton is not grown to the north in Kansas, nor west of Woods County in Oklahoma without irrigation.

TABLE 2

TENTATIVE RELATION BETWEEN ET_p 32° OR DEVELOPMENT UNITS AND CROP SUITABILITY

ET_p 32°	Development units*	Suitable irrigated crops
inches	units	
Less than 8	Under 2,000	Small grain for hay
8 to 12	2,000–3,000	Small grain for hay or grain, limited number of alfalfa cuttings
12 to 18	3,000–4,500	Those above plus corn and sorghums for silage and additional cuttings of alfalfa
18 to 24	4,500–6,000	Those above plus corn and sorghums for grain
24 to 38	6,000–10,000	Those above plus cotton
More than 38	Over 10,000	Those above plus citrus† and avacados (Arizona)

* Hutchings (1954*a–d*, 1955) computes ET_p 32° in centimeters of water and multiplies by 100 to obtain Development Units. When ET_p 32° is computed in inches of water, it is necessary to multiply by 254, i.e. 100×2.54, to obtain a comparable number of Development Units.

† Citrus is commercially grown in California locations with as low as 28 inches ET_p 32°.

Actual evapotranspiration for the frost-fee season (ET_a 32°), study traverse

Along the traverse through Central California and Nevada, the calculated ET_a 32° for a soil with AWC equal to 4 inches shows that the best area for frost-sensitive crops grown without irrigation is along the coast, but a limited amount of irrigation is helpful. Artichokes grow without irrigation, but high production requires added water. The same is true near Folsom for citrus. Irrigation would be of little value between Blue Canyon and Sierraville on frost-sensitive crops, but it would be well worth while at Fallon, Nevada, if water is available. The ET_p 32° is too low for irrigated cotton, however, at Fallon.

STATEWIDE STUDY

The water balance has also been computed for 211 stations in California and 27 adjoining stations in Nevada and Oregon. The results are given in the Appendix and are plotted in Figures 6 to 9.

Annual potential evapotranspiration (ET_p), statewide study

Figure 6 shows the distribution of calculated annual potential evapotranspiration, by 3- to 6-inch intervals in California. Maximum values (greater than 51 inches) are in the desert regions where high temperatures and clear

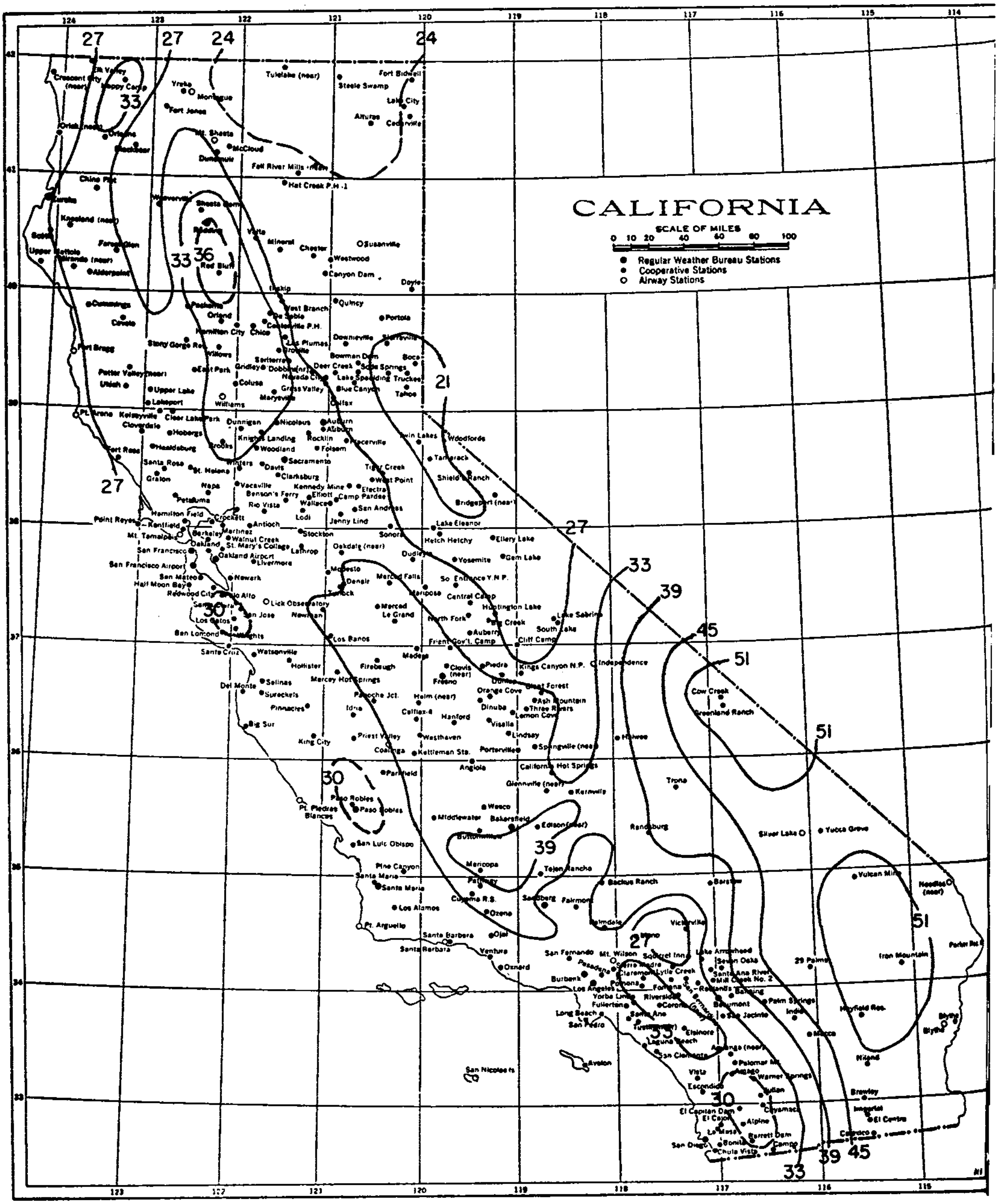


Fig. 6. Isograms of ET_p, potential evapotranspiration in inches: a relative index for frost-tolerant irrigated crops.

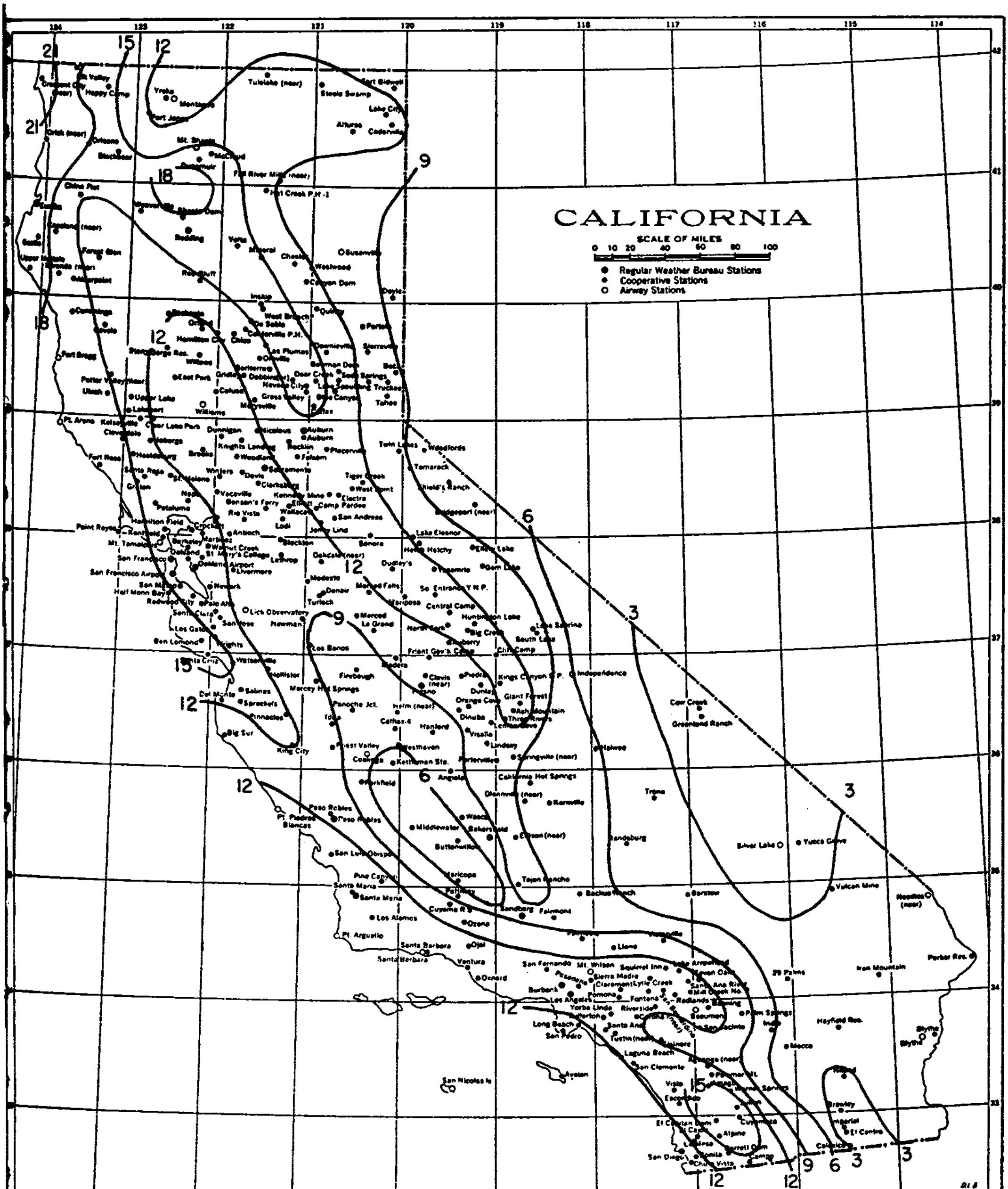


Fig. 7. Isograms of ET_a, actual evapotranspiration in inches for soils of 4 inches available water-holding capacity: a relative index for frost-tolerant crops grown under natural rainfall.

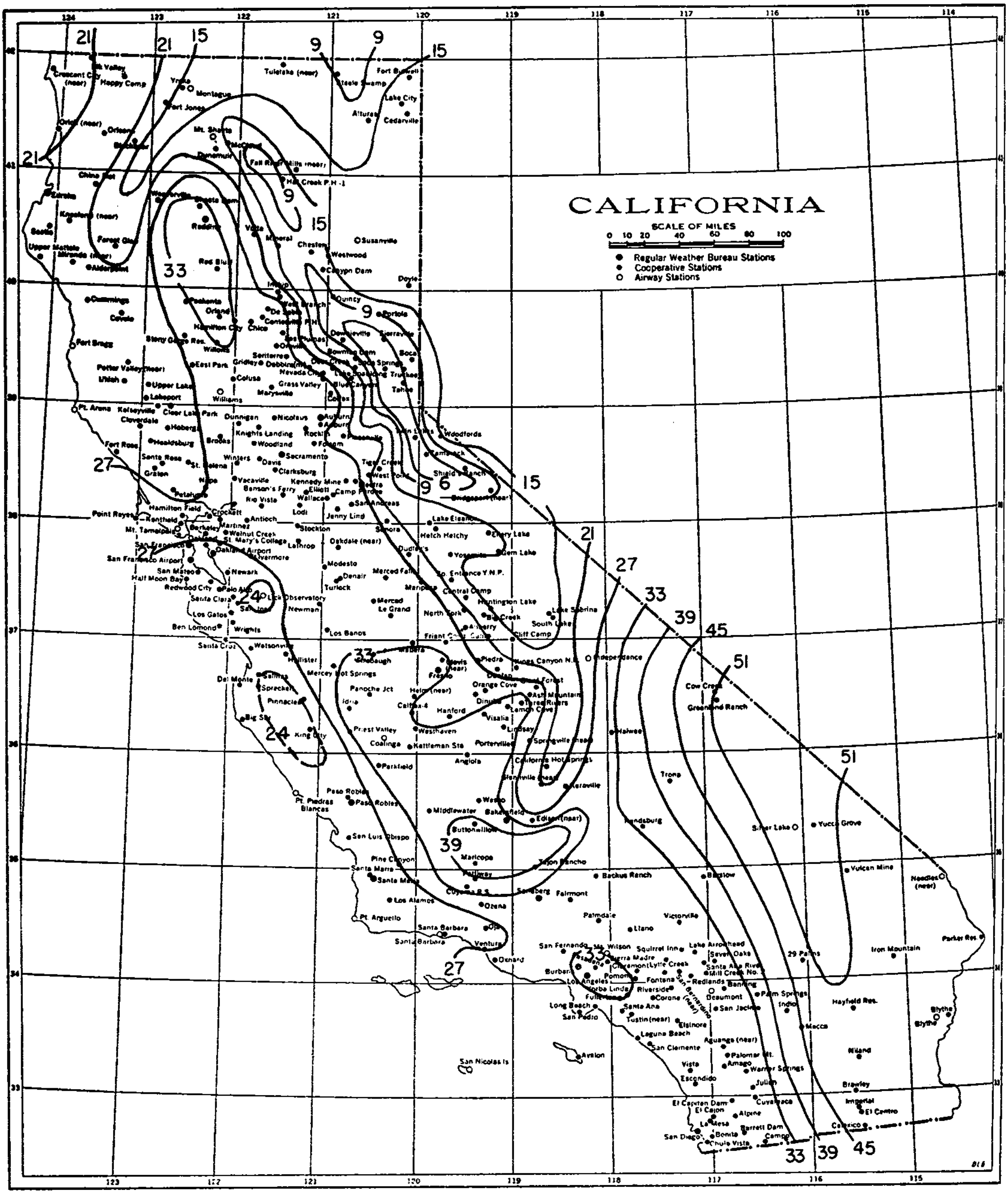


Fig. 8. Isograms of ET$_p$32°, potential evapotranspiration in inches for the frost-free season (32°F): a relative index for frost-sensitive irrigated crops.

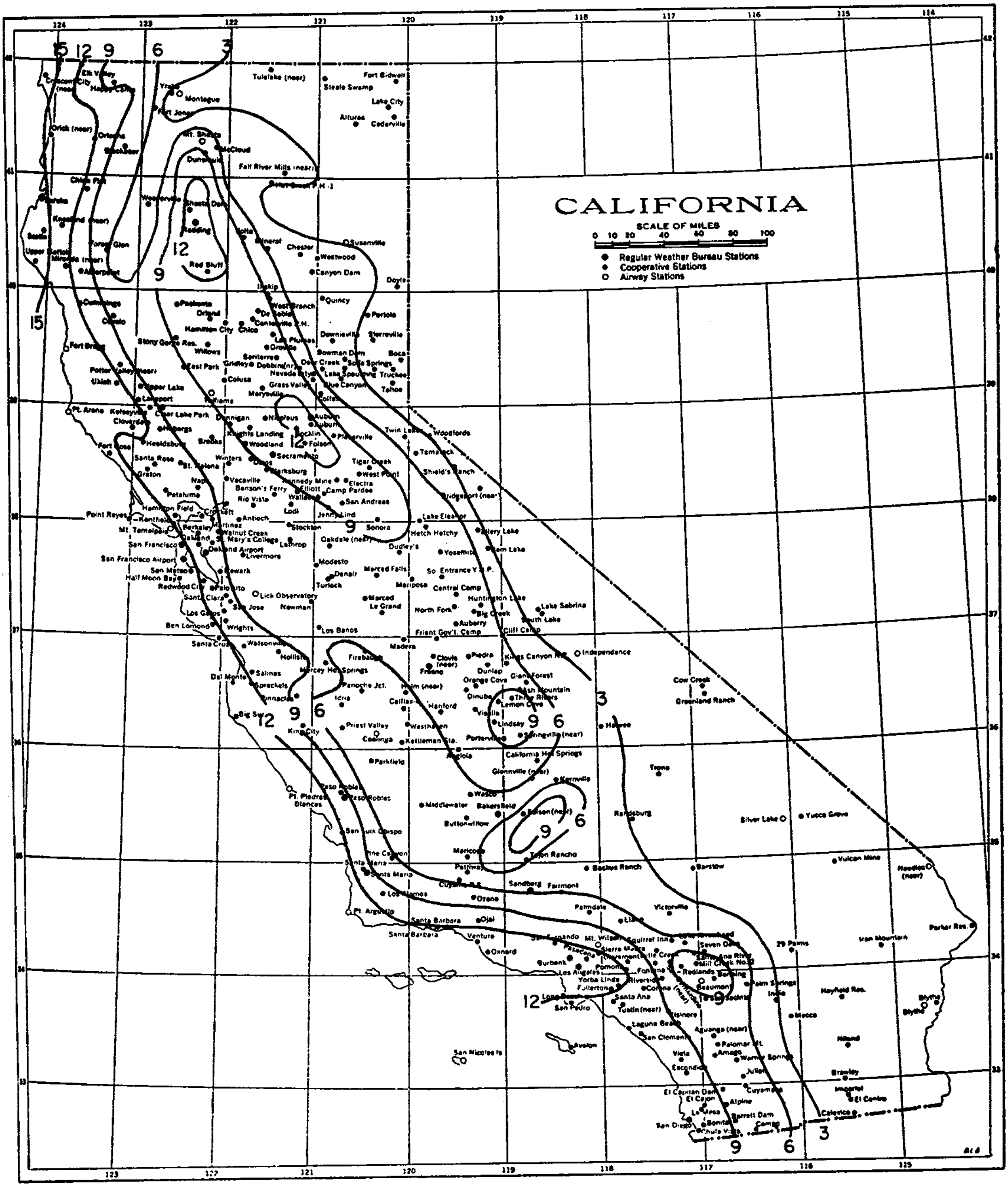


Fig. 9. Isograms of $ET_a32°$, actual evapotranspiration in inches for the frost-free season (32°F) for soils of 4 inches available water-holding capacity: a relative index for frost-sensitive crops grown under natural rainfall.

skies prevail much of the year. Precipitation, however, is very low so that plant growth reflects the high potential only with irrigation, as in the Imperial Valley. Here, very high yields of alfalfa, cotton, and truck crops are obtained.

Minimum values are in the high Sierra Nevada, and they are as low as 16 inches at the coldest weather stations. They are probably lower still in the highest areas, where climatic data are lacking. California, however, is a warm state, generally speaking. Frost-tolerant crops, such as small grains, can be grown with irrigation almost everywhere in the state except at high elevations or where soil conditions are unfavorable. This is shown by annual potential evapotranspiration values above 18 inches over most of the state.

Annual actual evapotranspiration (ET_a), statewide study

Figure 7 shows the distribution of calculated actual evapotranspiration for soils of 4 inches AWC in the state. At every station the values are less than annual potential evapotranspiration (Fig. 6), although the differences in the north coastal area are small. This reflects the summer moisture deficit that prevails to greater or lesser degree everywhere in the state. Commercial timber grows only where the values of ET_a are greater than 12 inches. However, trees put down deep roots and probably obtain water from a depth of soil holding considerably more than 4 inches of available water. Figure 7 also indicates that the lower limit of actual evapotranspiration for dry-farmed crops is near 7 inches. For example, in the San Joaquin Valley dry-farmed barley is grown successfully in the areas where ET_a is greater than 9 inches but not at all in the area where ET_a is less than 6 inches. Range pasture likewise produces only a very limited amount of forage where the values are less than 6 inches. High yields of forage, however, are obtained in the north coastal region, where the ET_a exceeds 15 inches.

Potential evapotranspiration for the frost-free season ($ET_p 32°$), statewide study

Figure 8 shows the distribution of ET_p 32°. Most of the important cultivated crops grown in California are frost-sensitive irrigated crops. The least favorable climatic areas for these crops are in the Sierra Nevada and the northeastern part of the state. Here, ET_p 32° values vary from 6 to 15 inches. On the other hand, citrus is grown mainly in areas where ET_p 32° is above 28 inches. Figure 8 suggests that citrus can be grown commercially in the San Joaquin and Sacramento valleys wherever relatively frost-free conditions exist. Cotton is grown mainly in areas where the values are above 30 inches in the San Joaquin and Imperial valleys but Figure 8 indicates that, so far as ET_p 32° is concerned, cotton may be a feasible crop in the northern Sacramento Valley.[5] Some cotton has been grown in central coastal valleys such as the Salinas, where ET_p 32° values are as low as 24 inches. Most other frost-sensitive crops do not require so much heat or so long a growing season as do

[5] It should be kept in mind that this paper deals only with climatic limitations involving moisture and seasonal evaporative energy. Other climatic limitations such as day and night temperature fluctuations also affect crop production, especially with respect to flowering and seed or fruit development (Kimball and Brooks, 1959).

citrus and cotton, and they can be grown with as little as 18 inches ET_p 32°. Values in excess of 18 inches cover much of the State except in the higher parts of the Sierra Nevada and the northeastern portion.

Actual evapotranspiration for the frost-free season (ET_a32°), statewide study

Figure 9 shows the distribution of calculated ET_a 32° over the state. The values greater than 12 inches occupy a narrow band along the coast from Orange County northward, as well as two local spots around Auburn and Redding. Dry-farmed frost-sensitive crops such as lima beans are grown in the coastal belt, where the growing period is prolonged by cool fogs or overcast skies. The areas around Auburn and Redding are not so favored. Temperatures rise rapidly in the spring and only soils of high water-holding capacity would enable growth to continue long enough for frost-sensitive dry-farmed crops to mature. Unfortunately, soils of high water-holding capacity are not common in the vicinity of Auburn or Redding.

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[6] Microfilm copies may be purchased from the University of California Library Photographic Service, Berkeley 4, California.

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APPENDIX

APPENDIX

Elevation, Precipitation, and Evapotranspiration Data for 211 California and 27 Nevada and Oregon Stations

Station*	Elev., feet	Annual ppt., inches	Potential evapotranspiration, inches					Actual evapotranspiration, 4″ AWC, inches		
			Annual, ET_p	32°F		28°F		Annual, ET_a	$ET_a32°$	$ET_a28°$
				Days	$ET_p32°$	Days	$ET_p28°$			
211 California stations										
Alderpoint	435	52.59	30.41	202	24.84	291	28.78	16.43	10.86	14.80
Alturas RS	4,365	12.88	22.44	74	10.19	128	16.65	10.53	2.47	5.70
Angiola	205	7.65	35.89	...	.....	...	.....	7.65	.....	.....
Antioch	46	13.18	32.00	266	29.44	313	30.98	10.99	8.46	9.97
Ash Mountain	1,692	27.66	36.57	247	33.74	329	36.00	12.70	9.87	12.13
Auberry	1,985	25.94	32.31	205	27.97	265	30.32	11.95	7.61	9.96
Auburn	1,295	35.78	32.65	271	30.72	326	32.15	13.95	12.02	13.45
Avalon Pleasure Pier	0	12.98	29.67	365	29.67	365	29.67	12.98	12.98	12.98
Bakersfield WB AP	489	6.36	38.72	287	37.18	330	38.16	6.36	4.87	5.80
Barrett Dam	1,623	17.71	32.69	274	30.05	319	31.43	12.57	9.95	11.31
Barstow	2,142	4.72	38.67	233	35.61	267	36.95	4.72	1.99	3.17
Beaumont 1E	2,589	17.86	31.68	227	27.21	275	29.17	12.93	8.52	10.42
Berkeley	299	22.72	27.69	355	27.34	365	27.69	15.02	14.67	15.02
Big Creek PH1	4,900	31.84	27.29	182	22.14	217	23.58	12.96	7.83	9.25
Bishop WB AP	4,108	5.38	29.27	151	22.00	195	25.18	5.38	0.70	2.01
Blue canyon WB AP	4,750	53.51	25.30	148	17.85	188	20.94	13.38	5.93	9.02
Blythe	266	3.53	47.70	290	46.13	329	47.04	3.53	2.21	2.87
Boca	5,532	22.81	18.72	12	1.44	40	4.93	10.62	0.75	2.93
Bonita	105	11.51	30.86	316	28.87	352	30.37	11.51	9.52	11.02
Bowman Dam	5,347	68.23	23.47	143	17.14	179	19.66	13.88	7.55	10.07
Brawley	−119	2.46	49.53	317	48.59	348	49.21	2.46	1.86	2.26
Bridgeport	6,420	10.47	20.95	68	9.01	103	12.77	7.95	1.52	2.38
Brooks Farnham Ranch	350	20.46	33.12	232	29.75	283	31.64	11.14	7.77	9.66
Burbank WB AP	699	13.88	32.62	334	30.14	365	32.62	12.71	11.58	12.71
Burney	3,127	26.20	23.33	54	7.48	117	14.77	12.40	1.60	4.64
Buttonwillow	295	5.49	36.63	259	34.39	291	35.37	5.49	3.59	4.26
Calaveras Big Trees	4,792	54.72	25.37	134	17.26	183	20.87	13.52	6.99	9.02
Camp Pardee	658	20.96	34.54	295	33.56	333	34.01	12.47	11.49	11.94
Canyon Dam	4,555	38.29	22.69	119	15.37	152	17.96	11.50	4.46	6.77
Cedarville	4,675	12.62	25.37	126	18.18	169	21.79	9.98	4.42	5.16
Centerville PH	520	43.68	33.93	224	29.87	283	32.24	15.58	11.52	13.89
Chico Exp. Station	230	26.35	33.62	241	30.29	269	31.25	13.87	10.54	11.50
Chula Vista	9	10.42	29.68	349	28.96	365	29.68	10.42	9.70	10.42

Colfax	2,418	47.33	31.14	225	27.42	296	29.84	15.00	11.28	13.70
Colusa 1SSW	60	15.98	34.30	278	32.50	329	33.69	11.36	9.58	10.75
Corcoran Irrig. Dist.	200	5.97	35.87	246	33.30	295	34.92	5.97	3.56	5.02
Corona	600	12.92	32.91	286	29.99	340	32.05	11.69	8.77	10.83
Covelo	1,385	40.58	30.16	168	23.44	208	26.14	14.30	7.48	10.28
Crescent City 1N	40	65.36	24.96	254	20.67	336	24.08	21.73	17.44	20.85
Cuyamaca	4,670	38.35	26.29	183	20.01	229	23.31	16.06	8.50	10.60
Davis Agri. College	51	16.60	31.97	246	28.85	295	30.59	11.42	8.30	10.04
Deer Creek PH	3,700	67.80	26.69	133	16.61	181	20.11	16.05	6.47	9.97
Denair	124	12.38	33.44	261	31.03	306	32.43	10.93	8.55	9.92
De Sabla	2,700	61.97	28.20	186	24.18	233	25.37	15.34	11.32	12.51
Doyle	4,266	9.51	25.36	105	15.43	140	18.98	8.32	1.33	2.93
Dudleys	3,000	39.24	26.03	179	20.60	222	22.76	13.02	7.59	9.75
East Park Reservoir	1,205	18.70	31.61	202	26.52	251	28.77	11.86	6.75	9.00
El Cajon 2E	540	13.47	31.41	261	27.24	313	29.57	12.48	7.43	10.62
El Centro 2SSW	−30	2.80	49.23	300	47.87	338	48.71	2.80	1.81	2.40
Electra PH	715	30.68	33.51	252	30.50	313	32.52	14.28	11.27	13.29
Elk Valley	1,711	84.27	25.18	126	15.43	178	19.41	17.45	7.50	11.48
Elsinore	1,300	12.50	35.51	239	30.79	280	32.97	11.24	6.76	8.70
Escondido	660	16.79	31.74	278	28.68	341	30.94	13.12	10.06	12.32
Eureka WB City	43	36.15	24.85	335	23.71	359	24.64	18.13	16.99	17.92
Fall River Mills, Int.	3,340	18.56	24.87	128	16.83	165	20.04	11.71	4.10	7.14
Fairmont	3,060	15.13	32.36	258	30.22	301	31.30	9.69	7.55	8.63
Five Points - 5SSW	325	6.05	35.50	234	32.40	288	34.28	6.05	3.43	4.83
Folsom	252	24.19	33.31	271	31.39	332	32.59	12.48	10.56	11.95
Forest Glen	2,340	58.42	25.45	132	16.83	166	19.84	14.53	5.91	8.92
Fort Bidwell	4,498	14.62	24.66	124	16.55	152	19.19	10.92	4.28	6.03
Fort Bragg	80	38.35	25.17	293	22.25	352	24.69	17.86	14.97	17.37
Fort Jones RS	2,720	20.97	25.08	102	14.43	142	18.39	11.75	2.69	5.23
Fresno WB AP	331	9.31	36.38	303	35.48	345	36.13	9.31	8.33	8.98
Friant Gov't Camp	410	14.54	35.94	242	32.97	283	34.27	10.51	7.56	8.84
Giant Forest	6,360	45.51	21.85	121	14.40	151	16.49	11.32	3.98	6.02
Glennville - Morrow Rch	3,140	20.57	27.56	134	18.45	179	21.86	11.25	2.49	5.73
Graton 1W	190	40.49	28.40	247	24.04	313	26.90	15.97	11.61	14.47
Grant Grove	6,580	44.83	19.91	111	12.71	140	14.96	9.72	2.90	4.77
Grass Valley	2,693	55.48	31.13	240	28.07	300	29.95	15.64	12.58	14.46
Greenland Ranch	−168	1.78	53.81	316	53.44	340	53.63	1.78	1.41	1.60
Half Moon Bay	48	24.82	25.80	340	24.68	365	25.80	15.57	14.45	15.57
Haiwee	3,825	6.09	33.86	229	31.42	268	32.68	6.09	3.94	4.98
Hamilton Field AFB	−2	26.33	28.84	298	26.76	356	28.60	13.61	11.53	13.37
Hanford	249	8.40	34.75	260	32.68	315	34.03	8.40	6.50	7.68
Happy Camp RS	1,090	54.19	34.28	175	25.31	226	29.73	18.55	9.58	14.00
Hat Creek PH1	3,015	18.08	26.25	111	15.81	152	19.68	11.95	3.05	6.02
Healdsburg	115	39.36	30.92	246	26.90	309	29.48	15.80	11.78	14.36
Hetch Hetchy	3,870	35.96	27.21	180	22.15	215	23.98	14.07	9.03	10.84

* Symbols following station names are Weather Bureau station indexes.

APPENDIX (*Continued*)

Elevation, Precipitation, and Evapotranspiration Data for 211 California and 27 Nevada and Oregon Stations

Station*	Elev., feet	Annual ppt., inches	Potential evapotranspiration, inches					Actual evapotranspiration, 4" AWC, inches		
			Annual, ET_p	32°F		28°F		Annual, ET_a	$ET_a32°$	$ET_a28°$
				Days	$ET_p32°$	Days	$ET_p28°$			
211 California Stations										
Hollister	284	13.29	29.35	275	26.36	327	28.21	12.19	9.23	11.05
Huntington Lake	7,020	32.50	19.16	116	12.22	145	14.18	10.40	4.24	6.10
Idria	2,650	16.25	34.06	257	31.48	318	33.17	10.75	8.18	9.86
Independence	3,950	5.12	32.58	202	28.40	241	30.44	5.12	1.81	3.30
Indio U. S. Date Garden	11	3.63	49.55	282	47.61	319	48.65	3.63	2.06	2.73
Imperial	69	3.01	48.01	324	47.23	355	47.81	3.01	2.43	2.85
Kentfield	10	47.07	28.23	252	24.21	316	26.80	16.12	12.10	14.69
Kern River PH1	951	11.25	42.16	348	41.90	365	42.16	10.71	10.45	10.71
Kern River PH3	2,703	10.70	33.97	215	30.47	251	31.86	8.59	5.09	6.48
Kettleman Station	502	5.60	37.84	310	36.93	343	37.53	5.60	4.69	5.29
King City	320	10.37	29.55	210	23.07	273	26.37	10.37	4.81	7.39
Laguna Beach	56	12.48	30.54	326	28.89	352	29.95	12.48	11.38	12.44
Lake City	4,613	21.27	24.25	126	16.75	153	19.39	12.82	5.48	7.91
Lake Eleanor	4,662	45.26	26.12	157	19.94	201	22.78	13.38	7.20	10.04
Lakeshore	1,075	64.24	31.60	204	26.97	249	29.27	19.39	14.71	17.01
Lake Spaulding	5,156	66.61	22.65	101	9.96	142	15.84	14.32	2.68	7.51
Las Plumas	506	51.08	36.86	301	35.55	350	36.57	15.68	14.37	15.39
Le Grand	255	12.99	34.84	256	32.26	307	33.90	10.48	7.90	9.21
Lemon Cove	513	14.59	37.09	279	35.43	338	36.68	11.27	9.61	10.86
Lindsay	395	11.92	35.05	244	31.94	295	33.71	10.49	7.45	9.15
Livermore	478	14.61	30.64	255	27.22	314	29.36	11.56	8.14	10.28
Lodi	40	16.24	30.94	243	27.30	291	29.17	11.99	8.35	10.22
Long Beach	34	13.32	32.27	365	32.27	365	32.27	12.92	12.92	12.92
Los Angeles WB AP	99	12.37	30.71	365	30.71	365	30.71	12.37	12.37	12.37
Los Angeles WB City	312	14.54	33.15	365	33.15	365	33.15	13.20	13.20	13.20
Los Banos	125	8.74	35.12	251	32.29	295	33.84	8.74	6.09	7.47
Los Gatos	400	28.38	30.57	294	28.27	345	29.98	13.90	11.60	13.31
Madera	270	10.95	34.79	265	32.74	308	33.94	10.22	8.20	9.37
Maricopa	680	5.70	40.37	310	39.46	349	40.13	5.70	4.79	5.46
McCloud	3,252	49.06	24.28	92	12.03	141	17.15	15.16	4.78	8.03
Marysville	65	20.72	34.85	284	33.23	335	34.33	12.31	10.69	11.79
Merced Fire Sta #2	169	12.14	34.23	256	31.69	307	33.22	10.47	7.93	9.47
Middlewater	803	5.07	38.17	276	34.55	330	36.60	5.07	3.50	4.88
Mineral	4,850	51.15	21.42	78	10.03	129	15.09	13.11	3.97	6.78

Nevada City	2,570	53.45	26.83	142	18.01	195	21.97	14.41	5.90	9.86
Newman 2 NW	91	10.26	34.99	267	32.78	311	34.05	10.26	8.12	9.32
Newport Beach Harbor	8	12.29	30.55	363	30.47	365	30.55	12.29	12.21	12.29
North Fork RS	2,665	34.49	29.92	191	25.13	228	26.85	12.44	7.57	9.37
Oakdale Woodward Dam	215	13.70	32.87	247	30.15	298	31.81	10.81	8.09	9.65
Oakland WB AP	3	17.63	27.47	328	26.28	358	27.25	13.66	12.47	13.44
Ojai	743	20.25	31.61	236	26.63	298	29.52	12.64	7.66	10.55
Orange Cove	431	13.65	35.36	251	32.49	308	34.34	10.77	7.90	9.75
Orick Prairie Creek Park	161	69.20	25.24	216	19.45	293	23.12	19.53	13.75	17.41
Orleans	403	50.68	29.25	222	25.54	287	27.89	16.75	13.03	15.38
Orland	254	18.97	35.32	273	33.94	326	34.90	11.44	10.06	11.02
Oxnard	45	15.03	28.53	354	28.05	365	28.53	12.72	12.25	12.72
Palmdale	2,655	9.25	33.74	226	29.97	256	31.33	8.84	5.77	6.68
Palm Springs	411	6.74	46.65	317	45.65	351	46.35	6.74	5.74	6.44
Panoche Jct	500	6.02	35.03	282	33.40	327	34.72	6.02	4.39	5.71
Pasadena	846	20.96	32.95	328	31.57	359	32.75	13.96	12.58	13.76
Paso Robles	700	14.36	30.45	206	24.37	233	25.99	11.09	5.76	6.81
Placerville	1,890	41.15	28.21	170	21.94	224	25.15	13.84	7.57	10.78
Petaluma Fire Sta #2	10	24.41	28.81	268	25.55	321	27.52	15.74	10.31	12.28
Pomona	855	18.19	31.97	246	27.65	305	30.16	12.60	8.28	10.79
Porterville	393	11.21	36.15	261	33.65	318	35.35	10.31	7.85	9.51
Portola	4,834	20.62	21.41	25	3.15	54	6.94	10.40	1.01	2.23
Potter Valley PH	1,014	42.70	30.09	190	24.05	247	26.99	14.45	8.42	11.36
Quincy RS	3,409	40.09	23.37	64	8.67	131	15.66	12.78	3.77	6.34
Red Bluff WB AP	320	21.57	37.22	277	35.47	325	36.49	13.26	11.51	12.53
Redding Fire Sta #2	577	38.57	36.67	284	35.12	340	36.24	15.91	14.35	15.48
Redlands	1,352	14.30	33.04	291	29.62	343	32.41	12.53	9.60	11.90
Redwood City	31	19.42	28.89	302	26.88	352	28.52	12.78	10.77	12.41
Riverside Fire Sta #3	820	11.48	33.80	257	29.74	328	32.82	11.48	7.60	10.50
Rocklin	239	23.58	31.95	234	28.83	293	30.71	12.07	8.95	10.83
Sacramento WB AP	17	15.02	31.87	321	31.10	353	31.63	11.69	10.92	11.45
Saint Helena	255	32.66	29.99	215	24.70	289	27.99	14.39	9.16	12.39
Salinas 2E	56	14.47	27.82	290	24.83	353	27.33	12.80	9.81	12.31
Salt Springs PH	3,700	45.85	28.16	207	24.07	262	26.26	15.21	11.12	13.31
Sandberg WB	7,734	12.42	28.07	194	23.44	235	25.59	8.78	4.71	6.38
San Bernardino County Hospital	1,094	18.24	34.50	273	31.25	332	33.47	13.36	10.11	12.23
San Diego WB AP	19	10.86	31.91	365	31.91	365	31.91	10.86	10.86	10.86
San Fernando	950	17.72	33.21	290	30.29	356	32.90	12.86	9.93	12.55
San Francisco FOB	52	20.51	27.14	364	27.10	365	27.14	15.32	15.28	15.32
San Francisco WB AP	8	17.43	26.64	333	25.51	364	26.60	13.79	12.66	13.75
San Jacinto	1,550	12.99	33.60	237	29.01	294	31.50	11.86	7.59	9.76
San Jose	95	12.69	29.88	336	28.92	361	29.75	12.64	11.68	12.51
San Luis Obispo Poly	300	21.98	28.92	321	27.05	361	28.76	14.70	12.83	14.66
San Mateo	30	20.86	28.67	320	27.09	365	28.67	13.40	11.82	13.40

* Symbols following station names are Weather Bureau station indexes.

APPENDIX (*Continued*)

Elevation, Precipitation, and Evapotranspiration Data for 211 California and 27 Nevada and Oregon Stations

Station*	Elev., feet	Annual ppt., inches	Potential evapotranspiration, inches					Actual evapotranspiration, 4″ AWC, inches		
			Annual, ET_p	32°F		28°F		Annual, ET_a	$ET_a32°$	$ET_a28°$
				Days	$ET_p32°$	Days	$ET_p28°$			
211 California Stations										
San Pedro	10	11.05	30.43	365	30.43	365	30.43	11.05	11.05	11.05
San Rafael	31	38.63	29.15	327	28.11	358	28.97	15.74	14.70	15.55
Santa Ana FS	133	15.11	32.28	307	29.98	345	32.56	13.02	10.72	12.30
Santa Ana River PH1	2,765	24.72	33.77	260	30.58	320	32.59	14.19	11.00	13.01
Santa Barbara	120	17.82	30.06	331	28.66	360	29.87	13.19	11.79	13.00
Santa Clara Univ	88	14.21	29.64	265	26.05	329	28.51	12.17	8.64	11.04
Santa Cruz	125	31.88	27.97	276	24.50	349	27.37	15.61	12.14	15.01
Santa Maria	224	14.19	27.82	272	23.69	339	26.73	13.09	9.00	12.00
Santa Maria WB AP	238	13.48	27.52	272	23.47	347	26.74	13.07	9.08	12.29
Santa Rosa	167	29.34	28.94	225	23.58	289	26.65	14.98	9.62	12.69
Scotia	139	48.14	27.05	319	25.38	353	26.60	18.40	16.73	17.95
Shasta Dam	1,076	52.50	36.67	285	35.26	351	36.51	17.99	16.58	17.83
Sierraville RS	4,975	25.78	21.68	33	4.21	88	10.03	10.90	1.02	3.21
Soda Springs	6,750	52.32	18.19	72	8.53	108	12.03	10.97	4.07	5.52
Sonora	1,830	32.62	31.67	237	28.59	315	30.86	13.23	10.15	12.42
Squirrel Inn 2	5,723	42.28	25.63	166	19.13	204	21.40	12.77	6.28	8.54
Stockton Fire Sta #4	11	14.30	31.41	272	29.36	316	30.55	11.03	8.98	10.17
Stony Gorge Reservoir	800	18.99	33.46	214	29.37	277	31.99	11.63	7.54	10.16
Susanville AP	4,152	14.69	24.56	133	17.64	180	21.14	9.34	3.26	6.35
Table Mountain	7,500	14.84	23.43	157	18.18	165	19.76	9.11	4.02	5.37
Tahoe	6,228	31.17	19.43	74	9.31	119	13.63	9.70	2.18	4.32
Tehachapi	3,975	11.76	26.89	169	21.11	216	23.82	10.17	5.07	7.10
Tejon Rancho	1,425	12.63	37.34	320	36.61	350	37.09	11.53	10.80	11.28
Three Rivers Edison PH 2	950	21.99	34.41	237	30.95	301	33.24	12.63	9.17	11.46
Tiger Creek PH	2,355	46.60	29.81	198	24.83	256	27.47	15.31	10.33	12.97
Torrance	80	12.66	30.47	333	29.10	355	30.07	11.64	10.27	11.24
Trona	1,695	4.16	42.19	248	40.05	281	41.05	4.16	2.27	3.17
Truckee RS	5,982	31.57	19.99	42	5.58	97	10.90	10.15	1.54	2.47
Tulelake	4,036	9.99	22.38	78	10.49	114	14.29	9.99	2.95	3.51
Turlock	104	12.00	31.21	...	.....	...	.....	10.48	.....	.....
Turn Table Creek	1,080	58.61	33.05	276	31.85	340	32.78	16.59	15.39	16.32
Tustin Irvine Ranch	118	13.40	31.91	285	28.83	341	31.02	12.55	9.47	11.66
Twin Lakes	7,829	49.96	16.63	28	3.19	59	6.10	10.52	2.62	3.87
Ukiah	650	35.61	31.34	211	25.69	265	28.57	15.46	9.83	12.69

Warner Springs	3,180	16.81	29.09	194	23.24	234	25.27	12.79	7.01	8.99
Wasco	333	6.56	37.37	259	33.80	306	35.09	6.56	4.39	5.64
Weaverville RS	2,050	36.37	26.49	116	15.99	169	20.27	13.98	4.63	8.23
Willows	136	17.66	34.47	261	32.00	317	33.59	11.87	9.40	10.99
Westhaven	285	6.92	36.41	...	.....	...	.....	6.92	.....	.....
Winters	132	16.83	33.68	260	31.33	316	32.95	10.70	8.35	9.97
Woodfords	5,671	20.06	23.87	129	16.82	178	20.32	10.25	3.66	6.84
Woodland 1 WNW	63	17.08	34.35	275	32.17	333	33.67	11.71	9.53	11.12
Yorba Linda	385	15.54	33.07	318	31.25	357	32.78	12.96	11.14	12.67
Yosemite NP	3,985	37.46	27.21	153	20.37	195	23.34	12.90	6.19	9.05
Yreka	2,631	17.63	26.06	137	18.98	173	21.70	11.56	4.80	9.77
Nevada stations adjacent to California										
Carson City	4,675	11.50	24.85	116	16.03	136	17.95	8.43	1.64	3.16
Empire	3,980	6.16	27.21	146	21.39	174	23.50	6.16	2.04	3.18
Fallon Expt. Sta.	3,965	5.34	25.75	89	13.82	119	17.06	5.34	0.64	1.05
Glenbrook	6,400	16.39	21.76	...	.....	...	.....	8.24	.....	.....
Imlay	4,209	6.64	26.93	126	19.25	152	21.37	6.64	1.60	2.41
Lahontan Dam	4,158	4.31	28.82	...	.....	...	.....	4.31	.....	.....
Lovelock	3,977	5.76	26.85	135	19.92	162	22.39	5.76	1.62	2.22
Minden	4,700	8.96	24.57	107	14.79	140	18.10	8.38	1.48	3.51
Reno WB AP	4,397	6.96	24.77	141	18.42	175	20.74	6.96	2.20	3.65
Rye Patch Dam	4,135	7.57	25.92	...	.....	...	.....	7.57	.....	.....
Sand Pass	3,900	6.53	26.02	148	20.65	178	22.72	6.53	2.46	3.87
Sheldon	6,500	11.27	19.05	40	5.43	74	9.44	9.57	1.83	2.92
Smith	4,750	7.29	24.51	...	.....	...	.....	7.29	.....	.....
Wellington RS	4,800	7.72	25.47	...	.....	...	.....	7.72	.....	.....
Winnemuca WB AP	4,299	8.75	24.91	...	.....	...	.....	8.75	.....	.....
Yerington	4,375	5.32	25.12	102	14.88	135	18.19	5.32	0.97	1.35
Oregon stations adjacent to California										
Brookings	80	81.86	25.72	300	23.32	358	25.49	22.96	20.56	22.73
Chiloquin	4,200	17.49	21.23	31	4.09	73	9.57	11.20	1.39	2.79
Grants Pass	925	30.13	27.92	162	20.94	208	23.26	14.76	7.78	10.10
Klamath Falls	4,190	13.94	23.61	126	16.79	164	19.22	10.15	4.52	6.60
Lakeview	4,756	14.25	22.54	85	11.83	122	15.53	10.93	2.88	4.98
Medford Expt. Sta	1,457	20.70	26.54	178	21.46	220	23.83	13.50	6.30	10.79
Modoc Orchard	1,270	22.62	27.50	146	19.60	200	23.51	13.87	5.97	9.88
Prospect 2SW	2,482	41.64	25.48	102	13.42	153	18.17	17.15	6.07	9.84
Riddle 2NNE	700	31.54	27.83	179	21.30	244	24.78	16.34	9.81	13.29
Talent	1,550	18.95	27.30	164	21.00	212	24.01	14.24	7.94	10.95
Valley Falls	4,326	12.17	22.86	58	8.25	98	13.05	11.36	1.96	4.17

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