drought tips

Number 92-46

Sacramento Valley Evapotranspiration and Crop Coefficients for Field Crops

Knowing how much irrigation water to apply to a crop is particularly important during a drought, and knowing the rate at which water is lost from the plant as it grows *(crop evapotranspiration,* or *ETc)* is helpful in determining how much water to apply. The water loss rate is affected by the crop coefficient — such factors as how irrigation is managed and the way a particular crop develops in different geographic areas.

This leaflet describes how to determine crop evapotranspiration and gives crop coefficients — factors reflecting the effects of irrigation management and crop development on ETc — for Sacramento Valley field crops.

Crop Evapotranspiration

Water is lost from a field as it evaporates from soil and plant surfaces (evaporation) and from inside plant leaves (transpiration). Together, evaporation (E) and transpiration (T) are called evapotranspiration (ET). In cultivated crops, ET is called crop evapotranspiration (ETc). Daily ETc is often called the ETc rate, and cumulative ETc (CETc) is the sum of ETc rates over a given number of days. The ETc rate depends on the drying power of the air (evaporative demand), and it increases and decreases with changes in solar radiation and weather factors.

ETccan be found by multiplying reference evapotranspiration (ETo) by a crop coefficent (Kc) as shown in Equation 1:

$$ETc = ETo \times Kc \qquad (1)$$

where ETo is the estimated evapotranspiration of a 4- to 6-inch tall cool-season grass. ETo, which accounts for the weather effects on ETc, is mainly influenced by changes in solar radiation, but also responds to changes in temperature, humidity, and wind speed. Crop coefficients (Kc's) account for the effects of irrigation management and crop growth and development on ETc. Differences in soil type have little effect on the ETc of well-managed irrigated crops. Table 1 gives the historical average ETo and ETc rates for major Sacramento Valley field crops. Table 2 lists the corresponding Kc's.

Reference Evapotranspiration

Reference evapotranspiration is the factor that adjusts ETc for differences in evaporative demand. Either historical averages of ETo or current (real-time) ETo are used in Equation 1 to estimate ETc. Using real-time ETo is more accurate, but using historical ETo often significantly improves irrigation management. In most years, historical and current (real-time) ETo are nearly the same, and ETc estimated from the historical ETo is sufficiently accurate to derive good irrigation schedules.

In some years, real-time ETo is sufficiently different from historical ETo for short periods that using real-time ETo improves irrigation management, but taking advantage of the more accurate ETc estimate requires the flexibility to change the timing or amount of water applied. Using real-time ETo to estimate ETc is therefore most beneficial to growers who use low-volume (drip or micro-sprinkler) or permanent set sprinkler systems. The best irrigation management consists of deriving a pre-season schedule using historical ETo and updating with real-time ETo as the need arises.

Sources of Real-time ETo

Real-time ETo data are available directly from the California Irrigation Management Information System (CIMIS) through a computer dial-up service, from local news media, and through the ATI-NET computer network. ETo forecasts are disseminated by the National Weather Service. For information on locating or gaining access to CIMIS information, write to:

The California Department of Water Resources
Water Conservation Office
P.O. Box 942836
Sacramento, CA 94236-0001

Crop Coefficients

To determine crop coefficients, ETc is experimentally measured and compared with measured or estimated ETo through a calculation of the ratio of ETc to ETo as in Equation 2:

$$Kc = ETc \div ETo \qquad (2)$$

The Kc corresponds to a particular crop, growth stage, and management. In fu-

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ture seasons, when a crop reaches the same growth stage, the Kc is multiplied by ETo to estimate ETc.

Crop coefficients are affected by irrigation management and change as a crop grows and ages. Soil surface wetting has a significant influence on the ETc rate — frequent wetting by rainfall or irrigation increases ETc relative to ETo and results in a higher Kc. Since most of the soil surface is exposed to sunlight from planting until approximately 10 percent shading by the crop foliage, a higher Kc is needed for fields that are frequently wetted by rainfall or irrigation during early growth.

As the crop canopy develops, transpiration becomes the dominant component of ETc and soil surface wetness has less influence on ET rates. During midseason and late season, ETc is mostly transpiration. Late in the season, ETc rates drop for many crops because aging reduces the plants' ability to transpire.

The ETc and Kc data in Tables 1 and 2 are based on typical management and the planting dates indicated. Adjustments for irrigation or rainfall frequency may be necessary during early growth and may differ for growers in the same area. Leaflet 92-52 in this *drought tips* series provides guidance on selecting a Kc to allow for surface wetting during early growth. Growers using a planting date different from those shown in the tables should move the ETc or Kc data up or down in the table to correspond with the correct planting date. Crops with planting dates more than two months earlier or later than those shown may have different growth and development rates. Where this is the case, see University of California Publication 21454 for more information on how to derive Kcs.

Adjusting for Real-time ETo

Real-time ETo data from CIMIS are used to adjust ETc estimates for the current weather. Using Equation 1, multiply the average CIMIS ETo rate for the given time interval by the proper Kc from Table 2 to obtain an estimate of average real-time ETc rate. Then multiply the average real-time ETc rate by the number of days to calculate CETc for the correct time interval. If there is no rainfall, fog, or water table contribution to the crop's water use, CETc provides an estimate of the required net application amount.

Sample Calculation

Given: a corn crop planted on May 1 and last irrigated on July 10, with the next irrigation planned for July 18. From Table 1, the historical ETo and ETc rates are 0.26 and 0.29 inches per day, respectively. Assume that the irrigation on July 10 refilled the soil to field capacity and that the irrigation on July 18 will replace the water loss from July 11 through July 18. Using historical ETo, the net application requirement for eight days at 0.29 inches per day is 2.32 inches.

If you choose to use real-time rather than historical ETo, estimate the Kc from Table 2 and use Equation 1 to calculate ETc. For the period July 11 through July 18, the estimated crop coefficient for corn planted May 1 is Kc = 1.15. If the average real-time ETo rate from CIMIS for the period July 11 through July 18 is 0.28 inches per day, the average real-time ETc rate is:

ETc = 0.28 x 1.15 = 0.32 inches per day

Therefore, real-time CETc for the eight-day period is 2.56 inches. Assuming there is no rainfall, fog, or water table contribution to the crop's water use, the required net irrigationamount is 2.56 inches. In this case, the difference in required net irrigation amount between using CIMIS and historical ETo is 0.24 inches for the eight-day period.

The amount of irrigation water to apply is determined by dividing the required net irrigation amount by the irrigation system's application efficiency. Contact your local farm advisor for information on how to determine application efficiency.

References

Goldhamer, D.A., and R.L. Snyder, Eds. 1989. *Irrigation scheduling: A guide for efficient on-farm water management.* University of California Publication 21454. Oakland, CA.

Snyder, R.L. 1992. "Irrigating up crops efficiently with sprinklers." Drought Tips No. 92-52. University of California.

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Table 1. Sacramento Valley evapotranspiration rates in inches per day on every tenth day of the year

Date	Day	ETo	Alfalfa	Beans (pinto)		Corn			Melons
			Jan 1	Jun 15	Mar 15	Apr 1	May 1	Jun 15	Apr 15
10-Jan	10	0.03	0.03						
20-Jan	20	0.04	0.04						
30-Jan	30	0.05	0.05						
09-Feb	40	0.06	0.06						
19-Feb	50	0.07	0.07						
29-Feb	60	0.08	0.08						
10-Mar	70	0.09	0.09						
20-Mar	80	0.10	0.10		0.02				
30-Mar	90	0.12	0.12		0.02				
09-Apr	100	0.14	0.14		0.03	0.03			
19-Apr	110	0.15	0.15		0.05	0.03			0.03
29-Apr	120	0.17	0.17		0.09	0.04			0.03
09-May	130	0.18	0.18		0.13	0.08	0.04		0.04
19-May	140	0.19	0.19		0.18	0.12	0.04		0.08
29-May	150	0.21	0.21		0.24	0.18	0.08		0.13
08-Jun	160	0.24	0.24		0.27	0.24	0.14		0.19
18-Jun	170	0.25	0.25	0.04	0.29	0.29	0.20		0.26
28-Jun	180	0.26	0.26	0.04	0.30	0.30	0.26	0.05	0.28
08-Jul	190	0.26	0.26	0.12	0.30	0.30	0.30	0.12	0.29
18-Jul	200	0.26	0.26	0.22	0.24	0.29	0.29	0.20	0.28
28-Jul	210	0.24	0.24	0.27	0.17	0.25	0.28	0.26	0.19
07-Aug	220	0.23	0.23	0.25	0.11	0.20	0.25	0.26	0.09
17-Aug	230	0.21	0.21	0.24		0.15	0.19	0.24	
27-Aug	240	0.20	0.20	0.22		0.11	0.14	0.23	
06-Sep	250	0.19	0.19	0.19			0.10	0.22	
16-Sep	260	0.17	0.17	0.12				0.19	
26-Sep	270	0.15	0.15	0.06				0.14	
06-Oct	280	0.13	0.13					0.09	
16-Oct	290	0.11	0.11					0.06	
26-Oct	300	0.09	0.09						
05-Nov	310	0.07	0.07						
15-Nov	320	0.05	0.05						
25 Nov	330	0.04	0.04						
05-Dec	340	0.03	0.03						
15-Dec	350	0.03	0.03						
25-Dec	360	0.03	0.03						

Table 1. Continued (ETc rates in inches per day on every tenth day of the year)

Date	Onions	Pasture	Rice	Small Grains			Sugar Beets	Tomatoes		
	Nov 15	Jan 1	May 15	Nov 1	Dec 1	Jan 1	Apr 1	Mar 1	Apr 1	May 1
10-Jan	0.02	0.03		0.03	0.02	0.01				
20-Jan	0.03	0.04		0.04	0.02	0.01				
30-Jan	0.05	0.05		0.05	0.03	0.01				
09-Feb	0.07	0.06		0.07	0.05	0.02				
19-Feb	0.08	0.07		0.08	0.07	0.04				
29-Feb	0.09	0.08		0.09	0.09	0.06				
10-Mar	0.10	0.09		0.11	0.11	0.08		0.02		
20-Mar	0.12	0.10		0.12	0.12	0.12		0.03		
30-Mar	0.14	0.12		0.14	0.15	0.15		0.03		
09-Apr	0.16	0.14		0.13	0.17	0.17	0.03	0.04	0.04	
19-Apr	0.18	0.15		0.11	0.18	0.18	0.04	0.04	0.04	
29-Apr	0.19	0.17		0.09	0.15	0.20	0.06	0.04	0.04	
09-May	0.20	0.18		0.06	0.12	0.21	0.08	0.08	0.04	0.04
19-May	0.22	0.19	0.18		0.09	0.20	0.12	0.13	0.08	0.05
29-May	0.24	0.21	0.20		0.06	0.18	0.16	0.19	0.14	0.06
08-Jun	0.27	0.24	0.22			0.16	0.20	0.25	0.21	0.11
18-Jun	0.29	0.25	0.25			0.12	0.24	0.29	0.28	0.16
28-Jun	0.27	0.26	0.27			0.07	0.28	0.30	0.30	0.20
08-Jul	0.25	0.26	0.30				0.29	0.30	0.30	0.25
18-Jul	0.21	0.26	0.31				0.29	0.26	0.29	0.29
28-Jul	0.18	0.24	0.30				0.27	0.22	0.27	0.28
07-Aug		0.23	0.28				0.25	0.18	0.23	0.26
17-Aug		0.21	0.27				0.24		0.19	0.23
27-Aug		0.20	0.25				0.22		0.15	0.19
06-Sep		0.19	0.24				0.21			0.16
16-Sep		0.17	0.22				0.19			0.13
26-Sep		0.15	0.19				0.17			
06-Oct		0.13	0.15				0.14			
16-Oct		0.11	0.12				0.12			
26-Oct		0.09	0.09				0.10			
05-Nov		0.07		0.02			0.07			
15-Nov		0.05		0.01			0.06			
25 Nov		0.04		0.01			0.04			
05-Dec		0.03		0.01	0.01		0.04			
15-Dec		0.03		0.01	0.01		0.03			
25-Dec		0.03		0.02	0.01		0.03			

Table 1. Sacramento Valley evapotranspiration rates in inches per day on every tenth day of the year.

Table 2. Sacramento Valley crop coefficient (Kc) values on every tenth day of the year

Date	Day	ETo	Alfalfa	Beans (pinto)		Corn			Melons
			Jan 1	Jun 15	Mar 15	Apr 1	May 1	Jun 15	Apr 15
10-Jan	10	0.03	1.00						
20-Jan	20	0.04	1.00						
30-Jan	30	0.05	1.00						
09-Feb	40	0.06	1.00						
19-Feb	50	0.07	1.00						
29-Feb	60	0.08	1.00						
10-Mar	70	0.09	1.00						
20-Mar	80	0.10	1.00		0.20				
30-Mar	90	0.12	1.00		0.20				
09-Apr	100	0.14	1.00		0.20	0.20			
19-Apr	110	0.15	1.00		0.31	0.20			0.20
29-Apr	120	0.17	1.00		0.52	0.26			0.20
09-May	130	0.18	1.00		0.73	0.45	0.20		0.20
19-May	140	0.19	1.00		0.94	0.64	0.20		0.40
29-May	150	0.21	1.00		1.15	0.83	0.37		0.61
08-Jun	160	0.24	1.00		1.15	1.02	0.58		0.81
18-Jun	170	0.25	1.00	0.15	1.15	1.15	0.79	0.20	1.02
28-Jun	180	0.26	1.00	0.15	1.15	1.15	1.00	0.20	1.10
08-Jul	190	0.26	1.00	0.46	1.15	1.15	1.15	0.45	1.10
18-Jul	200	0.26	1.00	0.86	0.93	1.15	1.15	0.77	1.10
28-Jul	210	0.24	1.00	1.12	0.72	1.02	1.15	1.09	0.79
07-Aug	220	0.23	1.00	1.12	0.50	0.86	1.09	1.15	0.41
17-Aug	230	0.21	1.00	1.12		0.69	0.91	1.15	
27-Aug	240	0.20	1.00	1.12		0.53	0.72	1.15	
06-Sep	250	0.19	1.00	1.02			0.54	1.15	
16-Sep	260	0.17	1.00	0.69				1.09	
26-Sep	270	0.15	1.00	0.37				0.91	
06-Oct	280	0.13	1.00					0.72	
16-Oct	290	0.11	1.00					0.54	
26-Oct	300	0.09	1.00						
05-Nov	310	0.07	1.00						
15-Nov	320	0.05	1.00						
25 Nov	330	0.04	1.00						
05-Dec	340	0.03	1.00						
15-Dec	350	0.03	1.00						
25 Dec	360	0.03	1.00						

Table 2. Continued (Kc values on every tenth day of the year)

Date	Onions	Pasture	Rice	Small Grains			Sugar Beets	Tomatoes		
	Nov 15	Jan 1	May 15	Nov 1	Dec 1	Jan 1	Apr 1	Mar 1	Apr 1	May 1
10-Jan	0.76	1.00		0.84	0.47	0.25				
20-Jan	0.94	1.00		1.06	0.61	0.25				
30-Jan	1.11	1.00		1.20	0.75	0.25				
09-Feb	1.15	1.00		1.20	0.89	0.39				
19-Feb	1.15	1.00		1.20	1.03	0.58				
29-Feb	1.15	1.00		1.20	1.16	0.76				
10-Mar	1.15	1.00		1.20	1.20	0.95		0.25		
20-Mar	1.15	1.00		1.20	1.20	1.14		0.25		
30-Mar	1.15	1.00		1.12	1.20	1.20		0.25		
09-Apr	1.15	1.00		0.93	1.20	1.20	0.20	0.25	0.25	
19-Apr	1.15	1.00		0.73	1.16	1.20	0.24	0.25	0.25	
29-Apr	1.15	1.00		0.53	0.93	1.20	0.36	0.27	0.25	
09-May	1.15	1.00		0.34	0.71	1.20	0.48	0.47	0.25	0.25
19-May	1.15	1.00	0.95		0.49	0.06	0.60	0.67	0.43	0.25
29-May	1.15	1.00	0.95		0.27	0.86	0.73	0.87	0.65	0.30
08-Jun	1.15	1.00	0.95			0.66	0.85	1.07	0.88	0.46
18-Jun	1.15	1.00	0.98			0.46	0.97	1.15	1.10	0.63
28-Jun	1.06	1.00	1.06			0.26	1.10	1.15	1.15	0.79
08-Jul	0.95	1.00	1.15				1.12	1.14	1.15	0.95
18-Jul	0.84	1.00	1.23				1.12	1.02	1.15	1.12
28-Jul	0.73	1.00	1.25				1.12	0.91	1.12	1.15
07-Aug		1.00	1.25				1.12	0.80	1.00	1.15
17-Aug		1.00	1.25				1.12		0.89	1.07
27-Aug		1.00	1.25				1.12		0.76	0.97
06-Sep		1.00	1.25				1.12			0.87
16-Sep		1.00	1.25				1.12			0.76
26-Sep		1.00	1.25				1.12			
06-Oct		1.00	1.20				1.12			
16-Oct		1.00	1.11				1.12			
26-Oct		1.00	1.02				1.12			
05-Nov	0.25	1.00		0.25			1.12			
15-Nov	0.25	1.00		0.25			1.12			
25 Nov	0.25	1.00		0.25			1.12			
05-Dec	0.25	1.00		0.25	0.25		1.08			
15-Dec	0.30	1.00		0.25	0.25		1.03			
25 Dec	0.48	1.00		0.48	0.25		0.98			

Table 2. Sacramento Valley crop coefficient (Kc) values on every tenth day of the year